Title

Survey and gap prioritization of U.S. electric vehicle charge management deployments

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Survey and gap prioritization of U.S. electric vehicle charge management deployments

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List of Acronyms

AMI	Advanced Metering Infrastructure
CalFUSE	California Flexible Unified Signal for Energy
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CSP	Charging Service Provider
DERMS	Distributed Energy Resource Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
HD	Heavy-duty
IEEE	Institute of Electrical and Electronics Engineers
LCMS	Load Control Management System
LD	Light-duty
MIDAS	Market Informed Demand Automation Server
MD	Medium-duty
OCPI	Open Charge Point Interface
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
SCM	Smart Charge Management
SEP	Smart Energy Profile
SOC	State of Charge
TOU	Time of Use
V2B	Vehicle to Building
V2G	Vehicle to Grid
V2X	Vehicle to Everything
VGI	Vehicle-Grid Integration
VPP	Virtual Power Plant

1 Executive Summary

This study surveys and characterizes the scope of current technical and programmatic knowledge pertaining to EV charge management technologies and practices in the US and relevant international jurisdictions. This characterization of existing field demonstrations and associated knowledge derived were used to determine gaps in the charge management demonstration landscape. Addressing these gaps through research and demonstration could increase confidence in the United States that load management and EV charge control could achieve overarching societal benefits.

A survey of charge management deployments and input from stakeholders was completed to determine the state-of-the-art of EV charge management. Broadly, EV charge management refers to a variety of approaches to balance the needs of the EV owner and the electric grid. Smart Charge Management (SCM) refers to controlling the amount of power exchanged between chargers and EVs to meet customers' charging needs while also responding to external power demand or pricing signals to provide load management, resilience, or other benefits to customers and the electric grid.

The survey was the basis of the gap analysis to determine which areas are well understood, and which areas need further investigation. Existing deployments of EV charge management are characterized to determine technologies and practices that are ready for widespread deployment and have been demonstrated in the field. These include demonstration studies, pilots, programs, and EV-specific tariffs. In all, 110 deployments of EV charge management were characterized. The data sources were public literature and utility filings as well as 43 targeted interviews with stakeholders.

This study prioritizes gaps in SCM capabilities based on (1) urgency of the particular use-case to offset traditional grid assets; (2) impact, extensibility, and scaling of results across the entire spectrum of more than 3,000 utility service territories, including projected technical and market potential for a given grid service; and (3) value of federal funding in addressing the gap, including potential to leverage and/or add scope to existing field demonstrations funded by other non-federal funding mechanisms.
The following were identified as the key gaps needing near-term action:

1. **Site level SCM is underutilized and could have widespread and cross-sector impact**. Site level load management could potentially ameliorate some equity concerns, particularly those related to multi-unit residences if SCM deployments included coordination with other site loads. Visibility of other site loads is a technical barrier given differing communication protocols between electric vehicle supply equipment (EVSE) and other industrial loads, system loads, or appliances. Improving technology for holistic site load management and completing SCM demonstrations with this visibility and coordination has high scalability implications for commercial load profiles, industrial operations, or residential appliances. This priority has high urgency because it could enable more rapid EV adoption in sectors which were previously site-capacity-constrained. It could also lower adoption costs by reducing EV charging loads coincident with other site peak loads, which would potentially reduce the need for panel service size

upgrades. Clear documentation of demonstrations in this area could increase utility confidence in approving oversubscribed interconnections with SCM systems.

2. **Lack of quantified economic value of capacity management in deferring substation and feeder upgrades related to EV charging.** Public data on available capacity of distribution systems are lacking and is needed to perform economic evaluation of SCM. Federal funds can have a potentially large impact in this area by leveraging existing demonstrations for analysis and creation of a toolkit to estimate SCM value for future areas. This gap is a particularly high priority for areas with higher EV adoption. The impact of filling this gap is relatively scalable as EV adoption increases in all regions and more utilities are faced with decisions between system upgrades and EV charging load management.

3. **Fragmentation in vehicle-grid integration (VGI) standards and lack of end-to-end certification of SCM capabilities**. Communication standards are fragmented between several components of the delivery chain from a utility or third-party to an EV or EVSE, resulting in the inability to identify which SCM path is of sufficient value for a vehicle maker, also known as an original equipment manufacturer (OEM), to invest in development and certification efforts. In addition, there are no functional test procedures or certification processes for end-to-end SCM capabilities. Filling this gap is crucial to enable multi-vendor charging and EV functioning of charge management. Interviewees strongly emphasized the need for standardized bidirectional communication protocols between EVs, EVSEs, utilities, and the grid. Integrating cybersecurity standards and data privacy requirements into the EV charging ecosystem was highlighted as a priority.

To address the current SCM gaps, the following actions are offered:

- To increase confidence in SCM effectiveness and reliability as a resource for grid operations, further field demonstrations should be conducted for various charging use-cases with the characteristics and objectives described below. Demonstrations should verify how SCM can avoid or defer distribution system upgrades, including substation transformer replacement or expansions, reconductoring primary lines, and upgrades of other voltage control devices.

- For distribution systems with little available capacity between existing current loading and maximally rated capacity, field demonstrations of the use of dynamic or variable rated site capacity are needed. Insights from such demonstrations could enable a site operator to energize charging stations and operate them at less than full capacity while the load serving entity upgrades the upstream supply. This measure will enable customers to take an incremental approach in transitioning to electrified transportation while providing data on a subset of their total vehicles, which would be particularly valuable to planning and operation efforts of fleet owners.

- Considerations for designing SCM field demonstrations:
    - Field demonstrations should be performed with EVSEs and EVs from multiple vendors offering multiple services to demonstrate interoperability. Performing

SCM services with high customer satisfaction will require adherence to end-to-end SCM conformance test standards which may require further development to exercise a variety of grid services.

- Field demonstrations should quantify the technical performance of individual and aggregated charging events to characterize the resources. Quantification should include time-based charging loads as well as statistical load behavior. If charge management is implemented by sending time-varying price signals, then charging behavior should be characterized as a function of price to estimate price elasticities by time, customer classes, and other characteristics.

- Demonstrations should evaluate the technical performance of SCM as well as the economic value created for each stakeholder (EV owner, aggregator, utility). A cost-benefit analysis would reveal if cost and value can be allocated among all players.

- Refinement of standards specification and conformance testing is required to avoid fragmentation of controls technology for SCM. These standards and conformance tests should be harmonized across technologies and support end-to-end integration. This is especially pertinent for charge management on a campus or in a building with other load controls and distributed energy resources.

- For all use cases in any future demonstration projects, data on customer demographics and behavior must be collected and analyzed. Sharing this data across studies would increase the usefulness of individual study datasets. Projects should be structured to test effectiveness across multiple customer demographics to better understand SCM's market potential and how SCM will scale across market segments.

- Demonstrations should attempt to address the needs of more than one sector (user, site, distribution, bulk) to identify and address the trade-offs and conflicts between the needs of each sector. SCM solutions that meet more than one stakeholder's goals have an increased likelihood of widespread adoption.

Table of Contents

List of Figures

List of Tables

2 Introduction

To meet long-term emissions goals, the United States will need to eliminate nearly all greenhouse gas emissions from the transportation sector by 2050. Achieving that future affordably will require closing the gaps identified in this report to enable widespread deployment of electric vehicle (EV) smart charge management (SCM). Broadly, EV charge management refers to a variety of approaches to balance the needs of the EV owner and the electric grid. SCM refers to controlling the amount of power exchanged between chargers and EVs to meet customers' charging needs while also responding to external power demand, pricing or other signals to provide load management, resilience, or other benefits to the customer and electric grid. In order to implement managed charging, three elements are needed: a signal to communicate the system conditions, a mechanism to motivate participation, and a control strategy. Realization of managed charging can take different forms—with a single entity such as a utility implementing all three elements or separate entities implementing each element. In addition, approaches can be layered together to provide the desired outcomes.

The U.S. National Blueprint for Transportation Decarbonization (U.S. DOE EERE, 2023) includes electrification of almost all light-duty vehicles and the majority of medium-duty and short-haul heavy-duty trucks and buses. To achieve this widespread electrification, effectively-deployed SCM is required to lower costs, speed deployment by reducing needed utility upgrades, and provide additional grid benefits. In this electrified transportation future, SCM will reduce customer electric bills, keep the total cost of EV ownership affordable, reduce interconnection wait times and grid infrastructure needs, and reliably provide services to the grid when called upon. If an SCM program is successful, these benefits will be extendable to any responsive and flexible load including buildings and electrified industrial processes, enabling faster realization of a clean and equitable electrified future.

The goal of this effort was to survey and characterize the technical scope of and knowledge derived from EV charge management deployments in the United States with respect to:

- Size (MW and participation)
- Interoperability capabilities and the degree to which they work in practice
- Applicability and ability to scale and extend learnings to other utilities and jurisdictions,
- Geographic characteristics (rural versus urban, concentrated versus dispersed loads, regions of the country, and utility profile)
- Rate structures
- Grid services targeted/provided (including renewable integration).

The results were used to determine gaps in the SCM deployment landscape. Addressing these gaps through research and demonstration could increase confidence in the United States that load management and EV charge control can achieve societal benefits.

2.1 A Vision to Scale-Up Successful SCM Deployments

The following describes the study team’s vision of the characteristics needed for future successful SCM implementations. The characteristics summarized below were determined from the study activities and results presented following this section.

Positive, seamless user experience:

- User charging needs, such as desired EV state of charge (SOC) and ready time are the highest priority
- Provides financial value to consumers, while limiting excessive risk
- Charge management is automated, requires minimal user intervention, and allows override when needed.
- Users are aware of options to lower cost.

Grid service capacity magnitudes and durations are defined for utilities and aggregators:

- Site grid service capacity management scope is defined.
- Distribution capacity management and power quality management are defined.
- Bulk energy balancing scope is defined.

Quantifiable reliability in providing grid services:

- Load shifting and event demand response can be predicted with high accuracy and are responsive when needed.
- The benefits of load shifting and event demand response can be quantified, validated, and compared to other methods of integration for both distribution planning and operation.
- Dynamic prices and additional control layers help address grid and generation needs in real-time.
- Metrics for evaluating the performance of load shifting and other grid services provided by SCM are clearly defined.

Economics:

- Value and cost of each service are clearly calculated and communicated to all stakeholders

Interoperable:

- Works with other load types such as dispatchable industrial loads, HVAC systems, and household appliances
- Works across nearly all EVSE and EV types, as well as other customer loads and responsive equipment
- Implementation can be certified to prevailing communication standards

Cybersecure:

- Personal data including personally identifiable information is maintained securely when collection and storage of such data are required
- Control signals are secured against adversarial attacks
- Measures are in place that enable systems to recover rapidly in the event of a successful cyber-attack.

Equity considerations:

- Includes cost impact analysis for various demographic groups
- Enables broad participation from diverse use-cases, including multi-unit housing, public charging, and/or more commonly accessible devices beyond EVs such as HVAC or water heaters etc. to allow wider participation
- Does not force customers with low energy needs to participate

Visibility and transparency to utilities, aggregators, and EV owners:

- Pricing visibility:
    - Highly dynamic pricing reflects changing grid and generation status over time and location
    - Demand response can read dynamic pricing in real-time and respond to minimize user bills within constraints of energy requirements
- The utility is aware of grid impacts and has the tools or resources to determine the best method to maintain reliable electric service
- Grid planners know where EV load growth is expected and where EVs are charging in real-time
- Other site load visibility so that site management is coordinated between EV charging and other loads

3 Characterization of Existing EV Charge Management Deployments

A survey of completed, current, and planned SCM deployments and a series of stakeholder interviews were completed to assess the state of knowledge of real-world SCM performance and perspectives on the future of SCM. Deployments include demonstration studies, pilots, programs, and EV specific tariffs. While the study team made their best effort at finding all completed, current, and planned SCM deployments, some may not have been captured. Deployments are characterized to determine aspects that are ready for widespread deployment and have been demonstrated in the field. The stakeholder interviews and the documentation of SCM deployments served as the basis for this study’s gap analysis which identified areas that are well understood, with high confidence, and areas that need further investigation.

3.1 Methodology

Interviews with stakeholders were conducted with a consistent set of questions. Interviewees included 17 utilities, 13 government entities, 2 advocacy groups, 5 electric vehicle OEMs, and 6 third-party or aggregator organizations (Table 1). The stakeholders spanned all regions of the United States, with a focus on larger stakeholders.

Table 1. Stakeholders Interviewed

Utilities Baltimore Gas and Electric Colorado Springs Utility ConEdison Dominion East Bay Community Energy Eversource Green Mountain Energy Holy Cross Energy Middle Tennessee Electric Membership Cooperative National Grid Pacific Gas and Electric Peninsula Clean Energy Rhode Island Energy Sacramento Municipal Utility District Southern California Edison Tennessee Valley Authority Xcel Energy	**Government Entities** California Energy Commission California Public Utility Commission Colorado Energy Office Colorado Public Utility Commission Connected Communities, U.S Department of Energy EVs@Scale Consortium (includes industry and government stakeholders) New York State Energy Research and Development Authority U.S. DRIVE Grid Integration Tech Team Vehicle Grid Integration Council
	Third-Party / Aggregators Energy Hub WeaveGrid Liberas Mobility House Nuvve Olivine Sprocket Power
OEMs BMW Ford GM Tesla	**Advocacy Groups** Drive Electric Northern Colorado Smart Electric Power Alliance

The interview questions are listed in Appendix A.

Stakeholders who attended the EVs@Scale Semi-Annual Stakeholder Meeting at NREL on February 28, 2024, were asked to contribute their ideas to discussion sessions on SCM implementation, valuation, codes and standards, and use cases. Discussion session questions are listed in Appendix A.

In addition to stakeholder interviews, SCM deployments were characterized using the attributes outlined in Table 2. The first set of SCM deployments were taken from a literature review of publicly available program reports. These reports included an Electric Power Research Institute (EPRI) SCM Summary (EPRI), reports from the EVs@Scale consortium, a Smart Electric Power Alliance (SEPA) Managed Charging report (SEPA, 2023), SEPA's The State of Managed Charging in 2021 report (SEPA, 2021), and research publications from a literature review. Categories that proved to be important for the gap analysis (discussed in more detail later in this report) are highlighted in light blue in Table 2. Tariff description is highlighted because tariff examples are diverse, and there is need for more consensus or analysis on best practices. Geography is highlighted because there are some regions without deployments. Furthermore, other categories which were expected to be highlighted, like EV customer optimization objectives, were not highlighted because many deployments do not include customer side optimization, and when they do almost always optimize for minimal cost of charging, meaning the categorization results did not provide much additional information. The EV customer incentive/motivation category was not highlighted because most programs did not struggle to find participants and all types of incentives used were effective in gaining participation.

Table 2. Characterizations Used to Categorize Existing SCM Deployments

Characterization	Definition
Lead entity and other partner entities	Who is leading and collaborating on this effort?
Funding level	Total funding amount for deployment
Size	Number of vehicles, EVSE, participants, or sites
Location	State the deployment is located in
Year	Timeframe or most recent year of deployment
Type	Program: which is intended to be ongoing, Pilot: which is limited in scope and may or may not become a program, or Project: which has a definite end in scope and often is for research or exploration purposes
Status	Active, planned, discontinued, or limited pilot
Utility type	Investor-owned utility (IOU), municipal utility (MUNI), public utility district (PUD), cooperative (COOP), community choice integrators
Utility business model	Is the utility vertically integrated or not?
Tariff description	Is the tariff a regular time-of-use (TOU) rate, a specific rate for EVs, an hourly dynamic rate, or another type of rate?
Geography	Does the study include dense-urban, sub-urban, and/or rural areas?
Environmental justice	Are there incentives for low-income customers? Is there a specified portion of participation in underserved communities?
Vehicle ownership	Who owns the vehicles (fleets, utilities, individuals, etc.)?
Vehicle segment	Which vehicle types—light-, medium-, and/or heavy-duty—are/were included?

Normal driving distance	What is the typical driving distance? This is categorized into short trips less than 100 miles, regional trips 100 to 300 miles for regional trips, or long trips more than 300 miles?
Charging types	Does the deployment include DC fast charging? If so, are the chargers on a public highway, a public non-highway, or at a private depot? Does the deployment include AC Level 2 charging? If so, are the chargers depot fleet chargers, retail or destination chargers, workplace chargers, curbside chargers, multi-family housing chargers, or single-family home chargers? Does the deployment include AC Level 1 charging in any capacity?
Coordination mechanism	Who coordinates the charging session limitations? Is it coordinated through a third-party aggregator, an EV-specific manufacturer cloud, direct interaction from the utility (as with a distributed energy resource management system (DERMS) or specific tariff), or is there another coordinator?
Control mechanism	How is the physical control limit implemented? Does the EVSE charging station, vehicle (including telematics), or user behavior limit the charging?
Additional elements	Are other elements controlled besides charging? Does the deployment include vehicle-to-grid (V2G) capabilities, stationary energy storage, or onsite renewables?
Input signals	What inputs are used to determine the charging limits? Vehicle characteristic inputs include SOC, battery capacity, make and model, and maximum charge rate; User need inputs include acceptable SOC, cost to charge, and when the vehicle is needed. Grid inputs include historical grid-level energy demand, dynamic grid-level energy demand, and required reserved capacity for grid services. Other potential inputs are local energy demand and carbon emissions.
Utility optimization objectives	If the SCM is optimized to meet a utility objective, what goal is it attempting to meet? This could be to benefit the wholesale power market; address transmission capacity constraints; reduce feeder, substation, or service transformer loading; regulate local voltage and frequency; track renewable energy generation; shift loads for decarbonization; reduce power distribution losses; enhance resilience, or something else.

EV customer optimization objectives	If the SCM is optimized to meet an EV customer goal, what goal is it attempting to meet? The objective could be to optimize charging cost for the customer; avoid demand charges through site-level management; maximize PV self-consumption through site-level management; enhance resilience to outages; enable bi-directional charging; or reduce carbon emissions.
EV customer incentive/motivation	What motivates the EV owners to participate? Is there a rebate on equipment, incentives for participating in demand response events, more favorable tariffs for participating EV owners, some kind of recognition certificate, or a benefit for avoiding infrastructure upgrades?
Utility incentive/motivation	What motivates the utility to deploy SCM? Does the utility receive additional revenue from market participation, meet a regulatory requirement, or improve operational efficiency?
Value for participant in dollars	How much monetary value does a participant receive from the SCM implementation? Is the monetary benefit given for car-years participating, for kilowatt-hours shifted, for demand response event responded to, for the kilowatt peak load reduced, or as a flat rate upon enrollment?
Utility interaction communication protocol	To control load, does the deployment use Open Charge Point Protocol (OCPP), ISO 15118-2, OpenADR (2 or 3), non-direct control communication to the user, SEP 2.0, or something else?
Load management performance metrics	Were there any performance metrics collected, and if so, what were they and their units? These might include resource flexibility in terms of kilowatt peak or kilowatt-hour shifted, customer impact and participation, resource consistency, or something else.

3.2 Summary of EV Charge Management Program Characteristics and Metrics

In this survey, the study team characterized 110 deployments of EV charge management programs from 2013 to the present (see Appendix C). Most states have at least one charge management deployment. There were fewer deployments in rural areas and states with low EV adoption. Many states only have either a basic special TOU block rate tariff for EV users or a rebate on EVSE for customers who agree to a special TOU block rate.

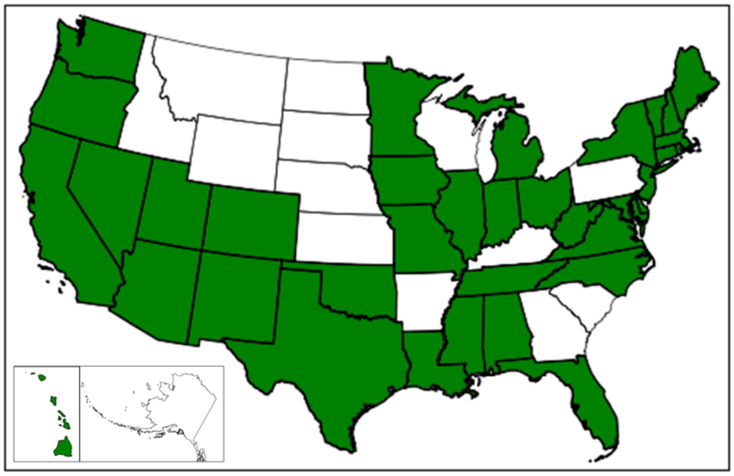

Figure 1. U.S. states with charge management deployments (shown in green)

Across the United States, the EV charge management deployments to date have focused primarily on light-duty vehicles and have often identified requirements for residential charging. Few deployments included medium-duty vehicles, with 11 outside California mostly involving school bus charging or local delivery vans. Very few examples included heavy duty vehicles, with only three outside of California. Two of these were demonstrations at Utah State University and one was a school bus pilot in Massachusetts. None of these pilots were large scale or expanded to other sites.

Integration of vehicle charging with other technologies was rare. Only seven deployments outside California included bi-directional charging and in several of those cases only uni-directional charging was physically demonstrated. Only five deployments outside of California considered on-site stationary storage, and only four deployments outside California considered onsite renewable generation. Site load and generation management were much more common in small experimental studies than in larger-scale, or real-world implementations.

Most EV charge management demonstrations focused solely on customer-directed charge scheduling to follow basic TOU rates. Most of these were ongoing programs, rather than pilots or projects (i.e. government agency or utility-funded research studies), which have limited time durations and allowed reduced participation. Figure 2 shows that programs were the most common type of deployment. Several programs were more in-depth, with direct control of charging via a utility signal, or an aggregator which dispatched charging in accordance with a utility signal. The widespread basic TOU rate programs may have had additional layers unseen by the utility where customers subscribed to multiple programs at once. However, the reports on the TOU programs do not discuss the possible layering of customer controls of EV charging, given the operator managing the TOU program may not have visibility into those additional layers. This potential control layering was also not discussed in any other reports found.

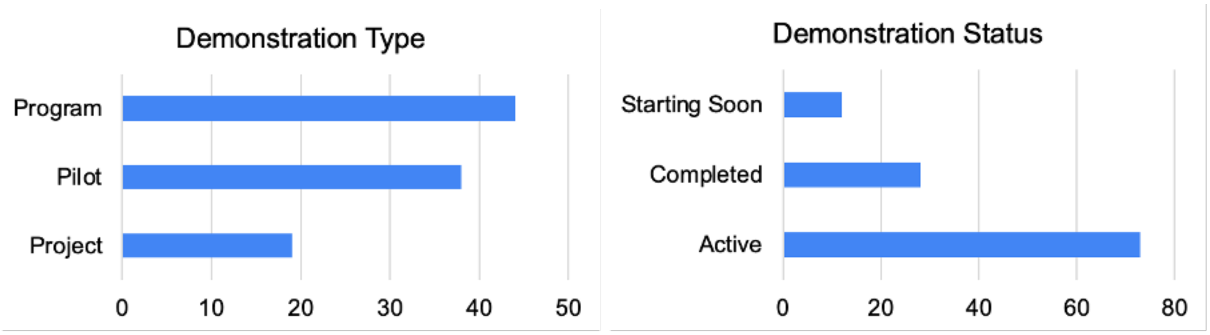

Figure 2. Demonstration type (left) and status (right)

Coordination mechanisms (Figure 3) are defined as the mechanism which makes decisions on how and when to incentivize or directly control reduced loads. Many programs use a third-party aggregator to collect inputs and determine charging limits. Other mechanisms included leveraging OEM clouds, utility DERMS, or another custom approach often via simple pricing sent to EV owners through a purpose-made app.

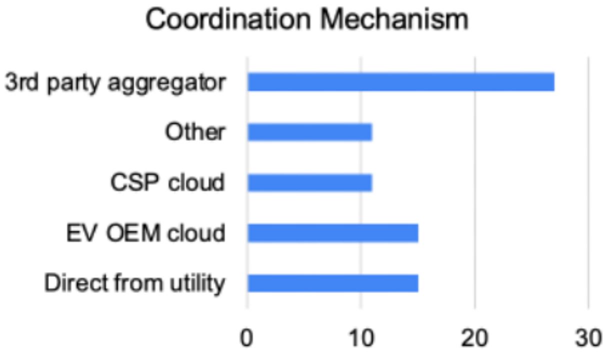

Figure 3. Coordination mechanisms in SCM deployments

Different utilities approached incentives in different ways, as shown in Figure 4. Given the wide range of EVSE options and compatibility, some deployments provided rebates on certain equipment to participants to ensure compatibility with SCM utility signals. Other deployments provided discounts on customer bills if customers participated in at least a certain number of demand response events per year. Some provided rebates on energy bills for participation in each demand response event. In addition to direct bill savings, prevention of infrastructure upgrades is characterized as a customer incentive in this report as it could expedite interconnection timelines or reduce customer interconnection costs, because many utilities directly charge customers if an upgrade is needed for supply to the specific customer site.

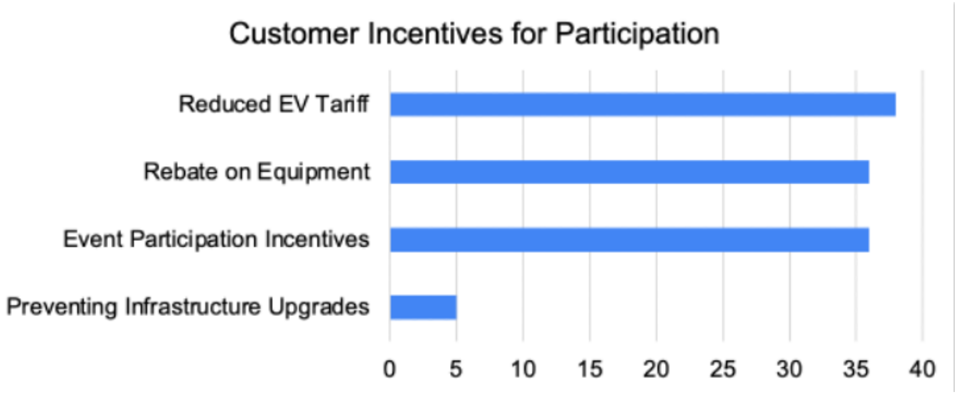

Figure 4. Customer incentives for participation in SCM

The deployments primarily used EV-specific TOU rates, labeled EV Rate in Figure 5. The second most common rate was a general whole-site TOU rate. There were a few examples of specific load management (LM) and demand response (DR) rates.

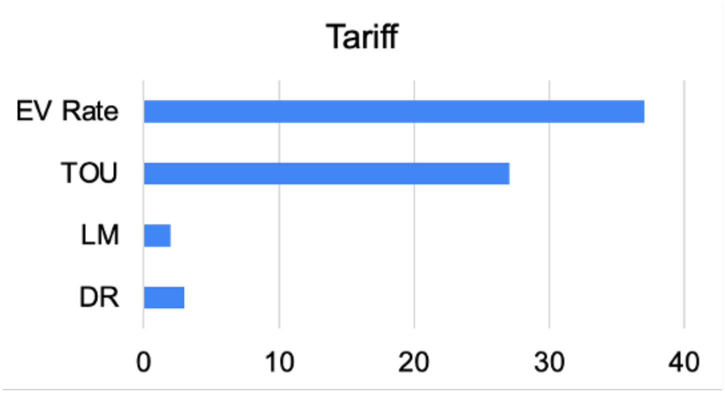

Figure 5. Tariff structure for the SCM demonstrations, show a prevalence of EV Rates.

Performance metrics included number of participating customers over a certain period, how consistently they participated, and the amount of flexibility or load shift provided (Figure 6). SCM deployments could report more than one performance metric. About a third of deployments reported no performance metrics or had not done so yet.

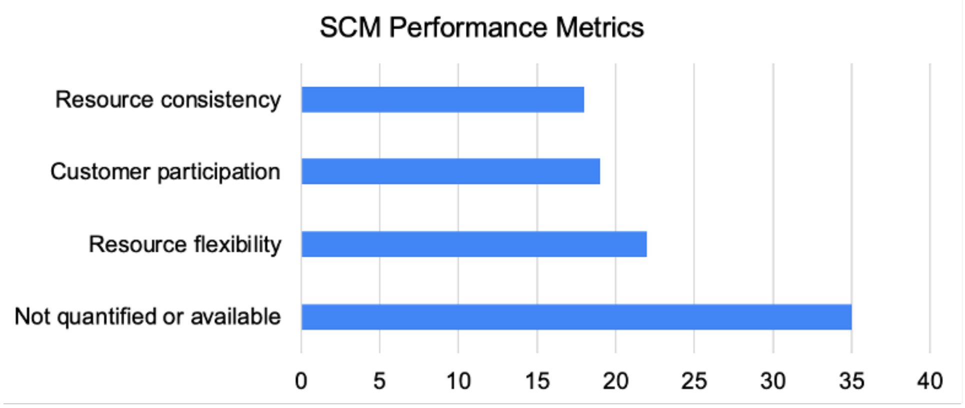

Figure 6. Metrics reported by SCM Deployments

The majority of SCM deployments in California included tens to hundreds of EVs or EVSEs (Figure 7). These numbers reached into the thousands for a handful of demonstrations. About three-quarters of the SCM deployments focused on light-duty EVs with the remaining quarter evenly split between medium- and heavy-duty EVs.

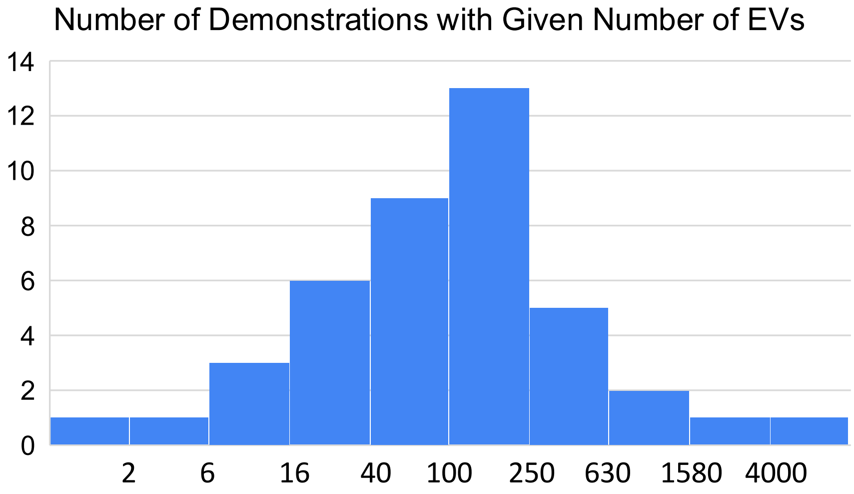

Figure 7. Histogram of number of EVs or EVSEs in SCM demonstrations in California for deployments that reported those values.

The study team identified representative completed, ongoing, and near-future deployments, described in detail in the subsections below:

3.2.1 Completed Studies

Marin Clean Energy Sync EV Charging (2021 pilot study; program on-going)
Marin Clean Energy (MCE), a community choice aggregator serving customers north of San Francisco, partnered with the charging management provider ev.energy to conduct a six-month pilot with 232 participants in 2021. The goals of the pilot were to: (1) decrease customer electric bill costs through off-peak charging; (2) support grid resiliency by decreasing EV charging demand between 4 p.m. and 9 p.m.; and (3) decrease carbon emissions by coordinating EV demand with renewable energy generation.

The results were encouraging, moving 93% of EV charging consumption out of the 4 p.m. to 9 p.m. period and reduced electricity-related carbon emissions by 55%. Customers on the EV2 tariff saved roughly $12 per month, not including event-based incentives. Households reduced peak period load by 12.4% on average with solar customers reducing peak load by 21.9% and non-solar customer by 3.6%. Pilot participants were encouraged to charge with solar power through day-ahead push notifications sent to their mobile phones. With 90% participation in at least one event, approximately 50% of nighttime EV load was shifted into daytime periods with up to 80% lower-carbon electricity.

MCE and ev.energy reported the following key insights:

- TOU rates alone are insufficient to address grid reliability and carbon emissions concerns.

- A combination of incentives and active load control yields the better load-shifting performance than either of these tools alone.
- Third-party assessment of demonstrations is necessary.
- Vendors should ensure telematics platforms are reliable and open to ease integration and minimize risk of stranded assets.

Peninsula Clean Energy (PCE) Managed Charging (2023 to 2024)
PCE conducted a study of residential EV managed charging utilizing no-hardware light-duty vehicle telematics to reduce overall daily peak loads, maximize use of daytime solar (when possible), and test customer reactions to different incentive types. The pilot objectives were:

- Learn more about charging patterns
- Determine how much load shifting is achievable with telematics
- Determine load shift variability by vehicle, home charging type, and electric rate
- Quantify incentive impacts by incentive type
- Determine what people think of SCM
- Determine if similar results be achieved without SCM.

A total of 698 customers were recruited and participated with over 30,000 sessions totaling over 600 megawatt-hours of EV charging during the study period that ended in early 2024. Participants were separated into treatment groups with different TOU rates. The key takeaways were:

- The telematics approach was compatible with ~90% of the market with moderately easy enrollment of participants and lots of potential
- Recruitment is challenging, with a best case of 10% enrollment at reasonable cost
- Negligible load shift during evening ramp up for EV rates
- Program will have limited impact in near term during evening ramp up and longer-term impacts on timer peak mitigation where rebound peak loads occur as soon as low TOU rates come into effect.

Based on the results of this study, PCE is planning to start an SCM program without rate modifications in March, 2024. The program will offer customers on any electric rate a one-time incentive of $100 to download an SCM app that will manage their EV charging based on their tariff and charging preferences.

3.2.2 Ongoing Studies

Portland Gas and Electric (PGE) and WeaveGrid (started 2023)
PGE's Test Bed EV Charging Study (Mills et al. 2023) is designed to develop and evaluate methods that best optimize EV charging for bulk system benefits while meeting distribution constraints. The study uses vehicle telematics to examine the impact of varying EV charging behaviors on the distribution grid. EV charging is managed to ensure that vehicles meet mobility needs while accounting for distribution constraints. Customer acceptance of charge rate, charge time, and location-based price signals will be evaluated. This study intends to gain a better understanding of the impact of EV charging on the grid, learn the best optimization strategies for varying distribution constraints, and determine methods to optimize existing assets and eliminate or decrease costly infrastructure upgrades.

U.S. Department of Energy Funded Baltimore Gas and Electric (BGE) Pilot with Argonne National Laboratory and WeaveGrid (started 2020)

BGE is running an SCM pilot with higher-than-expected enrollment and is considering expanding it into a full-scale program pending regulatory approval. Public enrollment of individual customers with light-duty EVs quickly reached the pilot limit, with additional positive response from public charger owners and operators. Participants had charging power limited during demand response events. However, participating fleet managers had concerns about rapidly scaling up the fleet program due to interoperability issues with existing technology beyond the few charger types that have been proven to work with BGEs implementation. Electric heavy-duty vehicles presently lack demonstration of sophisticated active control capabilities and EVSE options are currently limited. BGE's pilot program achieved up to a 45% reduction in energy costs for the utility to supply energy to participating residential customers over a three-month period by forecasting prices and directly controlling charging time. There is an interest in further integration of smart home and smart charge management to optimize overall load shifting and better enable demand response capabilities. Additionally, continued research is essential to characterize future loads as market adoption of EVs increases, particularly in the fleet space which represents most of projected load growth.

Dominion Energy SCM Evaluation Including Travel Corridors and Commercial Vehicles (Started 2022)

FUSE (Flexible charging to Unify the grid and transportation Sectors for EV's at scale) is a research and analysis project with an objective to develop strategies and tools for integrating SCM with vehicle-grid integration (VGI). The project analyzed approximately 400 million trips and more than 100 of Dominion Energy's distribution feeder models by simulating EV charging demands and grid impacts. While the analysis demonstrated SCM and VGI approaches to reduce grid impacts from electrification, many commercially available SCM solutions are limited to site-level controls rather than grid-scale coordination. Further interoperability testing, certification, and demonstration of grid-scale feedback and control for charging are required for the grid-scale SCM evaluated under this project.

Going forward, FUSE plans to expand its analysis to include medium- and heavy-duty EVs, demonstrate SCM capabilities at scale, and develop new VGI approaches like concentrated charging to accommodate EVs at scale. The project involves extensive collaboration with utilities and other stakeholders to ensure timely, practical outcomes to accelerate the EV transition.

BMW Greenhouse Gas Emissions Charge Control (Started 2023)

BMW launched the ChargeForward program in Northern California in 2015 in partnership with PG&E. The program aims to shift charging to times with abundant renewable energy generation on the grid. The program had over 400 participants with BMW battery electric and plug-in hybrid vehicles. A University of California, Berkeley analysis found that the program enabled EVs to use 1,200 kilowatt-hours per year of additional renewable energy compared to unmanaged charging. The analysis also found that the program reduced greenhouse gas emissions by 32%. The program used carbon emissions data specific to the electric grid to schedule charging times with the lowest carbon intensity.

In November 2023, BMW announced that it is expanding ChargeForward to the contiguous United States. The expansion allows all BMW EV and plug-in hybrid EV owners from model years 2018 and up to participate. Through the program's smartphone app, customers can opt to align vehicle charging with times of high renewable energy generation in their region and receive financial incentives. The program highlights the potential of vehicle telematics and incentives to manage EV charging in a way that benefits drivers, utilities and the environment on a large scale. This project also highlights the need for coordinated efforts to enable standard interoperable approaches from each OEM and to prevent each OEM from developing fragmented standalone solutions.

3.2.3 Near Future Studies

Responsive Easy Charging Products with Dynamic Signals (REDWDS) Funded by the California Energy Commission (CEC), (Awarded in 2023)

The ten projects awarded in late 2023 in the REDWDS research program are designed to support the development and deployment of charging products that help customers easily manage charging in response to dynamic grid signals (REDWDS, 2024). This solicitation builds on the OCPP and ISO 15118 technical requirements included in CEC's block grant projects, as well as the recent update to CEC's Load Management Standards (CEC-LMS).

Products developed as part of this project must at a minimum be capable of:

- Automatically retrieving grid signals
- Must be capable of retrieving electricity rates and Flex Alerts from the CEC's Market Informed Demand Automation Server (CEC-MIDAS).
- Receiving notifications for Emergency Load Reduction Program events and Demand Side Grid Support Program events. The latter of which are called based on Energy Emergency Alerts issued by the California Independent System Operator.
- Optimizing vehicle charging in response to dynamic signals and customer needs and preferences.
- Scheduling or otherwise managing charging in response to grid signals while ensuring that driver needs, including requested energy/range and departure time, are met. This may involve the use of artificial intelligence and machine learning.
- Using ISO 15118 to retrieve energy and departure time requests from compatible vehicles.

Minimum data collection and reporting requirements are described below:

- For all deployments, record charging power in kilowatts, connector status, and real-time electricity price (in dollars per kilowatt-hour) at 15-minute intervals or more frequently.
- Calculate, record, and plot two normalized profiles for each month: One for all deployments with customers enrolled on dynamic rates, and one for all other deployments.
- For all deployments, calculate the average price (in dollars per kilowatt-hour) of electricity used for charging that month.
- For all deployments with a customer enrolled on a dynamic rate, calculate the average price (in dollars per kilowatt-hour) of electricity for charging that would have been realized that month on an otherwise-applicable electricity rate. The aim would be to

determine whether customers are realizing additional savings on their dynamic rate.

Southern California Edison (SCE) Load Control Management System (LCMS) Pilot
The LCMS pilot described in SCE's Advice Letter 5138-E to the California Public Utility Commission is designed to provide safe, reliable service to new load customers requesting interconnection within grid capacity constrained areas during certain times of the day when there is sufficient capacity on the system to serve customers' load.

Currently, in certain areas of the grid, capacity limitations are causing significant delays in interconnecting customer load. These customers include, but are not necessarily limited to, public EV charging stations and individual customers who are installing their own EV fleet charging infrastructure. Both of the customer groups are important to support the transportation electrification and California's important energy and environmental policy goals. Most of these charging systems can manage the level of charging via a localized and/or communication-based LCMS. Customers who are installing equipment with these capabilities have requested SCE evaluate and approve the use of customer owned and operated LCMS as means for SCE to energize their project while a grid upgrade is being completed. The pilot will support customer ownership, installation, and operation of the automated LCMS.

The LCMS pilot will allow SCE to provide customers with an early service connection under the condition that SCE may reduce the charging load during certain hours of the day. This solution is a 'bridge' until SCE has installed a feeder upgrade. It allows the customer to have some charging capability, while SCE is expanding the feeder capacity. Customers in the LCMS pilot will manage their EV charging under the direction of SCE, so that it does not exceed existing electrical service capacity.

3.2.4 Stakeholder Interview Perspectives

Several common themes emerged from the interviews with stakeholders.

Standardization: One theme was that standardization would improve SCM applicability and ease of use. Many chargers, especially home chargers, have their own interfaces with unique control capabilities and data collection, making implementation of a standard control scheme difficult. One stakeholder specifically mentioned that OCPP for all charger types would increase programs' applicability. On the vehicle side, several vehicles have their own charge control capabilities, but this is also not standardized, making it difficult to leverage vehicle charge controls given the wide array of vehicle types. On the user interface side, there was concern that users were becoming frustrated with managing several including a vehicle app, any charging station app, and often a controls app associated with the SCM program. A streamlined approach would make SCM participation more intuitive and increase user satisfaction.

A strong desire for standards certification and enforcement was noted during several discussion sessions with manufacturers, researchers, and utilities. End-to-end certification of SCM capabilities was noted as a gap that must be addressed with a preference for government intervention as a third party. Participants emphasized the need for consistent, clear, adoption guidance for standardized bidirectional communication protocols between EVs, EVSEs, utilities, and the grid. They pointed to protocols such as ISO 15118, IEEE 2030.5, OCPP, and open charge point interface (OCPI) to build consensus around a limited set of implementation approaches for the various use cases. Such consensus is critical to speeding and streamlining SCM adoption.

Standardized interoperability testing procedures and conformance tests were deemed crucial for ensuring end-to-end compatibility across systems. Aligning standards with existing grid codes and incorporating data standardization for analysis and modeling were also stressed. Standardization of charger communications protocols would also improve customer participation, because it would remove the requirement for a single charger type to be used for controls implementation.

Integrating cybersecurity standards and data privacy requirements into the EV charging ecosystem was highlighted as a priority. This should include limits on collection of personally identifying information and requirements on how to store customer data. Cybersecurity measures should also be taken to maintain stable operations in the event of cyber-attacks including spoofing, man-in-the-middle, and denial of service attacks.

User outreach and education: User outreach and education was another common concern. Many stakeholders wanted to expand programs, but experienced challenges in communicating the benefits of enrollment and participation to potential participants. Often, prospective participants did not perceive sufficient value in the incentives and rates. Information on typical savings per year rather than slowly accruing incremental savings could improve the perceived value. Incentives that cover the costs of a specific charger installation may be unappealing to some participants if they have already installed a home charger, plan on installing a charger provided by the OEM, have a preference for the charger they would like to purchase, or prefer to fully own their equipment, as some incentives stipulate that the charger is owned by the utility after installation.

Data: Several stakeholders expressed a desire for more data ranging from user satisfaction and experience to utility savings and upgrades avoided. User satisfaction data usually comes from surveys and attrition data. Most programs were already collecting this data, but were less enthusiastic about survey data because they didn’t want to risk burdening participants with additional tasks. One important metric requiring a survey is the percent of control actions that the user noticed or which impacted their lives. This metric is difficult to gauge without directly asking users. A low percentage impact could be unacceptable. User benefit information was collected in some programs in the form of savings per month or per session. Collecting such data over longer periods would increase its value by enabling program managers to advertise substantial yearly savings.

While programs were beginning to collect user data, utility savings are more difficult to estimate given that the counter factual must be determined. Utility savings calculations require more detailed distribution system modeling to determine how close component loading is to requiring upgrades. Several ongoing National Laboratory studies are simulating load impacts with and without charging and comparing upgrade requirements under each scenario. However, these studies are lengthy and require detailed analysis, making simulation for all potential SCM impacted areas infeasible. If enough of these studies are conducted, they could be combined to develop and approach to quickly approximate SCM-related savings for a wide range of utilities. Such an approach could encourage more widespread SCM implementation.

Building confidence in SCM as a resource: Another interview theme was trust in the SCM controls when sizing new utility infrastructure. When installing new charging equipment or new residential feeders with home charging, utility component sizing is based on the highest feasible loads without consideration of SCM. This means that today SCM controls do not reduce the costs of installing new equipment. Establishing more SCM approaches and demonstrating their ability to reliably shift loads will build trust SCM. With this trust SCM can be created and specified in new installation contracts, facilitating lower capacity, lower cost infrastructure.

At least one stakeholder noted that it was challenging to quantify distribution grid upgrades. Because the impacts need to be measured at a feeder level or more granularly, utilities struggled to identify the extent to which they could defer investments and did not believe that they could eliminate the distribution grid upgrades entirely. For that reason, they tied their control strategy to wholesale price peaks. This limitation reinforces the requirement for different layers of SCM approaches to provide various functions from the bulk system to the site level.

The lack of interoperability between EVSEs and utility control signals limited the strategies some EVSE control industry members were capable of implementing. Other companies can respond to utility signals, but they are struggling with interoperability between their software and many automotive OEMs.

Rural perspectives: A few stakeholders in rural areas were not yet seeing EV adoption at levels where SCM would make a significant impact. Increasing adoption in those areas will require increased access to en route fast charging and education on cost savings compared to operating a gas vehicle with concrete numbers assigned to savings. One stakeholder in the southeast said that EV charging did not currently coincide with peak times, so SCM was not yet worthwhile as a load shifting practice. They are pursuing future SCM strategies in preparation for higher future adoption which will likely shift and increase the peak.

Stakeholder perspectives gathered at the EVs@Scale Semi-Annual Stakeholder meeting in February 2024: The perspectives expressed at this meeting mostly aligned with what was discussed during interviews. The key findings are as follows:

- Participants expressed a strong desire to showcase and demonstrate real-world use cases for SCM and grid integration, including large fleets, travel centers, workplace and residential charging scenarios, emergency response situations, and vehicle-to-everything (V2X) capabilities.
- Addressing grid impacts, interconnection challenges, and cost-sharing mechanisms emerged as critical needs, particularly in high EV adoption areas where issues like feeder panel limitations and charging beyond grid capacity could arise.
- While some viewed V2G and VGI capabilities as enablers for quicker adoption and demand management, others questioned their necessity if batteries become abundant and inexpensive.

- Calls were made for government subsidies and support, like the petroleum industry, as well as partnerships and collaboration between OEMs, utilities, and charging providers to match energy demand with supply.
- Regarding grid impacts of EV adoption, service transformer loading and distribution feeder loading were the two biggest immediate concerns and transmission loading was the primary long-term concern. Stakeholders expressed concerns with lead times for upgrades, especially for service transformer upgrades which have and will continue to prevent EV adoption in some cases unless SCM strategies are adopted.
- Permitting, interconnection, upgrade component procurement, and upgrade component installation lead times were all mentioned as delays slowing adoption, with a desire to work through lead times in parallel instead of in sequence. Technician workforce limitations were also noted as contributing to long lead times.
- Stakeholders expressed that some areas are already seeing EV adoption limitations from grid capacity constraints. There was a desire for better data and analysis to make strategic utility upgrade plans. Desired data included EV adoption locations and projections, vehicle charger usage data, advanced metering infrastructure (AMI) data for load tracking and forecasting, medium and heavy-duty vehicle usage and routing data, and fleet electrification plans. There were also requests for a national atlas of policies and rates.
- Stakeholders expressed preferences for simpler charge management methods if they could be effective. When asked which SCM approach they thought was best, most responding stakeholders said TOU rates, with fewer saying higher resolution rates, and even fewer saying active controls. Many stakeholders expressed the caveat that a more complex implementation should be leveraged if the simpler one was insufficient. This caveat will likely become extremely important as several charge management deployments with only TOU rate structures have proven insufficient at reducing peak loads in high EV adoption areas. Several charging service providers expressed a preference for less fluctuation in rates for en route charging and public charging so that users aren't surprised by changes in billing.
- When discussing SCM valuation, participants identified the following SCM costs which should be included in rate design: recurring costs of communications networks, backend, software management, network infrastructure, sensor installation, cybersecurity measures, interoperability testing and certification, substation usage, EVSE installation costs, and impacts to customer service. Participants identified the following SCM-related savings that should be included in rate design: avoided reconductoring, avoided transformer upgrades, avoided panel upgrades, avoided upgrade labor costs, avoided curtailment, and upgrade deferral valuation. Some stakeholders showed interest in including equity parameters in SCM valuation. A few resources were mentioned which may help with pricing and rate creation including the California Flexible Unified Signal for Energy (CalFUSE) framework and the E3 Avoided Cost Calculator.

Overall, stakeholders expressed desires to resolve standard certification gaps, long lead times for interconnection, valuation of SCM based on previous study data, and a need for government entities to lead and coordinate stakeholders in determining SCM development and deployment strategies.

3.3 Identifying Knowledge Gaps in Creating Confidence in EV Charge Management

Based on the characterization of EV charge management deployments, knowledge gaps were identified. These gaps may apply to constraints at all levels of the electric grid—site/customer, distribution, and bulk system. The gaps are characterized here and prioritized in section 4.

Local Active Load Management to Meet Distribution Capacity Constraints
Active load management for distribution systems involves dynamic control and adjustment of electricity loads in real-time to optimize the performance and efficiency of the distribution system. Unlike passive load management, which involves fixed strategies such as peak shaving or demand response programs, active load management utilizes advanced monitoring, communication, and control technologies to actively respond to changing grid conditions. A permission-based mechanism to do this is included in OpenADR 3.0. It involves subscribing customers to a capacity level for their typical use (without high levels of EV charging) that they normally never exceed. At any time, customers can charge at a level between their current use and a subscription limit. If they want to charge faster, a request can be made to the utility for extra capacity for a specific time duration. The request may be granted without constraints; it may be available for a fee (if it is a peak time for local capacity); or it may not be granted if there is no capacity available. The ability to modulate charging by tracking meter status is available from multiple vendors today. The OpenADR 3.0 User Guide (OpenADR, 2024) describes these mechanisms. Research is needed to investigate how best to coordinate capacity between the grid and customers. The communication semantics are uncertain, but the hardware needs are clear.

Integration with other site loads or generation: Only seven deployments included onsite renewable generation as a consideration for SCM integration. About a dozen deployments included consideration of onsite storage in addition to EVs. There was a lack of integration with other onsite loads. This lack of holistic planning and operations represents a clear gap that should be addressed to achieve site and campus-wide load management strategies.

Functional, end-to-end SCM interoperability: A major technological gap identified in stakeholder interviews is interoperability, defined as the ability of different hardware and software to work together in an end-to-end load management across different utilities, aggregators, vehicle types, and chargers. This is an expanded definition of interoperability, as the term is generally applied only between EV and EVSEs. This is a broader multi-vendor, multiple technology, multi-pathway ability to send control signals that affect hundreds or even thousands of EVs. Most deployments with automated responses are limited to either certain vehicle types, certain EVSE types, or both. Deployments that only provide pricing signals often do not specify a vehicle type or EVSE type, relying on users to respond to pricing, shifting the onus of response to the vehicle owner. Stakeholders identified interoperability of EV types, EVSE types, and aggregator services as a critical hurdle to scaling their SCM programs. Stakeholders also expressed a desire to extend the interoperability beyond vehicles to allow dispatching of other loads, creating full load profile applicability and integration to smart charging controls.

There were no direct control deployments that included multiple EVSE products and multiple vehicle models. Several existing deployments utilized telematics to send charging instructions directly to vehicles, while a few others leveraged communication protocols like OCPP to send control signals to the EVSEs. These deployments were limited either by the charger model or vehicle model. Telematics are often leveraged when partnerships exist among vehicle OEMs, utilities and aggregators which allow sharing vehicle data, enabling participation by owners of particular vehicle models and use of any charger. Conversely, control at the EVSE level, often using OCPP, allowed participation by those with particular EVSE models and use of any vehicle model. Standardization of communications and data sharing could allow wider user participation, use of any type of charger or vehicle, and avoid the need for utilities to partner with each participating manufacturer.

Dynamic rates: There were no deployments with dynamic pricing. This is due to an inability of EV and EVSE users to respond to dynamic rates, a lack of utility visibility into real-time status of distribution systems, and a lack of interoperability among EVs, EVSEs, and aggregator or utility control systems. Most rate structures were general TOU rates or EV-specific TOU rates that did not have any real-time feedback and response to accommodate grid status. Coordination among utilities, regulators, customers, and aggregators is needed to develop dynamic pricing mechanisms that meet the needs of both bulk and distribution systems.
Dynamic pricing needs to be highly responsive to real-time grid status and avoid creating new peaks due to responsive loads. Standardization is needed for communicating price and other related information to the customer, to equipment within customer sites, and to cloud entities that provide optimization services. California is working on highly dynamic pricing for retail customers—CEC-Load Management Standards (CEC-LMS), California Public Utility Commission-Demand Flexibility (CPUC-DF), California Load Flexibility Research and Development Hub (CEC-CalFlexHub). When the optimization is external to the EVSE (or vehicle) then standardization of charging controls is also needed; this can be the same control mechanisms used by virtual power plan (VPP) operators.

Behavioral responses to signals: Utility demand response programs that perform thermostatic reset on HVAC systems have some understanding of elasticity of demand to signals or dynamic pricing, but this knowledge has yet to be gained by SCM programs. Some stakeholders said that they did not want to overburden users with extended or frequent questionnaires to collect this information. There is value in understanding how participants respond to pricing signals as a function of time of day, day of week, and other circumstances that may influence customer flexibility and preferences.

Human behavior regarding SCM program participation and attrition: In addition to the behavior to pricing signals there is value in understanding the behavior for EV owners/drivers to opt in or out of SCM programs. What features are desirable and what features are difficult to accept for diverse customers.

Demographic variation is difficult to analyze because many early adopters may fall into the same demographic categories. Demographic variation may also coincide with different market segments. By understanding participation across a broader range of potential EV drivers, stakeholder can better understand how load management will scale and the multiple approaches that may need to be layered to maximize the benefits.

Magnitude and reliability of load shifting and demand response: Very few SCM deployments included recording, analysis, and publication of metrics. Utilities will often collect some metric data, but do not make it publicly available. As a result, utilities interested in adopting similar plans must duplicate the pilots and analyses. Particularly important metrics are the magnitude and reliability of demand response capabilities from SCM. It is difficult to quantify peak power reduction and total energy shifted because they require comparisons with a scenario of what could have happened without the program in place, using only historic data. Reliability of power and energy shifts can be quantified by the participation rate in each event, the occurrence of customers opting out of events, and/or the expected load shift compared to the actual load shifted.

Heavy-duty applications: Very few SCM deployments included heavy-duty vehicles, and almost all of them involved large transit buses. More deployments with heavy-duty vehicles could help reduce interconnection times, improve storm resilience, and reduce fleet owner operating costs. Stakeholders expressed they want to extend offerings to heavy-duty vehicle operators but limitations in the availability of heavy-duty EVs and EVSEs that meet fleet owners' operational requirements have presented challenges to the adoption and implementation. Utilities also see value in SCM for HD EVs in allowing faster interconnection, but are hesitant to permit oversubscribed interconnection(s) for HD EVSE chargers if the SCM limitations cannot be guaranteed.

V2G: Another gap in the existing SCM deployments was V2G implementation. There were very few deployments outside of California that included V2G. Several of those deployments included provisions for V2G capability, especially in a contingency event, but only a few documented any testing or implementation of the V2G capabilities and, only at a small scale. The deployments that included provisions for V2G revealed the value of this capability, but pointed to the limitations of existing vehicle and charger technologies.

Rural applications: The survey revealed a very limited number of SCM deployments in rural areas. This is due to lower EV adoption, higher investment costs versus revenue, and lower populations. Rural residents often drive longer distances, have less access to fast charging infrastructure, and may require larger vehicles to navigate rougher road conditions resulting in lower EV adoption. However, rural adoption is likely to grow as EV ranges increase, a wider range of affordable EV models become available, and more public charging infrastructure is deployed.

Rural area distribution systems also have unique characteristics. For example, rural loads are at the ends of longer primary and secondary lines than typical. They also may have fewer customers per transformer. Such rural configurations can create additional voltage needs and reduce the ability to smooth loads from aggregation and control of many customers. Deployments that included rural areas used basic EV TOU rate structures to accommodate bulk system constraints but not distribution system limitations. In the interviews, utilities said that they did not target rural areas because of low adoption. They also expressed concerns about stranding drivers with long travel when SCM limits distances.

4 Actions to Address Knowledge Gaps

The SCM gaps are prioritized based on three characteristics: urgency; impact, extensibility, and scaling; and value of federal funding.

Urgency of the particular use-case to offset traditional grid assets refers to how soon implementation would have an impact.

Impact, extensibility, and scaling are grouped together and describe how results could provide benefits across the entire spectrum of 3,000-plus utility service territories including projected technical and market potential for a particular grid service. Extensibility describes the ability of an action to be applied to other areas which might have different needs or constraints. Scaling is slightly different from extensibility in that it describes the ability of a project to ramp up easily to a larger pool of participants.

Value of federal funding describes the necessity of federal funding to fill a gap that industry or local government is unable to fund sufficiently. This value includes potential to leverage and/or add scope to existing field demonstrations funded by other non-federal funding mechanisms.

Descriptions of priorities are organized by economic sector. An overall priority list, not separated by sector, is provided in the conclusion section. Overarching gaps described later in this section pertain to all deployments.

4.1 Site-Level Integration Priorities

Site-level capacity limits can prevent EV adoption in residential, commercial, and industrial sectors. Addressing site limitations is urgent and scalable and could use federal funds to enable greater adoption across sectors. Together these factors make site-level capacity limits a high priority gap. SCM may enable EV adoption at limited capacity locations, but demonstrations with over-subscribed site-level infrastructure are not prevalent, partially due to a lack of utility confidence in SCM's ability to maintain site loads below capacity limits. This need could be met by designing dedicated depot smart charging platforms for locations with capacity limits.

4.1.1 Higher Priority Site Level Gaps

Site-level SCM could have widespread, cross-sector impact and potentially ameliorate some equity concerns if SCM deployments included coordination with other site loads. Visibility of other site loads is a technical barrier due to different communication protocols between EVSEs and other industrial loads, system loads, or appliances. Improving technologies for holistic site load management and deploying SCM with this visibility and coordination can provide high scalability for commercial load profiles, industrial operations, or residential appliances.

This priority has high urgency, because it could enable more rapid EV adoption in sectors where current site capacity constraints limit deployment of infrastructure needed to meet charging demands. It could also potentially lower adoption costs such as additional trenching for higher capacity conduits, or panel upgrade requirements if regulations were to allow older breaker panels to be used for EVSEs when SCM is implemented to maintain current below rated thresholds. Clear documentation of successful demonstrations and learnings in this area could increase utility confidence to approve oversubscribed interconnections with SCM systems. Site-level load coordination with SCM could benefit by incorporating additional data streams from AMI, smart home integration, and utility monitoring of controls. Such coordination will require local dispatch signals that can automatically respond to dynamic pricing and profiles with minimal human involvement.

Cybersecurity and privacy improvements will be necessary for SCM sites. SCM-related monitoring raises privacy concerns regarding customer data collection, storage, and access. Control signals require additional cybersecurity to ensure that bad actors cannot interrupt or fake signals that control critical systems. These measures are essential to prevent SCM operations from being compromised.

4.2 Distribution System Integration Priorities

Distribution system capacity constraints will limit EV adoption sooner than bulk system limits in most areas. Given that most examples of charge management have prioritized bulk system load management, there are several gaps in accommodating distribution system needs using SCM. The higher priority gaps relate to increasing distribution system hosting capacity without long lead times and expensive grid upgrades. The lower priority gaps relate to voltage regulation which may be possible using EV inverters if capacity needs are met.

4.2.1 Higher Priority Distribution Gaps

Several SCM deployments have existing or planned capabilities to prevent distribution system overloads or voltage excursions. These advanced demonstrations should be continued so that data can be collected and analyzed during a wide range of seasons, load shapes, and customer adoption levels. Analysis of long-term projects will be critical for filling several distribution gaps.

The highest priority distribution system gap is valuing capacity management for substation and feeder upgrade deferral as well as valuing right sizing of upgrades where they cannot be avoided. Increasing transformer and feeder capacities throughout networks would be costly and delay installation and interconnection of needed charging stations. Accurate valuation of upgrade deferrals enabled by SCM is needed to develop effective incentives correctly and to compare SCM deployments to infrastructure upgrades in different markets.

A tool to compare costs of existing SCM deployments with savings from avoided or deferred upgrades could inform new SCM deployments. General rules and guidelines for cost considerations could reduce utility efforts to repeat SCM deployment studies. A common framework for economic analysis would increase utility confidence in cost savings from SCM deployment and help guide financials available for rate structures and incentives for SCM participation. The best deployments will not require increased rates to offset incentives provided to customers.

Some of this valuation work will require separating utility profitability from upgrade expenses. In many cases, rate increases are tied to system upgrades, artificially inflating the utility’s valuation of upgrades with potentially long lead times. If utility profits can be separated from infrastructure upgrade expenses, then a more accurate valuation of the two would benefit customers by keeping rates affordable and support the growth in EV adoption. Separation of profits from upgrade expenses may require updates to public utility commission review criteria. This gap is a high priority, particularly for areas with high EV adoption rates or adoption targets.

The impact of filling this gap is relatively scalable. As EV adoption increases, more utilities must decide between system upgrades and SCM program deployment. Federal funds can have a potentially large impact in this area by supporting analysis of existing demonstrations and development of an SCM valuation toolkit.

Holistic controls integration is a priority gap to fill for distribution systems. Increased visibility of local grid status and real-time pricing to reflect that status could encourage demand management for all loads including SCM and thereby increase EV hosting capacity. Dispatching controls in response to these pricing signals would be required to assess how the signals leverage different load types and the role of SCM within more holistic load profile considerations.

4.2.2 Lower Priority Distribution Gaps

Once distribution capacity limits are met, SCM may be able to provide voltage regulation services. A few small-scale deployments have used EV charging Volt/Watt control in which the real power drawn by the vehicle is altered to support local distribution voltage. Such demonstrations could be extended to investigate impacts of local Volt/Watt control on entire feeders. Additional capabilities of EVSE inverters could also be investigated. For example, technology development to support Volt/Var control at the inverter may have lower impact on vehicle charging than Volt/Watt control.

Other EVSE capabilities could be developed to bring EVSE inverters in closer alignment with capabilities of other distributed energy resources as outlined in IEEE 1547. These inverter capability requirements could be applicable and useful to the distribution system if V2G capabilities were enabled on more vehicles. Bringing EVSE inverters in closer alignment with other requirements for distributed energy resources would enable more streamlined regulation and standardization across sectors and interconnections. This work is lower priority because capacity constraints must be met before voltage regulation is considered. Also, technology for this type of control is less developed than typical load shedding and demand response programs. As a result, it will take longer to complete lab-based, small-scale, and finally full-scale field deployments. The implication for this technology is scalability, and federal funds would be valuable in this area, but the urgency of EVSE inverter capability demonstration and deployment is lower than addressing capacity constraints.

4.3 Bulk System Integration Priorities

Most EV charge management deployments have been designed to accommodate bulk load profiles. These efforts often come in the form of TOU block rates that have been effective for low EV adoption levels, but will face challenges at high adoption levels if they do not incorporate more dynamic pricing and/or direct controls.

4.3.1 Higher Priority Bulk System Gaps

Timer peaks occur when EV owners start charging when the TOU rate switches to the lowest price. Timer peaks will be a bigger problem sooner for the bulk system compared to overall resource magnitude and persistence. This gap will require layering TOU rates on top of controls and/or finer granular resolution prices where charging is spread more evenly throughout a time period given smaller price differences and time durations for each rate block. Improved locational granularity would also improve timer peak behavior, but may cause equity concerns and discrepancies in fairness of customer billing.

VPP interoperability is another high priority gap. Among the needs are standardization of the interface between VPP operators and other grid entities. Additionally, standardizing the interface between VPP operators and in-building equipment can enable customers to choose among VPP operators, rather than use the operator selected by the manufacturer.

4.3.2 Lower Priority Bulk Gaps

Utility grids and wholesale markets include a diverse array of services from a variety of grid entities. Grid services beyond load shifting away from peak hours, often referred to as ancillary services, have not been demonstrated, but should be evaluated separately to understand the potential value. These grid service gaps include greenhouse gas rates and incentives for frequency regulation.

For customers, the vast majority of grid services involve shifting load from high-cost times to low-cost times. This is because there is not enough value in other grid services for most customers to meaningfully participate. All costs paid for grid services need to be paid for through customer bills. If all customers have an EV charger, then the revenue they get from the grid services provided will be paid for by them in the bill. The value of all grid services from EV SCM needs to be quantified to determine the best incentive structures for the appropriate desired responses while maintaining affordable customer bills.

It is also important to quantify the value of customer incentives for charging EVs in ways customers wouldn’t normally prefer that benefit the bulk or distribution grid. California electric rates include a carbon tax, but this approach is not widespread with other U.S. utilities. More work is needed to study how a greenhouse gas “signal” could impact EV charging behavior.

4.4 Overarching SCM Gap Priorities

Certain knowledge gaps apply to all sectors. These overarching SCM gap priorities are highly scalable given their wide applicability and reported need from stakeholder interviews. Gaps which apply across sectors include an end-to-end certification process for SCM functionality to address fragmentation in control methods and standards; evaluation of SCM approaches that incorporates users beyond early adopters; and energy equity analysis for SCM deployments.

4.4.1 SCM Evaluation Beyond Early Adopters

One high priority gap is to evaluate SCM deployments that scale to include users who are not early adopters.

Residential and workplace use cases will likely require such evaluation. Fleet and medium- and heavy-duty applications may not require demographic analysis.

A better understanding how SCM benefits consumers in a wider range of demographic groups will increase confidence in EV ownership. There have been many examples of programs and pilots for early adopters, which are predominantly suburban, affluent EV owners, but there will likely be differences in charging needs and behaviors in different types of housing and different income brackets. Expanding demonstrations and analysis to include more demographic groups could improve equity by reducing barriers to electrification in overburdened communities. Demographic analysis may reveal that different SCM approaches encourage different groups to adopt EVs.

4.4.2 Equity Implications in SCM Implementations

SCM costs should be structured so that overburdened communities are not disenfranchised from participating and receiving benefits. Technology requirements must be considered with an equity lens. For example, high-speed home internet may not be available in overburdened areas. More deployments are needed for multi-unit dwellings and for homes without access to home charging. This may require insights on how SCM in public charging can ensure equitable access and distribution of benefits.

4.4.3 Certification Processes

SCM capabilities to set charging limits or dynamic pricing in addition to communications and data sharing between EVSEs and EVs must be certifiable. Functional testing is needed of load control strategies starting from the initiation of the signal by a grid operator or aggregator to hundreds or thousands of EVs and/or EVSEs in addition to the communications and standards compatibility testing already being done in “testivals.” This testing could begin with hardware and software certification to control a single EV or EVSE and scale to the appropriate size for sufficient grid impacts. Conformance test procedures should be developed and then expanded into more complete, scaled, end-to-end testing. Certification process development could occur in public private partnerships with DOE National Laboratories and industry stakeholders.

There are many different EVs, EVSEs, aggregators, utility programs, and third-party applications. A credible certification process and possibly a centralized organization for certification administration could improve interoperability. Many SCM deployments were limited to certain vehicles or EVSEs or required specific utility meters. Any special metering must meet accuracy and precision standards for revenue grade meters. These limitations are created by fragmentation in control methods and communication protocols and standards. A certification that could verify that control signals effectively control charging at the plug or vehicle would increase confidence that SCM programs can and will work as planned. Associated communications standards should be tested within this framework. This gap is a high priority because it is urgent to prevent further fragmentation of technology implementations. It is highly scalable in that certified configurations could be implemented in any location and apply to many use cases. There is also a high potential benefit from federal funds in this area to further refine standards and create a certification process for the implementation of those standards and the performance of SCM deployments.

4.4.4 Avoid Fragmentation in Control Through Commonly-Accepted Control Messaging

Organically grown communication standards over decades have led to a multitude of different ways to communicate across the entire delivery chain from a grid operator to a utility, to an aggregator to a charging network provider to a site host to individual charging stations to vehicles. While each of the different communication paths have standards, there are too many paths and too many options to implement the controls across the entire delivery chain. This may lead to fragmentation of controls that may hinder large-scale implementation of interoperable SCM strategies (Figure 8).

Controls fragmentation limits flexibility in coordinating smart charging programs across geographically dispersed charging stations. Further standardization is required to enable a seamless, interoperable charging experience. Certification of cybersecurity capabilities to prevent compromise in SCM signaling or connected grid or transportation assets is necessary, as well as cybersecurity checks on any collected and stored customer data.

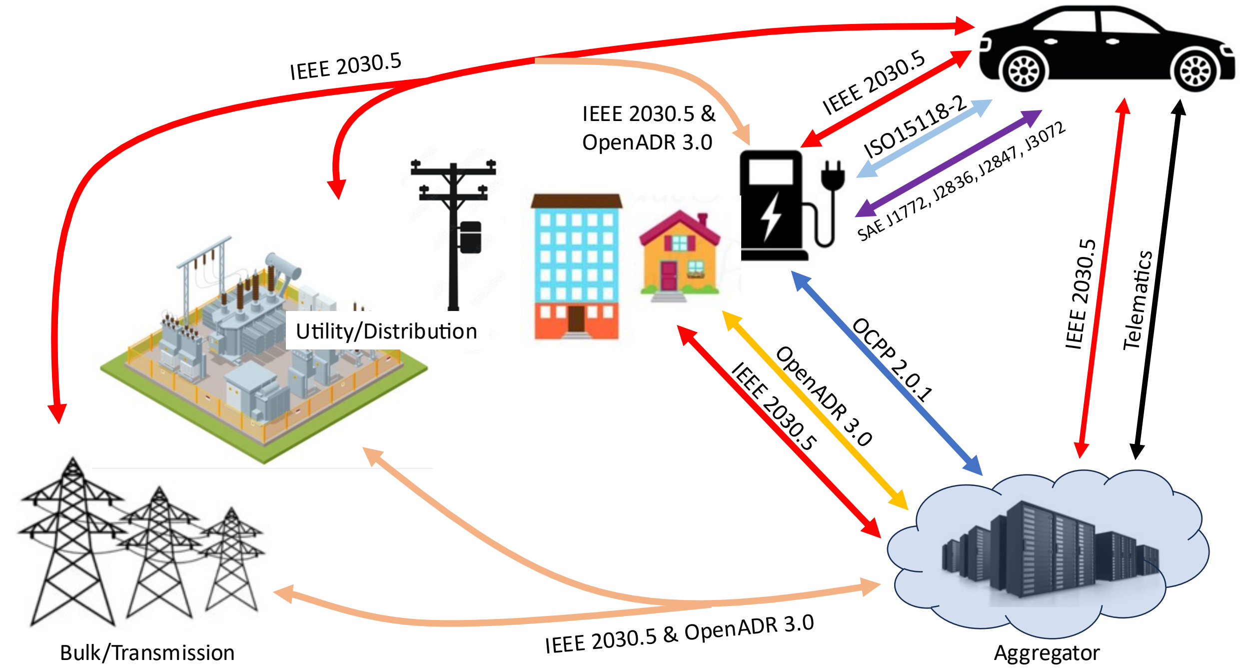

Figure 8. Multiple communication pathways and protocols between EVs, EVSEs, aggregators, buildings, distribution systems, and bulk power transmission systems. This figure is not exhaustive, with several other possible pathways and configurations.

Industry collaboration through global technical standards organizations will be needed to harmonize all of the standards. The ultimate objective is to develop a set of commonly-acceptable communication pathways and standards, leading to unified communication protocols, common interfaces between networks and payment systems, consistent equipment standards, and more integrated software architectures. Progress on these fronts will allow holistic management of public charging facilities. It will also prevent proprietary fragmentation that restricts the ability to leverage charging infrastructure flexibility for smart grid management.

5 Conclusions and Recommendations

EV charge management has the potential to be an essential resource for electrifying transportation. By increasing the utilization of the entire electric delivery system, it can improve economic efficiency and achieve faster energization of charging stations. Charging station energization timelines are of particular concern for medium- and heavy-duty vehicle electrification that requires high-capacity service connections, and light-duty vehicle electrification in capacity constrained areas with dense adoption.

TOU rates were included in the data collection and gap analysis, but rates themselves are not controls. Some type of control, even a simple timer, must be implemented alongside rates to adjust charging schedule based on rates.

Confidence in SCM capabilities must be increased to enable large-scale implementation. In addition, SCM strategies must provide value to each stakeholder. For EV owners and fleet managers, SCM must be user-friendly, not disrupt vehicle use, and generate financial benefits. For utilities, SCM must be a reliable resource that can be counted on when needed and be cost-competitive as compared to traditional wired solutions.

A series of field demonstrations must test functionality (technology works), as well as the SCM program rules and incentives to gain confidence in SCM.

5.1 High Priority Areas to Increase Smart Charge Management

The three highest priority areas for increasing smart charge management are site and distribution capacity management, VPPs that include EVs and other site loads, and highly dynamic pricing inclusive of EV charging.

5.1.1 Site and Distribution Capacity Management

Demonstration of SCM technologies for local distribution system component capacity management is needed. The most urgent needs are SCM technologies and programs that facilitate the deployment of charging stations for medium-duty and heavy-duty EV fleets in constrained distribution systems that have little headspace for additional loads. SCM will be enable early energization of charging sites.

To demonstrate SCM's cost-effectiveness, cost-benefit analyses need to be conducted for all solutions. Accurate valuation of SCM-enabled upgrade deferrals must be determined to inform development of incentives and accurate comparisons of grid upgrades and SCM deployments in different markets.

With the anticipated rate of MD/HD EV adoption to comply with states' emission and technology mandates, if a few demonstrations would quantify cost-effectiveness and reliability of SCM, those lessons learned could apply nation-wide.

5.1.2 VPPs that Coordinate All Site Loads Including EV Charging

There is a need for demonstrations of SCM technologies that coordinate VPP operations for support of local capacity management.

Currently, the VPP model is popular in utility and wholesale demand response programs nationwide. If large charging stations could be located near the generation or storage resources of

VPPs, large capacity distribution requirements for charging could be partially addressed with VPP generation. Furthermore, the load flexibility of any EV charging could effectively augment VPP resources.

The majority of such programs aggregate devices by type to deliver a greater number of megawatts of demand response. EV charging is also being aggregated under this model, often through vehicle telematics. The VPP model tends to be significantly more cost-effective and easier to scale compared to a customer-total-load optimization approach. However, aggregating EV charging load alone without incorporating other customer loads would not address the growing capacity management challenges at both customer panel and distribution grid levels with greater EV adoption.

The DOE Loan Programs Office has identified VPPs as a necessary part of future grid/customer coordination. The VPP Liftoff report (Downing, 2023) includes identifying interoperability and standardization as challenges to be overcome. It discusses the need to standardize the interface between VPP operators and other grid entities, and between VPP operators and in-building equipment. The latter interface enables customers to choose among VPP operators, rather than being able to only utilize the operator selected by the manufacturer.

5.1.3 Highly Dynamic Pricing Inclusive of EV Charging

Coordinating development of dynamic pricing mechanisms that meet the needs of both the bulk and distribution systems is important for SCM future deployments. This requires input from utilities, regulators, customers, and aggregators. Standardization is needed for communicating price and related information, including from the grid to the customer, within customer sites, and to cloud entities that provide optimization services. California is working on highly dynamic pricing for retail customers (CEC-Load Management Standards, California Public Utility Commission-Demand Flexibility, California Load Flexibility Research and Development Hub). When the optimization is external to the EVSE (or vehicle) then standardization of functional charging controls is also needed; this can be the same control mechanisms used by VPP operators.

Pricing signals reflecting the time-varying and location-specific cost of generation and delivery of electricity are powerful mechanisms for any end-use control. Sending these signals would require a service that can evaluate thousands of location-specific price points within a distribution system, then update them on a fifteen minute or hourly basis. A receiving entity would need to automatically interpret and respond to the information. While real-time, hourly pricing exists, all existing implementations are indexed on the locational marginal cost of the bulk power market. Layering locational marginal pricing for the distribution system over bulk power market pricing requires a level of complexity not yet available.

5.2 Use Cases

Use cases that could help address high-priority gaps are fleet charging, light-duty EV charging at single-family residences, light-duty EV charging at multi-family residences, light-duty EV charging at workplaces, and time-shifting EV loads with additional methods beyond just TOU rates.

5.2.1 Light-, Medium-, and Heavy-duty EV Fleet Charging

EV fleets pose a particular strain on the distribution system because of the large loads. As a result, there is an urgent need to demonstrate charging use cases for light-duty, medium-duty, and heavy-duty EV fleets.

Medium-duty and heavy-duty EV depot charging is particularly urgent, because of the approaching zero-emission mandates in some states. Therefore, use-cases with depot charging may deserve high priority in SCM demonstrations.

5.2.2 Light-duty EV Charging at Single-family Residences

Light-duty EVs in all homes, but particularly older homes, which are more likely to be in overburdened communities may be limited by site or distribution service capacity constraints. Electric circuit panel limits in homes could also slow EV uptake. Whole home energy management technologies are needed to enable installation of charging infrastructure without panel upgrades. Demonstrations should coincide with regulatory improvements that allow charger installations without costly upgrades if appropriate load management measures are taken.

The highest priorities are demonstrating light duty EV charging in affluent and middle-class neighborhoods where higher EV adoption will take place sooner and overburdened neighborhoods with lower distribution capacity per customer. There is currently no solution to the growing problem of distribution grid capacity constraints for charging in single-family residences. As the number of EVs increases, some neighborhoods are already seeing utilities applying limits to home charging station installation. SCM with hyper-local capacity management could address this. However, technologies and data sharing to reliably communicate local transformer capacity and EV charging needs are lacking and need to be developed and demonstrated.

5.2.3 Light-Duty EV Charging at Multi-Family Residences

There are some managed charging solutions for light-duty EVs in multi-family residences, but they are fairly simple and lack much user benefit. Technology advancements and demonstrations are needed. Technology for simple load splitting across ports in multi-family residences exists and has been and is currently being demonstrated. Technology for more sophisticated dynamic capacity management accounting for actual grid and building conditions is under development and needs to be demonstrated.

5.2.4 Light-Duty EV Charging at Workplaces

SCM is needed to increase total number of EVs that can be served cost-effectively with minimal to no electric circuit upgrades at workplaces. This capability has been demonstrated with current technology and standards. There is need to demonstrate SCM to modulate EV charging to match solar power generation's diurnal cycle to maximize charging with solar power and minimize greenhouse gas emissions related to EV charging.

5.2.5 Time Shifting of EV Charging Beyond TOU

TOU rates (EV-specific or whole-house) alone do not guarantee customers will schedule charging accordingly via EVSE or EV (directly or via an app). Customers must have a system to automate charge scheduling in response to dynamic rates or direct control signals while prioritizing vehicle needs, such as required SOC and unplug times. Getting customers to download an app and complete a one-time set-up for automated charge schedule shifting has been shown to be effective and may not require additional rate structures or increased rates to compensate for ongoing customer incentives. There is a need to determine the most cost-effective incentives for downloading, setting up, and consistently/persistently allowing an app to control home charge scheduling. It's preferable to have one customer charging control app to control customer loads instead of requiring customers to have different apps for each layer including utilities, third-party aggregators, charging service providers (CSPs), and vehicle OEMs.

The urgency of these needs is high because light-duty EV adoption will increase sooner with middle-class and affluent customers that are more likely to live in single-family homes. Federal research funding can greatly assist in addressing these gaps because an outside entity is needed to coordinate utilities, third-party aggregators, CSPs, and vehicle OEMs.

5.3 Suggestions of Pathways to Address SCM Gaps

Some gaps could be addressed through technology development to improve technical maturity, while other gaps will likely require policy or market changes.

5.3.1 Improved Technical Maturity

There are many technologies ready for widespread deployment, though these still need better integration methods. Other technologies need additional development before widespread deployment. Technology development needs include interoperability and standards for communications hardware and networks, V2G implementations, and heavy-duty EV and charging technologies.

Interoperability is important for V2G deployments because vehicles must be able to communicate with dispatchers to discharge to the grid. The vehicle, charger, and interconnection must also be interoperable to allow reverse flow of energy to the grid when called upon. More technical development of vehicles and EVSEs with V2G capabilities would allow SCM programs to leverage V2G more widely.

Improved maturity of heavy-duty EVs and associated heavy-duty chargers could make them more applicable to SCM deployments and more available to heavy-duty vehicle operators.

5.3.2 Understanding of Market Policy Potential

Some SCM gaps are due to a lack of market or policy knowledge. These gaps include a quantification of the magnitude, reliability, avoided interconnection delays, and cost savings of load shifting and event demand response.

Rural SCM applications may need to differ from applications in suburban or urban settings. These differences will likely stem from greater daily energy needs for customers to drive longer distances and different voltage regulation needs for longer feeders There will also need to be more precise SCM controls because distribution transformers in rural areas serve fewer customers per transformer. Such rural applications have yet to be evaluated, but will require insight with increased future adoption in rural areas.

Quantification of market and policy impacts will be critical for widespread implementation and continued support for continuing existing programs. This quantification will rely on metrics collected and analyzed from existing pilots, programs, and incentives.

Market, policy, and technical demonstrations and further analysis are all needed to assure advancement of SCM in pursuit of rapid and affordable EV adoption. These demonstrations and analysis as described in this report can leverage data from previous studies, continuing expanded demonstrations, and new application demonstrations and all could benefit from federal funding to achieve extensible and impactful results.

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Appendix A: Interview and Discussion Questions

The questions used in the stakeholder interviews:

- What are the barriers that you see slowing the adoption of SCM?
- What are the financial benefits that you see accruing to drivers, utilities, CSPs, and automakers from SCM programs?
- Are existing SCM programs adequately capturing those benefits? Why or why not?
- How would you quantify the success of an SCM program?
- Which existing SCM programs do you believe are the most successful based on those metrics or others?
- If you had carte blanche to design an SCM program, what components would you include?
- How do you scale an SCM program from 1,000 people to 1,000,000?
- What data, research, lab work, or field demonstration is needed to address any of the responses to the questions above?

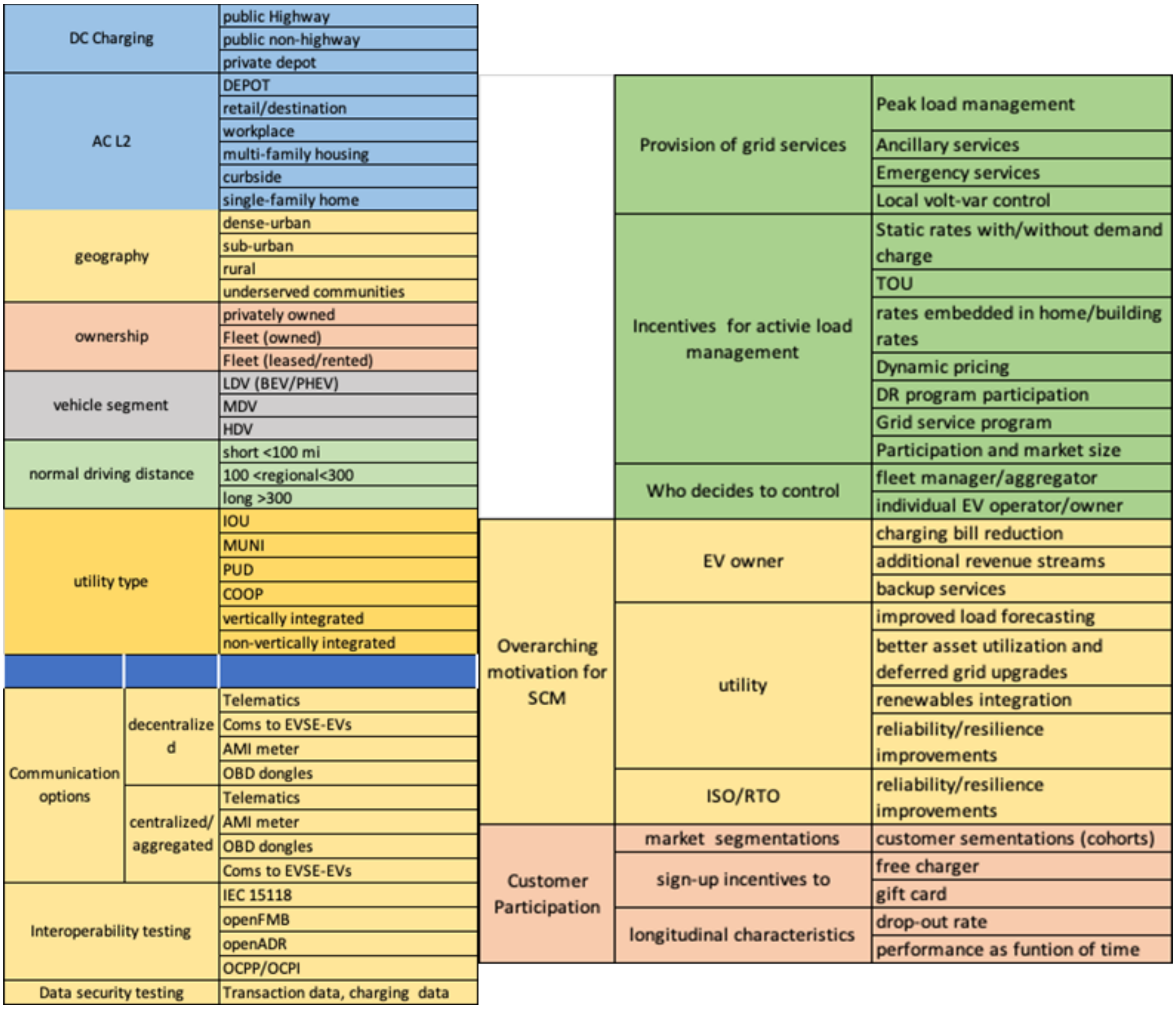
Below are discussion questions answered by participants during discussion sessions and the working lunch of the EVs@Scale Semi-Annual Stakeholder meeting on February 28th 2024.

Background: Vehicle Grid Integration (VGI) has the potential to create many benefits for customers and general rate payers. To quantify benefits and to reduce technological uncertainties, the benefits of charge management strategies *need to be demonstrated and the value quantified in the real world through field demonstrations: The diversity of use-cases is large, too large to test all of them. Here, we try to prioritize which variables/parameters that define a use-case are most important.*

Question 1: Look at the table of key characteristics or attributes of use-cases for charge management (table below)

Q1.1: Is the table complete? If not add parameters/characteristics/descriptors:

Q1.2: Prioritize the key parameters/characteristics/descriptors: (1 through 10. 1=most important, 10=least important. Write numbers on the colored table.



DC Charging		public Highway
		public non-highway
		private depot
AC L2		DEPOT
		retail/destination
		workplace
		multi-family housing
		curbside
		single-family home
geography		dense-urban
		sub-urban
		rural
		underserved communities
ownership		privately owned
		Fleet (owned)
		Fleet (leased/rented)
vehicle segment		LDV (BEV/PHEV)
		MDV
		HDV
normal driving distance		short <100 mi
		100 <regional<300
		long >300
utility type		IOU
		MUNI
		PUD
		COOP
		vertically integrated
		non-vertically integrated
Communication options	decentralized	Telematics
		Coms to EVSE-EVs
		AMI meter
		OBD dongles
	centralized/ aggregated	Telematics
		AMI meter
		OBD dongles
		Coms to EVSE-EVs
Interoperability testing		IEC 15118
		openFMB
		openADR
		OCPP/OCPI
Data security testing		Transaction data, charging data

	Provision of grid services	Peak load management
		Ancillary services
		Emergency services
		Local volt-var control
	Incentives for activie load management	Static rates with/without demand charge
		TOU
		rates embedded in home/building rates
		Dynamic pricing
		DR program participation
		Grid service program
		Participation and market size
	Who decides to control	fleet manager/aggregator
		individual EV operator/owner
Overarching motivation for SCM	EV owner	charging bill reduction
		additional revenue streams
		backup services
	utility	improved load forecasting
		better asset utilization and deferred grid upgrades
		renewables integration
		reliability/resilience improvements
	ISO/RTO	reliability/resilience improvements
Customer Participation	market segmentations	customer sementations (cohorts)
	sign-up incentives to	free charger
		gift card
	longitudinal characteristics	drop-out rate
		performance as funtion of time

Question 2: For field demonstrations of managed charging, what are the right set of metrics to measure success?

Examples: a) participation rate in program, b) ability to provide grid services, c) reduce peak demand, e) reduce time to energize charging station

Q2.1: Please write down metrics that are measurable (think of physical or economic units)

Q2.2: Please prioritize them by writing numbers (1-5) on top of the list of metrics above. 1=highest priority, 5=lowest

Background: Electric service requests for charging station may sometimes take a long time, particularly if upstream electric infrastructure upgrades have to be installed. This creates a mismatch between the time to deliver EVs and the time to get charging stations deployed.

Question 3: How can we streamline the service/interconnection request?

Q3.1: What are the barriers. Please characterize them as to how they impede the process

Q3.2: What are potential solutions/processes to expedite energization of charging station?

Q3.3 Are the results dependent on use-cases and size of installation?

Background: This is a discussion on cost allocation for the electric infrastructure investments to service a charging station. For instance, the request electric service for a charging station may require a new substation installation, who should bear the cost for it?

Question 4: Who bears the cost for service requests that require infrastructure upgrade.

Q4.1: Do feeder upgrade costs limit future adoption EV? Do you know of cases where it did happen or may have happened; and can you briefly describe them?

Q4.2: How do you assure that distribution infrastructure is planned and expanded in a future-proof manner and done equitably?

Q4.3 How do you factor in the needs of future capacity of feeders for additional electrification.

Background: this is a discussion about distribution system planning for additional load growth

Question 5: When do utilities need to know that electric services for EV charging stations will be requested?

Q5.1: When do utilities need to know for the distribution system planning process? Specify in weeks or months:

Q.5.2: How long in advance do fleets know when they transition to EVs ? (explain how large, medium, small fleets estimate/project turnover to new technologies.

Q5.3 How do we align and streamline the planning process to reduce long waiting time for charging station energization.

Q5.4: Who would be the best entity to support a more coordinated build-out of grid and charging infrastructure (state entity, association, utilities, partnership of _____?_

During topic discussions three sets of questions were posed to stakeholders for discussion on valuation of SCM, SCM use cases, and SCM codes and standards. The SCM valuation questions were:

The SCM use case session questions were:

What grid impacts are currently and potentially resulting from growing EV charging loads? Which portions of the grid are or likely will be impacted?

Is there a level of EV adoption where grid impacts are beginning to arise? What data sources are utilities/EVSPs/stakeholders using to track EV adoption/growing charging needs?

How are utilities managing new/upgraded interconnection requests for EVs? Are EVSE installers facing challenges with grid impacts or interconnection upgrades?

Bonus: are there specific applications where passive incentives and active controls are more or less effective at mitigating EV charging impacts?

The questions from the codes and standards discussion session were:

What critical hardware, software or standard limitation presents the biggest obstacle to widespread implementation of smart charge management (SCM) today? How can we overcome this hurdle?

Beyond ISO 15118: Are there additional standards needed to ensure scalability, interoperability, and data security in SCM and vehicle grid integration (VGI)? If so, what specific areas need standardization?

What particular and practical use case scenario would be very interesting and valuable to demonstrate regarding SCM and its effectiveness using the technologies of today?

Looking ahead 10-20 years, how will evolving battery technology, grid infrastructure, and energy needs influence the development and implementation of VGI? What strategic investments and partnerships are needed to ensure these technologies remain future-proof?

Appendix B: Characterization Metrics

The full list of characterized SCM deployments is below. This does not necessarily include input from interviews with stakeholders which may not have an associated program, pilot, or study.

Table B-1. SCM Characterization

Characterizations	Options	Count
Type	Program	44
	Pilot	38
	Project	19
Status	Active	73
	Completed	28
	Starting Soon	12
Utility Type	IOU	47
	MUNI	4
	PUD	2
	COOP	3
	Community Choice Integrators	3
Utility Business Model	vertically integrated	44
	non-vertically integrated	18
Tarriff Description	Regular TOU	27
	EV Rate	37
	Hourly Dynamic	0
	Other- brief description of tarriff structure	10
Geography	dense-urban	41
	sub-urban	80
	rural	22
Environmental Justice	Incentives for low-income customers?	8
	% in underserved communities	0
Vehicle Ownership	privately owned	82
	Fleet (owned)	20
	Fleet (leased/rented)	4
Vehicle Segment	LDV (BEV/PHEV)	89
	MDV	17
	HDV	7
Normal Driving Distance	short <100 mi	54
	100 <regional<300	8
	long >300	1

DC Charging	public Highway	7
	public non-highway	12
	private depot	11
AC L2	DEPOT (Fleets)	14
	retail/destination	14
	workplace	16
	multi-family housing	14
	curbside	4
	single-family home	55
AC L1	any	12
Coordination Mechanism	3rd party aggregator SCM	45
	EV specific manufacturer cloud	7
	direct interaction from utility as in via DERMS or Tarriff	7
	other with description	11
Control Mechanism	charging station, EVSE	64
	vehicle (telematics)	29
	user behaviors (e.g., response to dynamic pricing signals)	26
Additional Elements	V2G	16
	Energy Storage (besides the vehicles)	13
	Onsite renewables	6
Input Signals	vehicle (SOC, battery capacity, type, charging rate)	33
	user needs (acceptable SOC, costs to charge, when to use next)	29
	local energy demand	15
	historical (fixed) grid-level energy demand	14
	dynamic (actual) grid-level energy demand	12
	reserved capacity for grid services	0
	carbon emissions	7
	Local transformer loading	1
Utility Optimization Objectives	wholesale power market	28
	transmission capacity constraints	3
	feeder/sub/service xfmr loading	32
	local voltage/frequency	2
	renewable energy tracking	15
	load shifting for decarbonization	11
	power distribution losses	0
	resilience: outages/PSS/ride through capability	5
	other	1

EV Customer Optimization Objectives	cost of charging for the EV customer	63
	site level management (as in for avoiding demand charges)	18
	site level management (maximizing PV utilization)	8
	Resillience: outage mitigation (bi-directional charging)	3
	Carbon emissions	6
EV Customer Incentive/ Motivation	rebate on equipment	36
	event participation incentives	36
	reduced more favorable tarriff (ev-only)	38
	recognition certificate (public acccolade for participating)	0
	Preventing Infrastructure upgrades	5
Utility Incentive/ Motivation	revenue from market participation	1
	regulatory requirement	10
	system operational efficiency	20
Value ($) for participant	$1-100/car-year	15
	$101-1,000/car-year	26
	$1,001+/car-year	1
	<$0.05/kWh	2
	$0.05-0.10/kWh	5
	>$0.10/kWh	5
	<$1/event	1
	$1+/event	5
	<$1/kW	0
	$1+/kW	4
	$1-100/enrollment	13
	$101-1,000/enrollment	17
Utility Interaction Communication Protocol	OCPP	15
	ISO 15118-2	0
	Open ADR (2 or 3)?	5
	non-direct control communication to customers (app notification)	7
	SEP 2.0	1
	Other	0
Load Management Performance Metrics	None	10
	Not quantified, or available as study in process	25
	Resource Flexibility (kW max, kW shift per EV/EVSE, etc.)	22
	Customer impact (participation, enrollment, etc.)	19
	Resource Consistency (# of events, MW/event)	18
	Other	3

Appendix C: Deployment Names, Lead Entities, and Descriptions

Deployment Name	Lead Entity	Partners	Description
AES Indiana's EV DR Pilot	AES Indiana	NA	On occasional days when energy demand is really high, Peak Demand Hours are scheduled. During these hours, customer JuiceBoxes will pause charging, though the customer can still create settings in their JuiceNet app to ensure a charge by a particular time.
EV Night Charging Discount	Alabama Power		App from alabama power that shifts charging to night for a discounted rate
Amaren Ilinois EV Residential Rate Program	Amaren		EV TOU
Virginia Off-Peak Charging	Appalacian Power		15% less on off peak charging rate with separate EV meter
Tennessee Off-Peak Charging	Appalacian Power		15% less on off peak charging rate with separate EV meter
West Virginia Off-Peak Charging	Appalacian Power		25% less on off peak charging rate with separate EV meter
Plug-In Austin Rebates	Austin Energy		Rebate for public charging station installation at commercial businesses as long as OCPP compliant
Avista EVSE Pilot Final Report	Avista	None	Residential charging DR
Avista Transportation Electrification 2022 Annual Report	Avista	None	Using AMI to quantify pre- and post-EVSE household demand and some load management
Smart Charge Management	Baltimore Gas and Electric	WeaveGrid	Direct control of charging at residential, a few public, and very limited fleet stations during peak hours.
DOE Funded (MD utilities) Residential Smart Charge Management Pilot	BGE + Delmarva P&L + PEPCO (all are MD Exelon companies)	WeaveGrid (telematics) Shell Recharge	Four-year pilot funded by DOE to enable 'advanced managed charging' that will be the basis for full scale program. Includes an EV TOU rate and utility control of chargers during peak demand.
BSOOB Transit SMART Grid	Biddeford-Saco-Old Orchard Beach Transit (BSOOB Transit)	US DOT	Demonstrate renewable energy production, on-site energy storage, and electricity load management for Greater Portland’s transit agency
REDWDS: Bidirectional Residential V2X	Bidirectional Energy Inc		

Demonstration Project			
CalFlexHub: Residential EV with Dynamic Price	BMW	UCB, Olivine	
BMW ChargeForward 3.0	BMW	UCB, WattTime	
SEEV-4 Amsterdam Flexpower Operational Pilot	Cenex Nederland	University of Northumbria at Newcastle	EVSE power limit profile to defer upgrades and reduce peak demand, created a sharp higher rebound peak at EVSE but overal load shift which allowed for deferred upgrades
ComEd Commercial EV TOU rate	ComEd		ComEd offering an EV charging delivery rate option. This new rate option is available to all nonresidential customers with EV charging and provides them with an alternative to demand-based delivery rates. This is meant to help business customers that are expected to have low charger utilization in the near term as the electrification efforts continue to grow in northern Illinois. All non-residential customers are eligible, including public sector, businesses, mass transit agencies, and other commercial categories.
REDWDS: Optiwatt REDWDS Scalable, Grid-Connected, Rate-Optimized EV Telematics Solution	Compass Global Inc Optiwatt		
FlexEV Rewards	CPS Energy		Credit for allowing CPS to send charger limit signal 2-9pm M-F, or credit for only on-peak charging 2x/month during 4-9pm M-F
FlexEV Public Charging Program	CPS Energy		Public chargers get unlimited access for flat rate/month
REDWDS: REDWDS dcbel Ready Deployment with Dynamic Rates	dcbel LLC		
EV Charger Rewards	Dominion Energy		Small rebate and yearly gift card for participating in up to 45 charge events per year

"Charging Tariffs" pilot EV Charging Station Rebate program - requires Demand Response Program	Dominion Power/Berkshire Hathaway - VA	Guidehouse	Residential customers on non-TOU rate are eligible for EVSE rebates with requirement that they also enroll in EV DR program with up to 15 DR events per month
DTE Smart Charge	DTE		Direct control of certain makes
Smart Charge Program	DTE Energy	WeaveGrid, GM, Ford, BMW, Tesla (evPulse)	The DTE Smart Charge program rewards electric vehicle (EV) drivers for allowing DTE Energy (DTE) to manage your EV's home charging to occur during off-peak time periods, based on your time of use electric rate schedule
Off Peak Charging Credit	Duke Energy	Itron/Rolling Energy Resources	SCM from app to charge off peak in exchange for $10/mo
Off Peak Charging Credit	Duke Energy	Itron/Rolling Energy Resources	SCM from app to charge off peak in exchange for $10/mo
EV Complete Home Charging Pilot	Duke Energy Carolinas - NC	OEMs - GM, Ford, BMW, Honda	Subscription taroff with fixed customer charge $19.99/month for first 800 kWh - (Duke SC proposed similar program but with $24.99/month, no regulatory decision yet) - Automakers optimize scheduling - 3 DR events/year with 12-hour notification
ECIREC EV Rebate	East Central Iowa REC		EVSE rebate if sign up for TOU
EVs for Everyone	El Paso Electric		EV TOU and rebate for commercial or residential customers
Residential Smart Charge Pilot Program	Empire District Electric Company		EV specific Tarriff for financing of L2 EVSE installed by EDEC, up to 10 DR events called and compensated per year with V2G requests possible, fee for charger maintenance
JuiceNet	EnelX		JuiceNet powers thousands of smart charging stations across North America to enable local "virtual batteries," which enable drivers to earn cash for flexibly charging their EVs and provide the grid with a dynamic and responsive asset. JuiceNet also allows drivers to control and manage their electric vehicle's charging schedule, electricity costs and renewable energy mix.
Energy Smart BYOC	Entergy New Orleans	Sagewell	EV TOU and optimization offered by sagewell regardless of charger
REDWDS: ChargeWise CA	ev.energy Corp		
REDWDS: GridFleet CA	Evenergi LLC		

Phase II EV Programs - Residential Connected Solutions	Eversource - MA		Residential SF EV + home
EV Managed Charging Program	Eversource/United Illuminating - CT		Earn incentives for participating in off-peak demand response events under utility management.
V2X Pilot	Fermata Energy	National Grid, Electric Frog	In May of 2021, startup Electric Frog provided a Nissan LEAF to the Burrillville Wastewater Treatment Facility in Rhode Island. Fermata Energy installed its FE-15 bidirectional charger and proprietary V2X software to manage the charging of the EV and deliver power on call to the building.
ChargeTO	FleetCarma		Residents were willing to reduce min SOC and delay charge for small monthly incentive
SPIDERS Phase 2 Fort Carson	Fort Carson		Smart and secure microgrid with EV2G
Residential EVolution Program (subscription)	FPL/NextEra Energy - FL	Enel X Way	Flat monthly subscription-based rate for EV charging with off-peak renewable energy - $38/month for full EVSE equipment and installation, $31/month EVSE equipment only - Customers keep EVSE equipment if they stay enrolled for 10 years
EVmatch	Green Mountain Power	Burlington Electric Department	EVSE reservation system for mud and allows private EVSE participation to make open to public
Residential EV managed charging rate ('Rate 72')	Green Mountain Power - VT		Utility provides free use of chargers while a GMP customer is enrolled in Rate 72. Utility controls chargers during peak hours.
REDWDS: Rural Electrification and Charging Technology (REACT)	Gridtractor		
HECO Commercial Public Electric Vehicle Charging Service Pilot Rates	HECO	OpConnect, Greenlots, Hitachi Corporation, Nissan North America	HECO conducted a five-year electric vehicle pilot rate study from 2013 to 2018 and provides an annual report on the commercial public electric vehicle charging service pilot rates schedules EV-F and EV-U implementation at Oahu, Hawaii, and Maui.
HECO Commercial Public Electric Vehicle Charging	HECO	OpConnect, Greenlots, EPRI	HECO conducted a five-year electric vehicle pilot rate study from 2013 to 2018 and provides an annual report on the commercial public electric vehicle charging service pilot rates schedules EV-

Service Pilot Rates			F and EV-U implementation at Oahu, Hawaii, and Maui.
Smart Charge Hawaii - Residential Smart Charging Program	HECO	Enel X, Elemental Excelerator	Smart Charge Hawaii, Residential Smart Charging Program focused on deploying EV Service Equipment (EVSE) to residential customers to shift charging, as needed, to times of day when cleaner, renewable electricity is most available
HECO Commercial Public Electric Vehicle Charging Service Pilot Rates	HECO		The extension of EV rate pilot continues a time-of-use rate structure that incentivizes charging during mid-day hours when there is abundant solar energy flowing into the grid. The lower-cost mid-day period is designed to produce fuel savings for EV drivers compared with fuel costs for gas-powered cars, as well as compared with Hawaiian Electric's existing rate options. The pilot rates are for electric vehicle charging only and requires site hosts to install a separate dedicated meter.
Honda Smart Charge	Honda	eMotor Werks (EnelX)	Honda Fit owners in SCE service territory are eligible for bonus for participating in DR events coordinated through eMotorWerks' JuiceNet software platform and relayed via Honda's onboard vehicle telematics. eMotorWerks coordinates the DR events based on CAISO signals. The HondaLink EV App considers real-time electricity grid conditions to reduce costs to the customer, while also considering the customers charging preferences.
go green fixed rate	IGS Energy	Smart Columbus	36 month fixed rate charging with SCM for rebate
InControl	InCharge	Nissan, cruise, Navistar, Ryder, General Motors, BlueBird, Autonation, IC, Motional, International	InCharge is a Network Service Provider that offers SCM called InControl. InControl allows customers to manage chargers based on TOU rates, depot consumption, telematics, and more.
REDWDS: Residential Electric Vehicle Installation Supporting Innovative Tariffs (REVISIT charging project)	IoTecha Corp		
Jackson County School Bus V2G	Jackson County School District	Ampcontrol	SCM and V2G to power after hours (like athletics) at school to offset demand charges of facilities

EV Driven Program Sub program: Managed charging demand charge credits for off-peak charging	JCPL/First Energy - NJ		Approved by the BPU in 2022 and intended to run through 2026. The program (including the demand charge discount) was fully subscribed by 2023.
Project Sciurus	Kaluza	Indra (V2G charger); OVO Energy (utility)	Project Sciurus is a research and development project designed to develop and deploy Vehicle-to-Grid (V2G) charging technology in the UK. The mission is to validate the technical and commercial potential for a domestic Vehicle-to-Grid charging solution capable of providing flexibility services to electricity networks. At the time of the project, this is the largest V2G demonstration project in the world.
Kaluza and Charge Anytime Managed Charging Program	Kaluza (software company)	OVO Energy	App that optimizes EV's charging time according to utility TOU and renewable gen
REDWDS: Technology for Reliable ElectricVehicle Electricity - TREE	Kaluza Ltd		
Charge Up LA!	LADWP		In Phase 1, LADWP provided rebates to residential customers ($1.03 million to install 548 chargers). They expanded to Phase 2 and provided 2000 rebates.
Alameda County Smart Charging Demonstration	LBNL	PSV, Alameda County	This project developed and demonstrated a charging control system, consisting of software and hardware, that was applied to over 40 Alameda County fleet electric vehicles and charging stations to monitor and control the scheduling and magnitude of charging power for each charging station port and electric vehicle pair.
Los Angeles Air Force Base Vehicle-to-Grid Demonstration	LBNL	Kisensum	The demonstration successfully provided frequency regulation to the California Independent System Operator's market for a total of 255 megawatt hours of regulation up and 118 megawatt hours of regulation down for 20 months.
Missouri Residential Smart Charge Pilot Program	Liberty Utilities		

DOER V2G School Bus Pilot	Massachusetts Department of Energy Resources	Vermont Energy Investment Coorporation	EV buses for 3 districts: excessive heating use, monitoring barriers preventing V2G, and unmanaged charging resulted in operations savings than expected
MCE Sync: EV Smart Charging	MCE	ev.energy	This project launched as a six-month pilot with 232 enrolled participants. The pilot program's goals were as follows: (1) Reduce customer energy bills by automatically charging EVs off-peak; (2) Support grid resiliency by reducing demand during the 4 p.m. to 9 p.m. window; (3) Nudge customers toward low-carbon charging and automatically align EV load with renewable energy generation in real time.
Phase III EV Programs - Residential EV Smart Charging	National Grid - MA		Participants in residential EVSE infrastructure program must enroll in Smart Charging off-peak charging rebate program.
Smart Charge NY, part of NY state REV Connect, administered by NYSERDA (includes online platform)	National Grid and ConED	NYSERDA, Uplight, Enel X, JuiceBox, ev.energy	To receive EVSE infrastructure rebates customers must also enroll in DR through JuiceBox and not already be on a TOU rate. Automatic charging when maximum renewables are on the grid. Incentivizes telematics with connection to utility managed charging network. Existing pilot expired 2022: Q4 and new program started April 2023.
EV Rate	Nevada Energy		EV TOU
Charging Perks Pilot	No. States Power/Xcel Energy - MN	Qualifying vehicle manufacturers EV Pulse	Subscription-based rate in which customers charge as much as they need at night and on weekends for a flat price. Customers may also apply for EVSE infrastructure rebates
CEC EPIC Intelligent Electric Vehicle Integration (INVENT)	NUVVE	UCSD, SDG&E, PG&E, Strategen, Nissan, BMW, Honda, Mitsubishi	The project included a variety of commercially available electric vehicles and charging stations using several different communications protocols and power capacities in multiple locations distributed across the University of California, San Diego microgrid to represent a commercial rollout scenario. INVENT intentionally included drivers with diverse use and charging patterns to allow the research team to assess the appropriateness of the use cases being analyzed. The aggregation platform successfully coordinated and controlled electric vehicle charging and discharging to provide demand charge, renewable energy optimization, frequency regulation, and demand response services while meeting the mobility needs of drivers.

GIVe Platform	NUVVE	NYSERDA	Nuvve’s Grid Integrated Vehicle (GIVe) technology is a cloud-based platform that enables intelligent, bidirectional, vehicle-to-grid (V2G) charging. With GIVe, individual and fleet electric vehicles (EVs) are transformed into reliable, distributed energy storage resources that can provide grid services, vehicle-level services, and grid-connected building load management. Smart charging ensures that every EV is charged and ready to drive when needed.
EV Time Varying Rate Option	Ohio Edison	Cleveland Electric Illuminating Company and Toledo Edison	EV TOU rate
Managed Charging Pilot	Peninsula Clean Energy	UC Davis, ev. energy, Calpine	Residential EV LM utilizing no-hardware telematics to reduce overall daily peak loads, maximize daytime solar (when possible), and test customer reactions to different incentive types.
BMW I ChargeForward PG&E's Electric Vehicle Smart Charging Pilot	PG&E	BMW, Olivine, Whisker Lab	The main goal of this project was to understand the potential of using Electric Vehicles (EV) for grid services, which can result in cost savings associated with operating and maintaining the grid as well as owning and operating a vehicle.
BMW I ChargeForward PG&E's Electric Vehicle Smart Charging Pilot	PG&E	BMW, Olivine, Whisker Lab	The main goal of this project was to understand the potential of using Electric Vehicles (EV) for grid services, which can result in cost savings associated with operating and maintaining the grid as well as owning and operating a vehicle.
V2X Residential Pilot	PG&E		PG&E proposes a three-year V2X Residential Pilot focused on spurring adoption of V2X (bidirectional technologies) for 1,000 single-family residential customers with light-duty EVs. The pilot would seek to demonstrate V2X light-duty EVs and show how this technology can reduce the total cost of EV ownership once barriers are overcome. The pilots would seek to prove out five value-streams: backup power; followed by customer bill management, system real-time energy, system renewable integration and EV export for

			grid services (such as system resource adequacy, system capacity).
PG&E EV DR program	PG&E	Extensible Energy, Geotab, ChargePoint	This study assessed the potential to leverage EV ADR charging technologies through the DRET (Demand Response Emerging Technology) program from 2020–2021.
PG&E: EV Charge Network Program	PG&E	EV Charge Program Approved Vendors	Participants will be asked to shift the amount of EV charging at their site during DR events to support the grid. The incentive payment was awarded to the participant as a credit on their PG&E bill on a quarterly basis. The site's event performance was determined by comparing the usage during an event hour to the site's average usage on recent, non-event days. The performance for each event type was averaged for the entire month. If the average monthly performance for a site was at least 20% of the site's total EV charging capacity, then the participant would be eligible for an incentive payment of $10 per kilowatt ($5/kW in each direction) multiplied by the monthly average performance, computed independently for load increase and load decrease. Participants could work with their EVSP vendor to determine a strategy to participate in the events, or they can implement their own tactics.
PG&E evPulse	PG&E	Weavegrid	evPulse for PG&E is a Low Carbon Fuel Standard (LCFS) funded pilot designed to provide resiliency for EV drivers in the face of increasing wildfires. It is a two-phased pilot, with the following goals: Phase One 1) Identify EV drivers in High Fire Threat Districts (HFTDs) and areas that have been affected by Public Safety Power Shutoff (PSPS) events. Phase Two 2) Develop a baseline for EV driver charging behavior before a PSPS event. 3) Test customer experience and valuation of a third-party platform that provides proactive communication and managed charging of EVs as a resiliency service. PG&E is currently implementing Phase

			Two of the pilot which will conclude in December 2023.
PGE's Smart Charging program	Portland Gas and Electric	WeaveGrid	"Your charger will automatically shift its charging schedule away from peak times when energy use is high and sustainable energy resources are scarcer. We call these Smart Charging Events. You can opt out. To earn rewards: Have your charger connected to the internet at least 50% of the time Charge your EV at least 13 times Participate in at least 3 events"
PGE's Smart Grid Test Bed EV Charging Study	Portland Gas and Electric	WeaveGrid	Has to sign up for the PGE's Smart Charging program, then sign up for this study. Simply plug in when you park at home. Your Tesla will charge to meet your needs and you'll earn bill credits as we optimize your charging to times when electricity costs and energy demand is lowest.
Drive EV Smart Charging Rewards	Poudre Valley REA		Credit applied at end of month to charging times
REDWDS: Prologis Mobility Solutions	Prologis Mobility Bruns Auri Inc		
RSPEV	Public Service Company of Oklahoma		EV TOU rate
Reliant EV Charger Plan	Reliant an NRG company		Discount on charging 9pm-5am, free charger installation
EV TOU rate	Rocky Mountain Power		EV TOU rate

Managed Charging Pilots: > EV Flex Charging - uses EVSE > EV Smart Smart Charging uses telematics to manage > EV price plan	Salt River Project	EnergyHub, Brattle Group	Provide information on the value of managed charging systems and ideas for program design
Demand Response Workplace Charging Pilot	SCE	Greenlots	This study examined how EV drivers respond to DR events and dynamic pricing when charging their EVs at workplace. The data collected supported analysis of consumer behavior relative to pricing strategies, charging patterns, DR event participation, impact of PEV charging on building load, and utilization rates.
Charge Ready Pilot	SCE		
Charge Ready Transport Program	SCE		CRT program provides infrastructure for fleet electrification at a low or no cost to participants procuring or converting at least two MD or HD EVs. Goal: support 870 sites with 8,490 EVs converted to electric
Schools Pilot	SCE		SCE's Schools Pilot offers the direct installation of and incentives for installing approximately 250 L1 and L2 charging stations at 40 K–12 schools. SCE staff designed the Pilot to enable K–12 schools to offer public charging, which would support the school staff, and the communities in which the schools are located. Initial rebate was set at $2000 per charge port for L1 and L2 charging stations. SCE staff also plan to offer customers an option to manage and pay for the qualified state-licensed labor to install customer-side infrastructure, for which SCE will provide a rebate of up to 100% of the installation cost.
Parks Pilot	SCE		SCE offers the direct installation of approximately 120 L2 chargers, 10 DCFC, and an optional 15 mobile chargers across 27 state parks and beaches to encourage state parks and beaches to charge their own EV fleets of LDVs. SCE owns, builds, and operates the EVSE.

Load Control Management Systems Pilot	SCE		The pilot will support customer ownership, installation, and operation of the automated LCMS. The LCMS Pilot will allow SCE to provide customers the option to receive the electrical capacity service based on currently available grid capacity thus minimizing load energization delays and maximizing existing available grid capacity while maintaining grid safety. At the conclusion of the LCMS Pilot, if there is sufficient capacity to serve the customers' load, SCE will continue to serve the customer without requiring LCMS restrictions, but if capacity constraints continue for a LCMS Pilot participating customer and the LCMS Pilot has shown that LCMS is an effective way to serve customers in capacity constrained areas, SCE will either renew the Agreement with CPUC approval or disconnect the customer's load.
Distributed Plug-In Electric Vehicle Resources	SCE		This project studies the integration of energy storage systems with high-power, high-impact EV charging systems. It demonstrates the use of batteries to support customer bill management while simultaneously evaluating several utility VGI grid support use cases, including RE integration, grid infrastructure deferrals, and energy market services. This project plans to demonstrate the ability to shift EV charging load that may reach 17% of peak by 2030. The capability to shift charging from evening peak to late night could reduce emissions by over 33%, while shifting from early morning to noon could reduce emissions by up to 73% due to the difference in CO2 from grid power sources at different times. At a future population of 26 million EVs, shifting load could save over 27,000 metric tons of CO2 per year, which equates to approximately $2.1 million in CO2 equivalent reduction benefits annually by 2030.

SDG&E’s EV Demonstration and infrastructure	SDG&E	Ecotality	The EV Project had two primary goals. The first was to deploy charging infrastructure for both home and away-from-home use in a deliberate manner so as to understand the characteristics of the charging location, and to understand the circumstances associated with the installation process. The second goal was to collect data on the use of the deployed infrastructure and the vehicles that used it, and to analyze this data in order to better understand how vehicles and infrastructure were used. Ultimately this analysis could lead to understanding how or where best to deploy infrastructure to maximize its use and the benefit to the public.
SDG&E V2G Pilot	SDG&E	Nuvve, Cajon Valley Union School District	As part of a five-year collaboration between SDG&E, the Cajon Valley Union School District (CVUSD) and Nuvve, eight electric school buses will connect to 60kW bi-directional DC fast chargers. The electric buses will be able to discharge surplus energy to the grid during peak demand hours. They will also reduce energy costs for the district’s schools because electricity is typically cheaper than diesel fuel, and EVs generally have lower maintenance costs than gas-powered vehicles.
SVCE GridShift: EV Charging Final pilot report	Silicon Valley Clean Energy	ev.energy	Use vehicle telematics to control and optimize residential customers' EV charging at home. Goals: (A) help customers save money on their home energy bills automatically charging their EVs during the cheapest off-peak hours on their rate plan, and (B) align EV charging with off-peak hours of low-carbon generation powered by renewable power producers under contract with SVCE and other CA LSEs.

SMUD’s Managed EV Charging Pilot	SMUD	BMW, Ford, General Motors and Tesla (via Optiwatt)	"Plug in your EV and let your automaker or Optiwatt know when you need your vehicle charged. You will have an optimized charging schedule created based on your preferences and information from SMUD about the best times to charge. This charging schedule will be sent to your car automatically. All you need to do is plug in your car to charge and earn rewards."SMUD is currently piloting a residential EV managed charging program with multiple vendors and manufacturers. This pilot is testing the ability of EVs to respond to simulated day-ahead hourly price signals. While the price signals sent to EVs via telematics are dynamic and change on an hourly basis, customers are not financially exposed to these price fluctuations and are instead paid via a traditional incentive framework. These hourly prices are based on energy supply and locational capacity we expect to experience while optimizing for its zero-carbon goal and large-scale transportation electrification.
Commercial Vehicle to Grid	SMUD		Multiple pilots under the commercial program: 1. A pilot for V2X technology on school buses in partnership with a local school district, which is assessing the school bus’s ability to respond to a combination of TOD, CPP, and event-based price signals. 2. Light duty V2X fleet technical testing and 3. A plan to pilot utility-managed V2X within a commercial fleet and for workplace charging. SMUD Commercial EV Program also supports the growth of commercial vehicle electrification and the increased need for EVSE by offering direct incentives, as well as consulting or installation services through the SMUD eFuel program, for both fleet vehicles and installed on-site EVSE.

Ford Pro Partnership	Sonoma Clean Power	Ford	Ford Pro is collaborating in a pilot program that will supply three Sonoma County farms (CA) with the full suite of Ford Pro solutions, including F-150 Lightining Pro pickups and E-Transit cargo vans. The participating farms are being outfitted with Ford Pro charging stations to complement PV generation. The goal is how EVs and web-based fleet management tools can lower the total cost of fleet ownership between 10% - 20%. Farmers will have access to Ford Pro Intelligence software, home and depot charging, Ford Pro Telematics Essentials3 and Ford Pro E-Telematics4 and energy management – all to help reduce operating costs"
Vail Auto Smart Grid	Sprocket Power	Buick, GMC	Vail Buick GMC is a dealership in Bedford Hills, New York. The dealership wished to integrate an all-new set of EV Micro Grids. These microgrids will include solar energy, energy storage, ec charging management, facility controls, and complete energy management.
CEC EPIC Demonstration of Vehicle-Grid Integration in Non-Residential Environments (DEVINE)	Stanford		This project researched, developed, and demonstrated vehicle-grid integration in non-residential facilities; quantified the effects of electric vehicle charging on the grid, including its flexibility and revenue streams; and developed strategies to manage electric vehicle load to minimize the impact on the distribution system while minimizing customer utility costs.
Stockton Unified School District - Blueprint	Stockton Unified School District	Center for Transportation and the Environment (CTE), Schneider Electric, Sage Energy Consulting and The Mobility House	Stockton Unified School District will benefit from lowest cost electricity and a charging capacity that allows the buses to operate well beyond the longest daily routes - saving the district a projected $500,000 over five years in charging costs.
UCLA Smart Charging Demonstration	UCLA		This project was designed to develop and demonstrate advanced charging infrastructure (software and hardware) for smart charging, V2G and V2B, grid services, and cost recovery validation. Demonstration occurred in a controlled setting at the University of California, Los Angeles (UCLA) and then expanded into public infrastructure in the City of Santa

			Monica. This project developed and demonstrated a solution for smart charging, V2G and V2B, and grid services. This solution is helpful for PEV fleet and parking garage owners, because it can help bring down the cost of adding charging infrastructure and the cost of charging large numbers of PEVs through coordinated control.
Demonstration of PEV Smart Charging and Storage Supporting Grid Objectives project	UCLA	City of Santa Monica, Mitsubishi and Princeton PowerCity of Santa Monica	This project was designed to develop and demonstrate advanced charging infrastructure (software and hardware) for smart charging, V2G and V2B, grid services, and cost recovery validation. Demonstration occurred in a controlled setting at the UCLA and then expanded into public infrastructure in the City of Santa Monica.
CalFlexHub: Campus EV and BESS with Dynamic Price	UCSD	PowerFlex	
Beat the Peak	United Central Services		Rebate on home EVSE if programmable for delayed charging
Grid On Wheels	University of Delaware	Evgo	Very little public info, V2G pilot on campus
Intermodal Hub Project	Utah State University		SCM for control of bus charging, building, public L2 and DCFC, response to pulse power load of light rail
ASPIRE Test Track	Utah State University	Rocky Mountain Power, the Utah Transit Authority and WAVE	Wireless charging avenue SCM
REDWDS: Digital Responsive Infrastructure for Vehicle Electrification Readiness (DRIVER)	Weave Grid Inc		
Energy Charging Perks Pilot	Xcel Energy - CO	evPulse OEMs - BMW, Chevrolet, Honda, Tesla	Customers may be on any residential rate, but only those on TOU or demand charge rate will benefit financially - Participants earn 25+ cents/day monthly and an additional 30+ cents/day quarterly - Automakers optimize scheduling DR events with VV-hour notification