Smart Electric Power Alliance

Exelon's Managed Charging Program

Phase 1 Review

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In Partnership with

exelon

Argonne NATIONAL LABORATORY

Shell Recharge Solutions

WeaveGrid

Exelon's Managed Charging Program: Phase 1 Review

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We deliver value to our members through research, education, events, working groups, peer engagements, and custom projects. SEPA champions equity as a bedrock for everything we do. We facilitate collaboration, develop innovative strategies and guidance for regulatory and business innovation, and provide actionable solutions for our members and partner organizations. For more information, visit www.sepapower.org.

About Exelon

Exelon is the nation's largest utility company, serving more than 10 million customers through six fully regulated transmission and distribution utilities — Atlantic City Electric (ACE), Baltimore Gas and Electric (BGE), Commonwealth Edison (ComEd), Delmarva Power & Light (DPL), PECO Energy Company (PECO), and Potomac Electric Power Company (Pepco).

About Argonne National Laboratory

Argonne National Laboratory is a U.S. Department of Energy multidisciplinary science and engineering research center, where talented researchers work together to answer the biggest questions facing humanity.

About Shell ReCharge Solutions

Headquartered in Los Angeles with projects across the globe, Shell Recharge Solutions plays an important role in Shell's broader commitment to achieving net-zero emissions by 2050, in step with society, and to helping our customers achieve their own sustainability targets.

About WeaveGrid

WeaveGrid is a software company building data products to enable the electric transportation transition. The SaaS company's platform connects a growing wave of electric vehicles to an electric grid that was not designed to support the high-power needs of widespread charging. WeaveGrid uses cutting-edge data science and optimization to bring value to all stakeholders in this transition, including utilities, automakers, and drivers. For more information, visit www.weavegrid.com and find us on Linkedin at Linkedin.com/company/weavegrid

Disclaimer

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Introduction

Widespread electric vehicle (EV) adoption brings opportunities and challenges for maintaining grid reliability. Managed charging programs play an important role as EV adoption continues to gain traction, and utilities across the country are conducting research and hosting pilots to learn how to maximize grid and customer benefits. In the summer of 2020, the U.S. Department of Energy (DOE) awarded funding to Exelon for three of their Maryland operating utilities—Baltimore Gas and Electric (BGE), Delmarva Power and Light (DPL) and Potomac Electric Power (Pepco)—to carry out their Smart Charge Management (SCM) pilot program. Exelon proposed hosting this managed charging demonstration in its Maryland electric service territories, where it serves roughly two million customers.[1] The objective of this project is to research, develop, and conduct a wide-scale demonstration of a utility SCM system to determine optimal managed charging structures for grid value, assess the impact of EV charging on local distribution utility operations, and evaluate the utilities' ability to control EV charging load based on grid conditions.

This project has three components, each for a different customer class: residential, fleet, and public. The SCM program creates a foundation for Exelon to pilot their managed charging approach and make adjustments according to customer feedback before creating additional scaleup projects across their entire operating regions. The challenges, successes, and lessons learned from this program can be shared with other utilities nationwide to inform the development of managed charging programs.

The residential portion of the program is a multi-phased program that includes identification of EV drivers through analysis of AMI data, active managed charging that optimizes home charging based on customer preferences (e.g., charge needed by a specific time) and multiple utility inputs. All active BGE, Pepco, and DPL (jointly known as PHI) customers with electric vehicles are eligible to enroll in the residential program through WeaveGrid's evPulse website. The program seeks to enroll at least 1,000 customers for the 2023 demonstration year, and at least 2,000 additional customers for the 2024 demonstration year.

When residential customers enroll in the program, they agree to give the utility the ability to throttle their EV charging to help offset peak demand and encourage charging during off-peak hours. Drivers customize their experience by setting their own vehicle departure time so their vehicles are fully charged when needed. The continuous optimization of charging during the charging session will be seamless and unnoticeable to a customer. In return for their participation, residential customers receive a $10 incentive each month.

The commercial/fleet program is designed for active BGE and PHI commercial customers with electric vehicles within their fleet. Exelon plans to provide 200 Level 2 chargers at no cost to enrolled customers through this program; each customer is eligible to receive between 2 and 10 chargers, and must install the chargers themselves. Shell Recharge Solutions directly handles commercial customer enrollment and onboarding. BGE and PHI and design a set schedule for charging that meets both their customer and utility grid needs. In exchange for following the set charging schedule, customers receive $25 or $500 per month, depending on the customer size and their rate schedule (small vs. large commercial customer).

This multi-phased program, which is sponsored by the U.S. Department of Energy, seeks to:

- **Understand and reduce grid impacts of EV charging** on the utility's distribution and transmission systems
- **Lessen Exelon customers' capital investment** required to manage EV charging demand as EV ownership grows
- **Identify potential cybersecurity risks and vulnerabilities** of EVSEs and vehicle telematics software
- **Design managed charging plans** for residential, commercial, and public customers that can be shared industry-wide

Regarding residential program enrollment, WeaveGrid has analyzed AMI data for approximately 2 million residential accounts, detecting more than 10,000 accounts that may have an EV. The three utilities carried out a marketing outreach strategy to recruit these customers for the Smart Charge Management program starting in November 2022 and have already succeeded in enrolling

1 Within Exelon, Pepco Holdings (PHI) is the parent company of Pepco and DPL. In some cases, within this document, PHI will be used to collectively refer to both Pepco and DPL.

over 2,700 participants, surpassing Exelon's 2023 goal of enrolling 2,000 participants. For the next phase of the program, WeaveGrid will integrate with additional signal sources capturing the supply and distribution costs to the utility.

Managed charging takes into consideration several variables, including: 1) driver preferences, 2) rate information, and 3) additional utility and price signals. This is the order in which they are prioritized. Operationally, drivers may enroll in SCM regardless of what electric rate they have. During enrollment, Exelon confirms the customer's rate. If a driver is on a specific time of use (TOU) rate, WeaveGrid generates a charging schedule that meets the driver's departure preferences and minimizes cost based on the TOU window information provided by shifting charging to off-peak windows. If the customer is on a flat rate, their charge schedule simulates TOU windows and shifts charging to off-peak periods. Drivers are encouraged to adhere to the proposed charging schedules through their "Smart charge score," which helps determine

Figure 1. Project Phase Goals

Phase 1

Cybersecurity Testing & Validation

Demonstrating the integrity of EVSE and in-vehicle telematics systems prior to public deployment through cybersecurity testing and validation at ANL's Smart Energy Plaza.

Platform System Integration & Verification

Integrating and verifying the candidate platform system, including simulating and testing the provision of frequency regulation services, for deployment by the Exelon utilities in the demonstration Phase 2 at the Smart Energy Plaza.

Simulating EV Charging Impact

Simulating the impact of EV charging on the grid through 2035 in Maryland using ANL's Agent-based Transportation Energy Analysis Model (ATEAM) tool. This will include analyzing customer charging behaviors in response to alternative EV charging incentive programs, simulating large-scale co-evolution of EV adoption and charging deployment in study area, and potential load impacts to the grid.

Phase 2

Studying EV Owner Charging Behavior

Understanding EV owner charging behavior in response to a portfolio of utility price signals and incentive structures across various customer categories to maximize future enrollment in utility-led managed charging programs.

Simulating Distribution Utility Operations

Simulating and evaluating the impact of EV charging on local distribution utility operations and evaluate the utilities' ability to actively control EV charging load based on grid conditions at the feeder and transformer level.

Demonstrating Value of Smart Charging

Demonstrating the value streams from utility-managed smart charging to the EV owner, the EVSE partner, and the local electric distribution utility.

EV Charging for Grid Services

Demonstrating the ability for EV charging networks to provide frequency regulation and other electric grid services from EVs.

Source: Exelon Corporation & Smart Electric Power Alliance, 2023

incentive eligibility. Review of data so far shows that drivers who participate in SCM are more likely to charge off-peak than through participation in other programs. Starting June 2023, the program will launch a new testing scenario that will utilize a dynamic price signal provided by PJM, the grid operator for the Mid-Atlantic region.

Based on the interim findings produced by the first half of the project life, the project team recommends that when implementing managed charging programs, utilities:

- **Evaluate overall cybersecurity posture**, identify vulnerabilities associated with electric vehicle supply equipment (EVSE) and telematics software, and leverage industry best practices to mitigate identified weaknesses to reduce possible attacks.
- **Perform internal functional testing** using production hardware to isolate interoperability issues found in typical and atypical use cases.
- **Review EV industry trends and conduct market research** to understand driver needs to inform program design and recruitment strategy.
- **Prepare for the potential of supply chain problems and logistical issues** that could disrupt timelines and delay results if there is a hardware component to program design.
- **Coordinate with IT departments at inception** to automate program functions and incorporate security and technological improvements into the development process to maximize efficiency, security, and scalability.
- **Balance flexibility and structure in program design** to maximize participation and retention.

The SCM project kicked off in October 2021 and will run until December 2024, and it is split into two phases and four budget periods. In Phase 1, Exelon worked with its partners to conduct data validation and cybersecurity tests at the Argonne National Laboratory (ANL) which served as the foundation for the large-scale demonstration. In Phase 2, Exelon will carry out the large-scale Smart Charge Management (SCM) demonstration. Phase 1 of the project is complete, but Phase 2 is not yet complete; this report only presents the interim findings from Phase 1. The project team will share a comprehensive list of findings in a more detailed report at the end of Phase 2. The specific goals for each project phase are listed in Figure 1.

Exelon partnered with Shell Recharge Solutions (formerly Greenlots), WeaveGrid, Argonne National Laboratory (ANL) and the Smart Electric Power Alliance (SEPA) to conduct the SCM project. Details about these partners and their project roles are summarized in Table 1.

Table 1. Partners & Roles

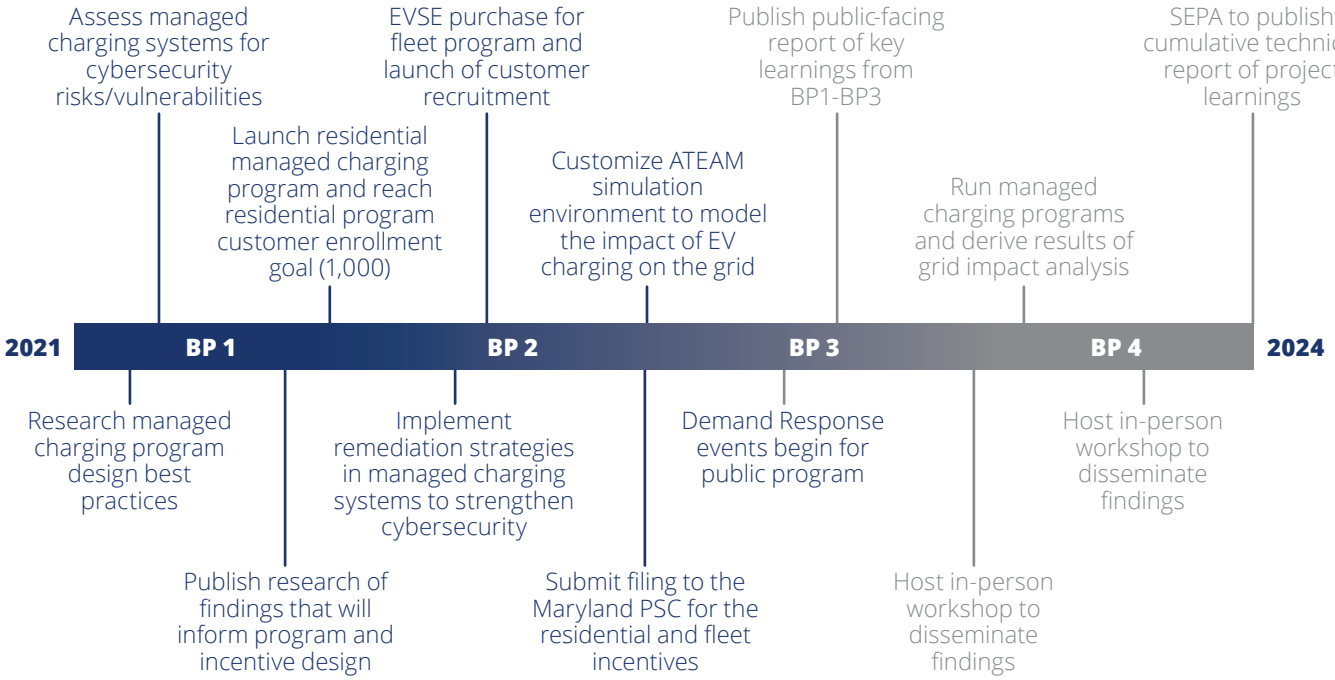
Partner	Company Type	Role
Exelon (PHI and BGE)	Utility	▪ Lead the design and implementation of the managed charging program.
Shell Recharge Solutions (formerly Greenlots)	EVSE hardware and network provider	▪ Develop smart charging technologies to actively manage EV charging sessions for fleet and public customer classes, utilizing EVSE. ▪ Support the operations of smart charge management, performance monitoring, and performance control during the SCM demonstration. ▪ Support customer enrollment and adjust the program for enhanced results.
WeaveGrid	Vehicle Telematics software solution provider	▪ Develop smart charging technologies to actively manage EV charging sessions for residential customers, utilizing vehicle telematics. ▪ Leverage machine learning to identify potential EV owners within Exelon's service territory for program marketing purposes.
Smart Electric Power Alliance	Nonprofit research organization	▪ Conduct market research and support Exelon in the design of the managed charging program. Coordinate the dissemination of program learnings.
Argonne National Laboratory	Federal R&D center	▪ Perform cybersecurity testing on EVSE and SCM platforms. ▪ Perform functional testing of network-based & telematics-based SCM platforms. ▪ Simulate the potential impact of projected EV adoption and managed charging strategies on the Exelon energy system.

Source: Smart Electric Power Alliance, Exelon Corporation, Argonne National Laboratory, WeaveGrid, and Shell Recharge Solutions, 2023

The project timeline consists of four year-long budget periods. Phase 1 of the project takes place from 2021 through 2022, and includes Budget Period 1 and Budget Period 2. Phase 2 of the project starts in 2023 and runs through 2024, and includes Budget Period 3 and Budget Period 4.

The timeline of the project and the key accomplishments of each budget period (BP) are laid out in Figure 2. At the time of publication, the project is in Budget Period 3.

Figure 2. Timeline of Key Accomplishments



Source: Smart Electric Power Alliance, Exelon Corporation, Argonne National Laboratory, WeaveGrid, and Shell Recharge Solutions, 2023

Budget Period 1: Testing, Research, and Program Design

The purpose of Budget Period 1 was to ensure the functionality of the managed charging technology ahead of the demonstration and proactively defend the public charging network from potential attacks.

The tasks of Budget Period 1 included:

- Perform cybersecurity testing
- Perform validation and functional testing of SCM platform using physical hardware (i.e,. EV and EVSE)
- Evaluate the ability of vehicle telematics-based software platforms to provide electric grid services and insight into EV owners' behavior under different incentive structures.

Cybersecurity

The cybersecurity evaluation identified potential issues that could surface in the SCM demonstration. Using Microsoft's Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service, Elevation of Privilege (STRIDE) methodology, MITRE's Adversarial Tactics, Techniques, and Common Knowledge (ATT&CK) framework, and an additional suite of cybersecurity attack methods, the team assessed the security of each SCM approach via three main attack planes:

- Internal network access;
- Physical access to the EVSE and related components; and
- Remote attack surface via internal and external interfaces, protocols, and services for EVSE- and telematics-based managed charging approaches.

Normal attack paths typically include gathering information, enumerating resources, and identifying potential weaknesses. To interact with and eventually compromise a system, an attacker will seek information about technologies used within it or the people that worked to develop it. Traditionally, this type of information might be obtained by directly interacting with SCM system company websites, devices, or people. If the aforementioned route proves to be insufficient in collecting information, an attacker may use a less direct approach. By searching employee social media profiles and public GitHub repositories, an attacker can piece together information about the skills and programming languages that were used to build the SCM system, or even pull pieces of company source code. Additionally, an attacker may leverage information disclosure notices to gain a better understanding of the system. Assumptions about skills and programming languages used to build the SCM system can be validated by publicly available job listings at the company.

In order to protect their own SCM system, companies can evaluate their cybersecurity posture, identify vulnerabilities, and remediate them. The highest level vulnerabilities identified during a cybersecurity evaluation are vital to address, as their compromise by an attacker could result in the greatest levels of damage. However, it is just as important to address medium, low, and informational vulnerabilities, as an attacker could use these weak spots to chain together different attacks to cause disruptions to the system. Taking steps to harden the entire system at all levels will improve its security posture and pose a more difficult challenge to potential attackers.

Functional Testing

The results of the evaluation indicated that each approach provided a functional user experience, multiple curtailment event stacks were processed correctly, and charging was responsive to driver inputs. Generally, the team found that the implementation of the practices listed in the Figure 3 lend to a secure and functional managed charging program.

Figure 3. Practices to Uphold Managed Charging Program Functionality

Protect the real-time communication stream between the car, the EVSE, and the utility.

Rely on industry best practices when implementing application programming Interfaces (APIs).

Conduct risk analysis of system architecture and future modifications.

Audit sensitive data no less than once per year.

Source: Smart Electric Power Alliance and Argonne National Laboratory, 2023

For a networked EVSE managed charging approach, an uninterrupted stream of communication between the car, the EVSE, and the utility is crucial because it ensures that the vehicle's charging is curtailed accurately and the battery is full when the driver requires. When Wi-Fi instability creates connectivity issues, the stream of communication is inconsistent, and the managed charging experience is compromised. Sending a notification to the driver when the vehicle is in an area with poor connection, or the connection is lost, would give the driver the opportunity to troubleshoot. Additionally, leveraging long-term evolution (LTE) can ensure EVSE communication continuity when Wi-Fi fails.

A managed charging approach that relies upon telematics rather than EVSE will leverage the vehicle manufacturer's Application Programming Interface (API) to perform actions on the EV driver's behalf. The API is a set of programming functions used to execute actions provided by a company. When the manufacturer does not provide an official API endpoint, open-source programmers can reverse engineer the processes to derive unofficial API calls. SCM operators may not necessarily follow best practices in implementing unofficial API calls and interactions within their operational procedure. When this functionality is leveraged, mitigating measures need to be considered. Therefore, program implementers will find it beneficial to follow API usage and integration best practices to minimize or prevent the interruption of managed charging functionality.

Market Research

When pioneering a new managed charging application, having a malleable program and a flexible team is vital. Market research was essential in informing residential and commercial program design; however, the lack of existing public managed charging programs meant that the team had to make certain approximations and adapt according to customer responses. Until recently, managed charging programs across the country have typically been geared towards commercial fleets or EV drivers who charge their vehicles at home because those vehicles are parked and plugged in for several hours at a time.

According to research findings, the team determined the following recommendations for program design:

- Residential EV drivers typically initiate charging sessions in the evenings; events called in the evening may provide more insight into customer behavior because a larger number of residential customers will be reacting to the DR event.[2]
- During DR events for all customer types, charging can be curtailed to reduce the energy demand at the charging location.[3] DR events should last for two to four hours, depending on system needs. Exelon will experiment with taking a system-wide or charging location-specific approach for load reduction.[4]
- Different incentive amounts can be tested during the program for all customer types, but utilities should start with a monetary incentive that is 50% of the maximum allowable (regulatory or economical) discount. Subsequent tests can be conducted with the full allowable discount. The difference in value streams will determine whether one DR event implementation style is more valuable (i.e., either at the feeder level or across the service territory). In the future, the discount should be based on the value of demand reduction at the event level assuming the value is large enough to incentivize customer participation.

It would also be beneficial to gather customer feedback after each DR event to help understand charging needs and receptiveness to different aspects of the proposed public managed charging program. The ability to deploy post-event surveys to customers depends on the data privacy laws of the EVSE or telematics providers involved.

2 Guidehouse, Inc. (July 11, 2022). National Grid EV and PHEV Demand Response Evaluation.

3 Muraturi, M., et. al. (n.d.). *Electricity Rates for Electric Vehicle Direct Current Fast Charging in the United States.* National Renewable Energy Laboratory, United States Department of Energy, Contract No. DE-A36-08GO28308.

4 SEPA. (2022). Public Program Recommendations.

Budget Period 2: Grid Impact Simulation, Customer Engagement, and Charger/Smart Device Deployment

The goal of Budget Period 2 was to simulate the impact of EV charging on the grid and design innovative tactics to maximize customer participation, flexible resource availability, and grid benefits. Additionally, the team was tasked with marketing programs to customers, enrolling them in the smart charging program, and installing the utility-owned charging network.

Grid Impact Analysis

The team began collecting data for and customizing the simulation of EV adoption on the utility energy system in Budget Period 2. They used the ATEAM model, an agent-based simulation platform developed by ANL, to conduct their analysis. The project team is still in the early stages of the simulation because the ATEAM must first be updated to reflect the most recent projection of EV adoption, EV adoption targets, and the types of households enrolled in EV managed charging programs. Ultimately, the goal is to design a scenario that reflects utility expectations for their service territory in the future.

The simulation of a service territory through ATEAM relies upon several key pieces of geospatial data, including household characteristics at the census tract level and grid conditions at the feeder level. While this more granular data can provide more impactful insights into grid impact, obstacles can arise when joining all of the data together. For example, the feeder-level distribution lines do not typically fit nicely into census tract boundaries; a single distribution line may serve several different census tracts with varying household characteristics. This concept is illustrated in Figure 4. As such, the team has been exploring other ways to accurately join the feeder data and census tract data together.

Additionally, the format of feeder data can vary across utilities and their subsidiaries, and there may be errors in that data. Most of the data was not in a format that was compatible with ATEAM, and the team had to clean and reformat it. The reformatting process required more time than planned for in the original timeline. Overall, the project team found that a standard geospatial data format compatible with most commercially available GIS software programs would make grid impact analysis more efficient for any utility that wished to leverage ATEAM.

While one can simulate many different ways that future EV adoption and managed charging strategies might affect the grid, no model can predict the future with 100% certainty. Creating updated EV penetration projections based on new data every few years and using that to inform the grid impact simulation will help keep the industry abreast of the most accurate predictions.

Enrollment

Public

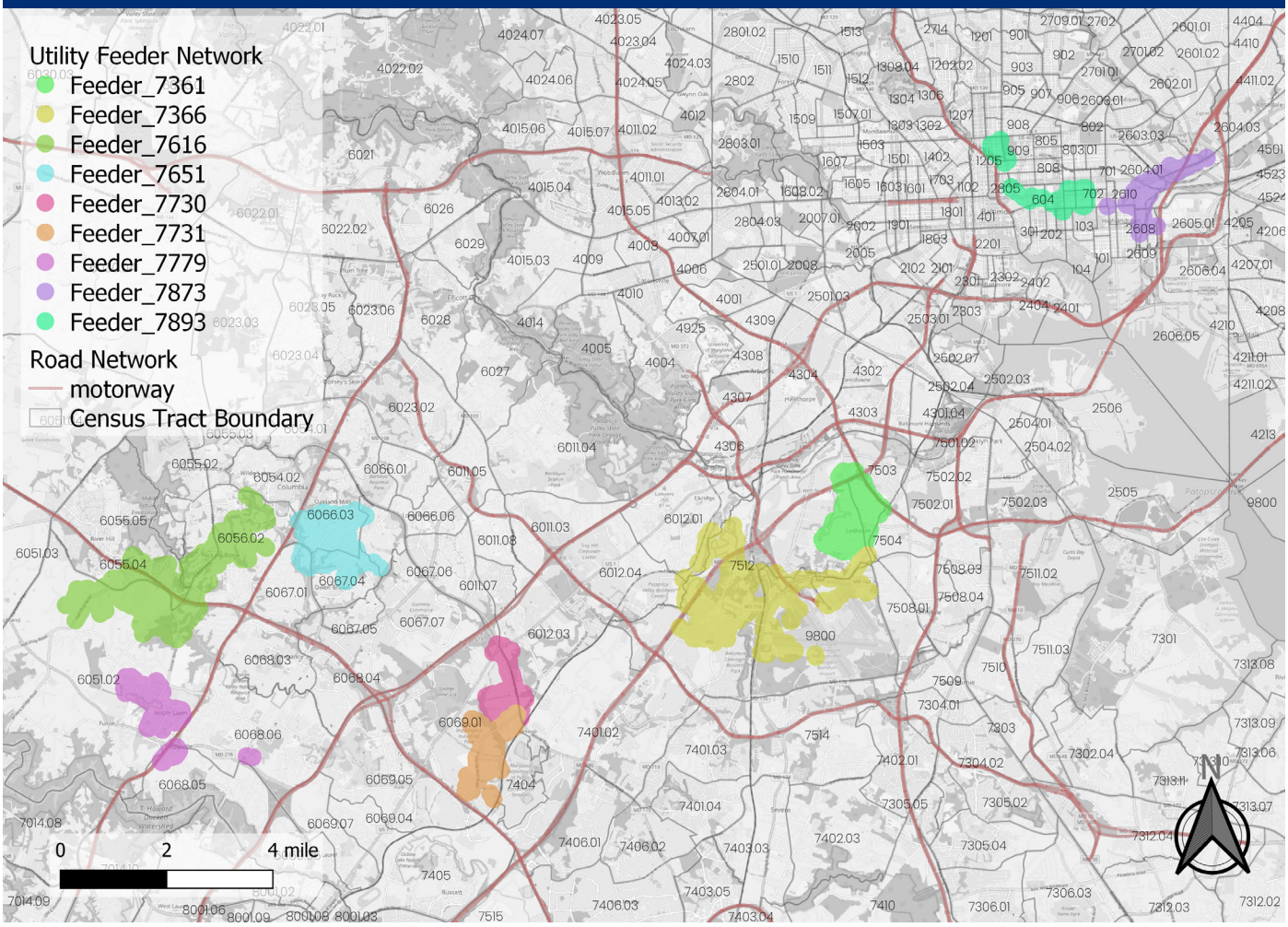
Early on in the project, the Exelon team brought in their IT group to automate the behind-the-scenes processing of program enrollment, which has enabled a future scale-up of the program.

Residential

After customer recruitment and marketing began, the project team found that they met residential program enrollment goals quickly after only one marketing campaign. The team ran an EV Detection algorithm using AMI data to accurately identify over ten-thousand potential EV households to target in marketing efforts. Additionally, residential customers are finding and enrolling in the program organically through WeaveGrid's website when looking for EV savings programs. As of December 31, 2022, 1,094 residential customers were enrolled, and in late May 2023, the number of enrolled residential customers jumped to over 2,100.

In marketing the program, it is important to provide the necessary information while avoiding unneeded cognitive burden. Residential customers in this service territory

Figure 4. An Illustrative Example of Feeder-Level Distribution Network Overlapping with Census Tract Boundaries



Source: Argonne National Laboratory, 2023

already have a foundation of TOU rate knowledge, and the project team is now facing the challenge of building upon that existing TOU knowledge and expanding customer education to include best practices for participating in a managed charging program.

Commercial/Fleet

While the team has had great success with the residential program and hit their enrollment goal in less than a month, the fleet program did not see the same level of success. Exelon's Large Customer Services team was brought in to conduct outreach to large commercial customers and smaller businesses, but it hasn't had the desired impact. The team continues to explore enrollment strategies for the fleet program into Budget Period 3.

Budget Period 3: Wide-Scale Customer Demonstration Stage 1

The goal of Budget Period 3 is to conduct the first year of a pilot utility-managed charging program under a portfolio of tactics to test customer behavior and grid impact. Additionally, the team will evaluate impacts and adjust tactics to deliver more beneficial grid results and better drive customer behavior. As of April 2023, the project team has just begun Budget Period 3, but still has the learnings in the following sections to share.

Managed Charging Implementation

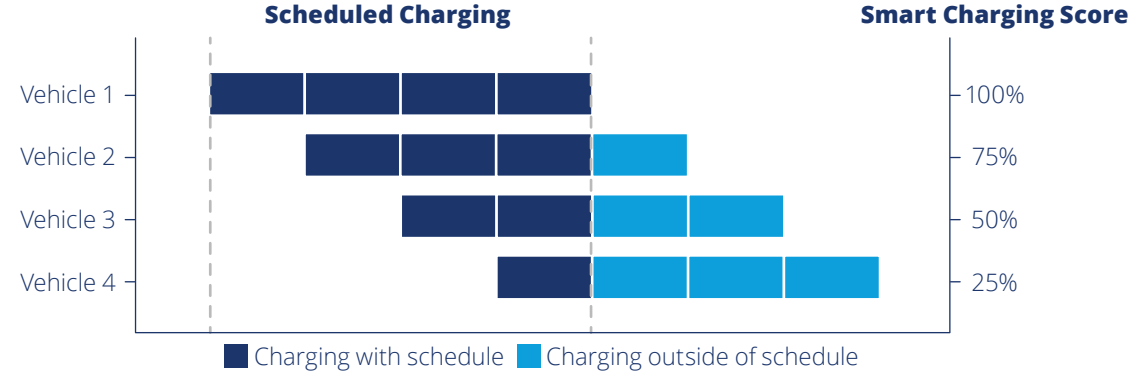
One of the major challenges of implementing a managed charging program across a public charging network is balancing the customer experience with grid impact. From a utility perspective, it is important to default customer participation settings to "opt-in" so the customer is automatically set to participate in the DR event when it is scheduled. However, with this default setting, not all customers may be aware that they are participating in a DR event and subsequently their vehicle is charging at a slower rate. This could lead to a negative customer experience. In order to test how well the managed charging demonstration can help mitigate grid stress, the project team will run several DR event tests where the customer participation settings are set to "opt-out," meaning the charging of their vehicle will not be managed to determine if customers actively choose to change their settings during a DR event to "opt-in" in order to receive the participation incentive. The team plans to collect grid impact and customer satisfaction data, and make changes to the default participation setting accordingly.

Participation-Based Incentive Design

Building off market research conducted during Budget Period 1, the project team took a unique approach to design customer incentives based on daily customer participation. With the intention of keeping customers engaged throughout the entire program, the team came up with the concept of an ongoing $10 monthly incentive for residential customers, a $25 monthly incentive for small commercial customers, and a $500 monthly incentive for large commercial customers. These incentive values equate to approximately 10% of the average residential, small commercial, and large commercial customer bill, respectively.

To meet the participation requirements, the amount of energy consumed during grid optimal times must be at least half the amount of energy the customer consumed in a day. The definition of grid optimal times will evolve over

Figure 5. Incentive Eligibility



Source: WeaveGrid, 2023

time as the program becomes more complex, but the goal is to create an incentive tied to the quality of customer participation while remaining motivating and flexible.

The customer is eligible to receive the incentive as long as they do not fail to meet participation requirements for more than four days in a month. After their third opt-out, customers will get an email so they know if they're trending toward not receiving their monthly incentive. After their fourth opt-out, they receive another email that indicates that they won't receive their credit that month. This incentive design also allows customers to understand where they stand, and if necessary, how they need to adjust their charging behavior to receive the incentive and do their part to mitigate grid stress.

Conclusion

Thus far, this pilot program has proven to be successful both in providing learnings and in setting a full-scale program up for success in the future. Different end customers (public, fleet, residential) have different challenges and needs that project partners adapted to during design, testing, and implementation of project scope. Stakeholders will be able to take lessons learned about mapping out detailed steps, tasks, and responsibilities when launching this as a full fledged utility program. The project team recommends that other regulated utilities who are interested in deploying a similar program vet the program with their state and local governments, as their buy-in and approval is required to implement the program long-term.

The early findings of this project indicate that leveraging research and customer feedback to build and amend managed charging programs will ultimately lead to a flexible program that meets driver and grid needs. Additionally, project partners recommend performing internal functional testing to ensure that the DR events will occur as intended before customers participate in a managed charging program. The team also found that automating program functions and proactively mitigating potential cybersecurity vulnerabilities maximizes efficiency, security, and scalability of the program.

The automation of EV charging to maximize benefits for the EV drivers and the grid is a technology that is still evolving conceptually and technically. By spearheading this pilot program now, Exelon can derive learnings at a micro level, make any necessary adjustments, and then implement a full scale managed charging program upon the pilot's conclusion in 2024. The findings have been positive and will lend themselves to a program that will be beneficial for both the utility and their customers.

During Phase 2, the project team will conduct the second year of the managed charging demonstration. At the end of the Phase 2, the team will share a detailed report of results from customer behavioral analysis and the quantification of the benefits of demonstration.

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