Advanced Multifamily Electric Vehicle Load Management System

Final Report

ET22SWE0026

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December 13, 2023

Disclaimer

Executive Summary

This project evaluates a new electric vehicle (EV) charging solution designed to provide charging access in existing multifamily buildings that have limited electrical capacity. This technology is worthy of study because it claims to offer features with significant potential for helping address barriers to implementing cost-effective multifamily EV charging access. Multifamily buildings rarely have available capacity to add traditional charging solutions for more than a few drivers, are often subject to significant demand charges (and grid impacts) from high-power charging solutions, require complex or expensive billing administration, and involve significant capital outlay to install EV chargers. This technology claims to offer power-sharing capabilities, built-in load shifting, scalability, and a turnkey subscription model which can help provide more charging access per site.

The objectives of this study are to:

- Verify the technical ability of the technology to leverage circuit-sharing and panel-sharing capabilities to provide charging within capacity-constrained environments.
- Evaluate the user experience with the technology.
- Complete a cost comparison to traditional Level 2 EV charging solutions.
- Evaluate the business model's appeal to market-rate and affordable housing multifamily property owners.
- Identify barriers to broader commercialization of this type of the technology.
- Understand the ability of Level 1 charging to meet daily driving needs in a multifamily setting.

Findings

The results of this project support the following conclusions:

- The evaluated technology, an ALM-enabled low-power smart outlet technology, represents a more cost-effective alternative to traditional Level 2 EVSE in smaller existing multifamily buildings.
- The evaluated technology, and similar low-power technologies, can meet the average daily charging needs of an EV driver whose vehicle is plugged in overnight.
- Tenant education is recommended to avoid a poor user experience due to expectations that greater overnight range can be provided by low-power EV charging solutions. Tenants will also benefit from additional education on how the additional features of the evaluated solution can be used to minimize charging costs.
- The evaluated technology does not provide meaningful energy efficiency savings but can provide significant peak demand management benefits compared to traditional Level 2 EVSE.
- The major barriers to scaling deployment of low-power EV charging adoption at multifamily properties are primarily due to policy, not technology. The complexity and opacity of the utility approval and permitting processes introduce significant confusion, delays, and potential expense for installation, jeopardizing the ability of these EV charging products to be deployed at the scale necessary to support California's transportation electrification goals.

- The low rate of EV ownership among multifamily residents today prevents some of the more advanced capabilities of ALM-enabled low-power smart outlets, such as load sharing, from being fully realized and tested.

Table of Contents

List of Tables

List of Figures

Abbreviations and Acronyms

Acronym	Meaning
A	Amps
AHJ	Authority Having Jurisdiction
CO2	Carbon Dioxide
DAC	Disadvantaged Communities
DOE	Department of Energy
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GFCI	Ground Fault Circuit Interrupter
GHG	Greenhouse Gas
HTR	Hard-to-Reach
IOU	Investor-Owned Utility
kWh	Kilowatt-hour
kW	Kilowatts
LCU	Local Control and Uplink
LMI	Low/Medium Income
OCPD	Over Current Protection Device
PCE	Peninsula Clean Energy
PG&E	Pacific Gas & Electric
PHEV	Plug-In Hybrid Electric Vehicle
SCE	Southern California Edison
V	Volts
VMT	Vehicle Miles Traveled
W	Watts

Introduction

This project evaluates a new electric vehicle (EV) charging solution designed to provide charging access in existing multifamily buildings that have limited electrical capacity. Today, most multifamily EV charging projects require significant capital investment and result in underutilized chargers that benefit relatively few tenants. This technology is worthy of study because it claims to offer some features with significant potential for helping address those barriers and provide cost-effective multifamily EV charging access. These features include:

- Power-sharing capabilities, which can help stretch the limited electrical capacity at multifamily properties further to provide charging access to more tenants;
- Built-in load shifting, which can keep charging costs down for tenants and minimize peak demand charges for landlords;
- Scalability, allowing property owners to activate chargers as on-site EV ownership increases and not pay for unused ports; and
- A turnkey subscription model, which can simplify the value proposition for property owners and reduce the initial capital cost of an EV charging project.

Providing EV charging access in multifamily buildings is a key element of achieving EV adoption at scale, especially for lower-income residents that have been so far left behind by the EV transition.

The baseline scenario for EV charging in multifamily buildings is unmanaged 240V Level 2 charging – this is typically the standard in building codes and investor-owned utility (IOU) Electric Vehicle Supply Equipment (EVSE) programs. Level 2 chargers can range from 3kW to 19kW of AC output depending on the vehicle being charged. The average Level 2 charger requires at least a dedicated 40A circuit and delivers power up to 7.68 kW (EvoCharge n.d.). In this baseline scenario, unmanaged Level 2 chargers provide power to EVs during the charging window until the battery is fully charged. Per the Department of Energy (DOE), the vast majority of aggregate EV demand is driven by home charging. A typical unmanaged EV charging load curve results in peak usage during the late afternoon and early evening. At a multifamily site, providing up to ten units with Level 2 EV charging would require 400 amps of capacity and add 76.8 kW peak load to the customer's bill and local distribution system. Lower-power solutions, like the one evaluated in this project, can theoretically provide access to charging for the same number of drivers while requiring far less power or can use the same amount of power to provide access to far more drivers.

The technology provider claims their product provides the following energy benefits over a Level 2 baseline installation:

- Energy savings: Each charging base includes three ports, replacing multiple separate Level 2 EVSE units provided by other manufacturer models and reducing standby power from inactive units.
- Peak demand savings: Managed charging features attempt to flatten the EV charging load curve and shift demand to off-peak hours. At its lowest power setting, two Level 1 ports deliver 1.92 kW of power each. This represents a 4x reduction in peak demand compared to the 7.68 kW of a typical Level 2 charger. Average vehicle dwell time at multifamily

buildings is typically more than 12 hours, which at that Level 1 charging rate would provide nearly 70 miles of daily range for a vehicle with an efficiency of 3 mi/kWh. The average daily vehicle miles traveled (VMT) for Californians is 31 miles – the amount of energy needed for this range can be delivered by a Level 2 charger in under two hours and a Level 1 charger in just over seven hours (Kelley Blue Book 2023).

- Daily load shifting: Because the average dwell time typically exceeds the charge time needed to meet daily driving needs, there is often flexibility in when EVs can be actively charging during a typical dwell session. The evaluated technology is able to shift the charging window to off-peak hours such that the kWh consumption and kW demand occurs after the 4-9 PM peak period. Compared to unmanaged Level 2 installation, where multiple stations can operate as coincident loads, just one relatively small multifamily site with six chargers (the minimum studied for this project) enabled with the ability to shift EV load off-peak would provide a demand savings of over 46 kW during peak hours.
- Lower system costs: Circuit-sharing and panel-sharing technology could reduce the capacity needs on-site and demand impacts on the grid, lowering the cost of behind-the-meter installation, service upgrades, and local distribution system improvements. This theoretically enables the technology to provide the same consumer benefits as the level 2 baseline (kWh to support daily driving needs) with far less cost to the electric distribution system and ratepayers.

The evaluated technology's primary target customers are existing multifamily buildings, which are underserved by much of the EVSE market.

Background

Market Characterization

While 32 percent of Californian's live in multifamily properties, EV adoption rates lag behind single-family homes (Ahrens, et al. 2023). Multifamily properties are a challenging use case; unlike single family homes, they have multiple stakeholders and the business case for EV charging is complex. Landlords pay for the equipment, but tenants receive the benefits – and since charging ports are typically wired to a house panel serving common areas, including the parking lot, landlords either need to administer a billing solution themselves to offset increased electricity costs or utilize a third party managed networked charging solution, which can include expensive administration fees on top of the hefty up-front cost. In addition to this part-residential, part-commercial arrangement, multifamily sites also vary widely in their layout and infrastructure, including low-rises to high-rises to garden apartments. Expanding EV ownership benefits to multifamily populations at scale will require cost-effective charging solutions with a straightforward, affordable business model, and the technical ability to maximize limited available capacity to provide as much charging access as possible.

EV charging equipment that serve the multifamily market include:

Electric Vehicle Service Providers (EVSPs): Private charging network companies own or operate public charging stations as well as banks of chargers at commercial and multifamily properties. Per the US DOT, networked charging stations are "connected to the Internet through cellular or wired broadband service to enable payment, access management, and usage monitoring" (US Department of Transportation 2023). EVSP-managed charging stations at multifamily properties are typically full-power networked Level 2 or, rarely, Level 3 solutions and are the most common solutions deployed in the multifamily market. EVSP Level 2 chargers operate at 208-240V and typically require a dedicated circuit of 40-100A per port (or per two-port bollard/wall mount). EVSPs have been influential in establishing Level 2 as the standard home charging option, but in multifamily environments Level 2 solutions typically use too much power to provide more than a handful of ports per a site without requiring significant and expensive infrastructure upgrades.

Low-Power Smart Outlets: Level 1 and low-power Level 2 "smart outlet" products leverage dedicated circuits of 15-50A per port, with 20A being the most common option, and operate at 110-120V, although some also have a Level 2 version (Peninsula Clean Energy Electric Vehicle (EV) Ready Program 2021). Energy Solutions conducted a pilot for Peninsula Clean Energy (PCE) deploying these solutions, and while they are dramatically more cost-effective than traditional Level 2 products. Unlike technology evaluated in this study, most low-power smart outlets lack panel-sharing or circuit-sharing capabilities.

Automated Load Management Solutions (ALM): ALM is a broad term that signifies the ability of an EV charging product to control the electricity draw of one or more EV ports to not exceed circuit or panel capacity. These products can be Level 1 or Level 2, leverage cloud-based controls or be relatively "dumb" solutions without sophisticated software, and come in a variety of form factors (Washington State Building Code Council 2021).

Technology Description

The evaluated technology combines elements of both low-power smart outlets and automated load management for existing multifamily buildings. Spreading out power consumption over a longer period while also moving as much of that consumption to off-peak hours as possible reduces impact to the electric grid as a location adds EV drivers. In addition to combining ALM capabilities with low-power smart outlets, the evaluated technology includes additional cost-lowering features, some of which are common to low-power solutions generally:

- Three ports per charging unit: Each EV charging unit requires a separate conduit run. Including more ports per unit increases the possible number of parking spaces served per charging unit, improving installation cost per port. Most products on the market include one or two ports per charging unit, the evaluated technology includes three (Figure 1),

Figure 1: Diagram depicting three-port configuration of charging unit

- Dedicated 20-amp two-pole 208/240V circuit per unit: The charging unit can provide power to a single vehicle at Level 2 (240V) or two vehicles simultaneously at Level 1 (120V). This circuit size provides a useful amount of charging while limiting peak demand, reducing the cost of the dedicated panel, Over Current Protection Device (OCPD) Ground Fault Circuit Interrupter (GFCI), wiring, and conduit. Lower capacity requirements per charging unit allow for more charging access while avoiding the need to upgrade the electrical service level coming into the property.
- Use of existing charging cords that comes with EV/Plug-in Hybrid Electric Vehicle (PHEV): Most low-power solutions on the market use the vehicle's charging cord, whereas high-power Level 2 chargers require a permanent charging cord installed on site. These permanent cords are prone to malfunction or damage and increase operational costs. Utilizing the vehicle charging cord substantially lowers maintenance costs by eliminating several of the charging components that cause operational problems.
- Modular design: The charging unit and ports attach to a pre-installed base that can be swapped out without an electrician in the case of any equipment issues. Level 2 public charging stations are notoriously unreliable across the US, with up to 39 percent of charging sessions resulting in failure, in part due to the challenge of servicing more complicated equipment that often requires an electrician to fix (Dnistran 2023).
- Single communications gateway: The evaluated technology includes charging ports that communicate to a single site gateway using a wireless mesh network, which in turn communicates to cloud controls via cellular signals. This eliminates the need for Wi-Fi connection and reduces the impact of connectivity issues in challenging areas like underground parking garages.
- Subscription model: The technology provider uses a pay-per-space subscription model for charging, rather than a pay-per-charge model. This helps minimize or eliminate upfront

installation costs that are typically the biggest barrier to entry for market-rate and affordable housing customers. Many low-powered solutions use this business model, but most Level 2 networked EVSP solutions do not.

Of the three ports on each charging unit (seen in Figure 1), the two outside ports are 120V outlets and the center port is 240V. A customer can plug their vehicle into any of these three ports. If they plug in to either of the two 120V outlets, their vehicle will charge at a Level 1 power mode. If they plug in to the 240V outlet, their vehicle will charge at a Level 2 power mode.[1] In theory, up to three customers can be plugged into the same charging unit at the same time and an algorithm will intelligently allocate the delivery of electricity among the plugged-in vehicles over the course of a charging session to meet user needs.

The maximum charging current for the chargers is dictated by the receptacle type and power type on the property. The receptacles are 2x NEMA 5-20 (rated for 120V at 20A, or 2.4kW max) and NEMA 6-20 (rated for 240V/208V at 20 A, or 4.8kW max).

In reality, EVs using these receptacles will only draw 80 percent of the maximum circuit rating (or 16A on a 20A circuit), so the receptacles charge the vehicles at a maximum of 1.92kW and 3.84kW respectively. One complicating factor is that some buildings are wired with 208V power instead of 240V power; in that case the circuit rating is reduced to 4.16kW, and the vehicle will draw 3.328kW.

Customers are given several charging choices in a smartphone application (app) when they plug their vehicle in to the charger. Customers are asked to indicate:

- Their intended departure date and time.
- How much range they would ideally get (called "Range Required" in the user interface), selected via a sliding bar.
- Their preferred charge mode. The three charge mode options are ECO, AUTO, or ASAP.
    - ECO mode costs the least, charges the slowest, and charges primarily off peak. This is intended for a person who can plug their vehicle in for a long period of time.
    - AUTO mode is the mid-range option and will determine how much power to provide based off the user inputs automatically taking various factors into account including time of day, number of other vehicles charging, and available power.
    - ASAP mode is the most expensive and will charge the vehicle fastest. It is intended for users who either do not care about price or who are not able to plug in for a long time and need maximum charge.

The user interface for this app can be seen in Appendix C: Software Application Interface.

Business Case

Transportation represents 28 percent of greenhouse gas (GHG) emissions in the US as of 2021 according to the EPA - the single largest emissions-generating sector (United States Environmental Protection Agency 2023). Access to charging is one of the two biggest barriers to the electrification of

[1] According to the technology provider, most of their installations currently provide low-power Level 2 utilizing a 20-amp breaker as opposed to a traditional full-power Level 2 installation which uses 40 amps or more per charging station.

passenger vehicles (Santos 2017), with the multifamily sector particularly underserved. The climate impacts of installing EVSE are substantial – while all EVSE increase site kWh consumption, by driving EV adoption they lower overall GHG emissions. A County of Santa Clara study found that each EV port installed in a multifamily property led to a calculated 3.3 metric tons of carbon dioxide (CO2) reduction per year (The Electric Power Research Institute 2018).

Currently, the primary IOU approach to provide EVSE in multifamily environments is a “make-ready” approach in which the utility pays for a significant portion, or all, of the infrastructure upgrades necessary to provide full-power dedicated Level 2 charging, generally at least 40 amps per charging port. This approach is extremely expensive – for example, PG&E’s EV Charge Network reports costs of nearly $18k/port (PG&E n.d.) and problematic due to high-capacity requirements on existing infrastructure. Dedicated Level 2 chargers are designed to charge vehicles quickly and require significant electrical capacity to do so, however the average tenant has a long dwell time and drives less than 40 miles per day (Kelley Blue Book 2023). The result is that under the current EV charging paradigm most multifamily properties that do install charging receive relatively few, expensive chargers that are either unused for long periods of a vehicle dwell session or require multiple tenants to swap cars around to share the equipment.

The alternative approach is to focus on ALMS and low-power solutions that typically provide power more slowly, but are usually still effective in meeting at least 80 percent of an EV driver’s range needs. Absent the IOUs’ willingness to spend significant amounts indefinitely to provide at-home full-power multifamily Level 2 charging access, solutions in these categories will be necessary to achieve mass-market home charging access in multifamily buildings.

There are currently only a few products designed to cost-effectively maximize EV charging access at multifamily sites. These solutions provide a combination of low-power Level 2 or Level 1 charging, circuit sharing, and panel-sharing – all promising strategies for leveraging limited capacity to provide charging access to the greatest number of possible tenants without major upgrades. The evaluated technology claims the ability to provide all three of these features at a price point that is much lower than the installation of a traditional Level 2 EV chargers. In this report the project team assessed the effectiveness of this technology to determine if it can deliver the claimed benefits.

Objectives

This project is intended to evaluate a new EV charging solution designed to provide access to charging in existing multifamily buildings with limited electrical capacity. Objectives include:

- Verify the technical ability of the technology to leverage circuit-sharing and panel-sharing capabilities to provide charging within capacity-constrained environments.
- Evaluate the user experience with the technology.
- Complete a cost comparison to traditional Level 2 EV charging solutions.
- Evaluate the business model’s appeal to market-rate and affordable housing multifamily property owners.
- Identify barriers to broader commercialization of this type of the technology.

- Understand the ability of Level 1 charging to meet daily driving needs in a multifamily setting.

Methodology & Approach

To execute this project Energy Solutions partnered with the technology provider for:

- **Site Acquisition:** Recruited at four existing multifamily sites to participate in the project. The number of sites were intended to provide sufficient diversity in property type, electrical infrastructure, and tenant mix to provide greater insight into the technology's applicability to a wide market.
- **Installation:** Developed proposed project scopes for site hosts, finalized a site agreement with participants, applied for any required permits, and oversaw a local, licensed electrical contractor in installing equipment. Each site installation included: a panel for EV charging, at least four charging bases that can provide charging access to 2-3 parking spaces each, charging units with three ports (see Figure 1), and any required OCPD breakers, conduit, wiring, and other materials necessary to provide charging access in excess of the number of resident EV drivers.
- **Customer Support:** On-site commissioning and testing of the equipment to ensure full functionality, and ongoing monitoring, maintenance, and customer support during the duration of the project.
- **Stakeholder Education:** Engaged and educated property managers to understand the technology and business model and set prices appropriately to mitigate operational costs. Provided tenant engagement and training on how to use the equipment and resources to encourage EV adoption.
- **Evaluation:** Interviewed property owners/managers and surveyed tenants/drivers to evaluate customer experience and identify any concerns or barriers to the utilization and scalable deployment of this technology.

Utilization Data Analysis

To evaluate the EV charging solution, this report relies primarily on quantitative and qualitative data from site deployments. Utilization data was provided by the technology provider using charging sessions at the sites where they were able to deploy their technology and where there were current EV residents who charged regularly with the installed charging units. The data recorded includes minute by minute breakdowns of every charging session since installation.

Utilization data is current as of October 10th, 2023, and was collected from Sites 1, 5, and 6. No utilization data was collected from Sites 2, 3, or 4 as these sites do not yet have active EV tenants, although there was one EV tenant onboarding at Site 3 as of October 23, 2023. All the data has been anonymized to protect the information specific to each charging site. Therefore, all visualizations are based on averages from the three sites with active EV owners. See Site Status Summary for details.

The utilization data provided included two files:

Session Summary: This file contained a complete summary of each charging session between 11/30/22 and 10/17/23, representing 182 sessions. The fields in this document include:

- Duration of the charge
- Power consumed in kW
- Customer-selected power mode
- Whether the customer was plugged in to the 120 or 240V charger port
- Customer-reported intended departure time
- Customer-reported range requirement

Activity Report: The activity report contained a minute-by-minute breakdown of each charging session. An ID was assigned to each individual charging session to associate it with the charging session summary in the Session Summary file. The fields in the activity report file include:

- Average amps drawn in that minute.
- Average volts drawn in that minute.
- Accumulated energy drawn in that minute.
- Start time and end time of the data contained in that cell.

The project team created bar graph visualizations by taking the averages of different charging metrics from the data and grouping them by dimensions, including power mode (ECO, AUTO, ASAP) and level of charge (Level 1 or Level 2). To visualize what an average charge curve looks like in a day, the project team created line graphs with session times collated into a single 24-hour time span. This required time stamps to be normalized into a single 24-hour period, instead of being spread across multiple days, to get an aggregate measure for each minute/hour. This was done with calculated fields and date functions in Tableau.

Below are the primary research questions the project team sought to answer with the analysis of the utilization data.

1. What does a typical charging session look like? What does an ECO vs. AUTO vs. ASAP charge look like? What does a typical Level 1 charge session look like vs. a Level 2 charge session?
2. What is an average charging session duration?
3. How much range are users able to get?

Data Quality Control

When conducting analysis, a large number of sessions under 30 minutes were observed, skewing the data. In many of those sessions, the customer had input a high range required number. This may be due to any number of reasons, including customers initiating a charging session and then finding an alternate solution after being frustrated by not charging as quickly as desired. There was no feedback from customer surveys to indicate this or any other specific reason for the high number of short charging sessions. Regardless, the primary use case being evaluated was the ability for the technology to provide sufficient charge during longer-dwell charging sessions (e.g. overnight), and it was determined that these short sessions were creating sufficient noise to make evaluation of that use case a challenge. To address this problem two versions of the data included below. One set of graphs contains all the sessions including short dwell times. These graphs can be seen in Appendix D: Utilization Data Containing Outliers. The set of graphs shown in the Findings section have the outliers removed and can be identified by the phrase “outliers removed” in the graph title. There were 55 sessions under half an hour in the data that were removed from graphs with “outliers removed” in the title. Below is a graph showing the prevalence of these shorter charging sessions.

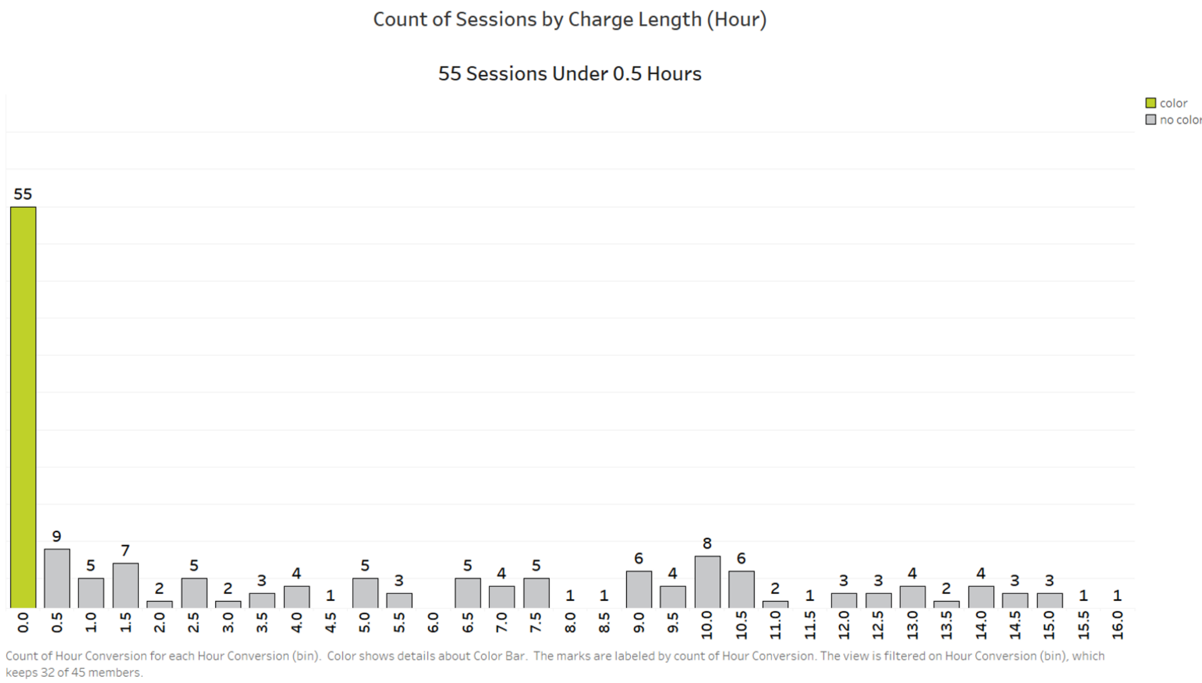

Figure 2: This graph shows the prevalence of charge sessions less than 0.5 hours. These sessions have been removed from the data in the Findings section, but are included in the data in Appendix D.

Energy Efficiency Benefits

Energy efficiency in an EV context means two separate things: the efficiency of the vehicle-charger combination while charging and the efficiency of the EVSE while in standby mode. The former is primarily driven by on-board vehicle battery characteristics and ambient conditions as opposed to EVSE efficiency. Typical EVs use 12-15 percent more energy than is added to the battery during charging. Some energy is converted to heat, some is necessary to preserve a healthy battery temperature during charging as batteries heat up considerably as they near max capacity, and some is subject to transmission losses (Car and Driver 2021). During charging, the EVSE is essentially an extension cord, with both Level 1 and Level 2 chargers operating with a relatively high efficiency – 83.8 percent for Level 1 compared to 89.4 percent for Level 2 (IEEE 2016).

The greater variation in efficiency among EVSE is during standby mode. This is why ENERGY STAR focuses on standby mode in its evaluation of Level 1 and Level 2 EVSE[2] and claims ENERGY STAR models are 40 percent more efficient in standby mode than non-rated chargers (EPA ENERGY STAR® 2021).

To evaluate the energy efficiency benefits, the project team took average daily charging time and non-charging time for Level 1 utilization at the project sites and calculated the equivalent charging time for a full-powered 40A Level 2 product. For active charging, the above IEEE efficiency numbers were used to calculate daily and annual kWh usage for these two data points. For standby charging, the project team used published ENERGY STAR data about the electrical efficiency of Level 1 and Level 2 electric vehicle chargers (EPA ENERGY STAR® n.d.) and unpublished ENERGY STAR certification test data on the evaluated chargers[3].

Findings

Overview

The results of this project support the following conclusions:

- The evaluated technology, an ALM-enabled low-power smart outlet technology, represents a more cost-effective alternative to traditional Level 2 EVSE in smaller existing multifamily buildings.
- The evaluated technology, and similar low-power technologies, can meet the average daily charging needs of an EV driver whose vehicle is plugged in overnight.
- Tenant education is recommended to avoid a poor user experience due to expectations that greater overnight range can be provided by low-power EV charging solutions. Tenants will also benefit from additional education on how the additional features of the evaluated solution can be used to minimize charging costs.
- The evaluated technology does not provide meaningful energy efficiency savings but can provide significant peak demand management benefits compared to traditional Level 2 EVSE.
- The major barriers to scaling deployment of low-power EV charging adoption at multifamily properties are primarily due to policy, not technology. Project design and installation can be completed quickly and affordably. The business model of the evaluated ALM-enabled technology suggests operations and maintenance are likely to be less expensive than Level 2 charging products. However, the complexity and opacity of the utility approval and permitting processes introduce significant confusion, delays, and potential expense for installation, jeopardizing the ability of these EV charging products to be deployed at the scale necessary to support California's transportation electrification goals.

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[2] As opposed to standby and active charging efficiency for DC fast chargers.

[3] The evaluated chargers have been tested for ENERGY STAR certification, but were waiting to receive final paperwork on their status as of November 11, 2023

- This study did not produce sufficient data to evaluate the technology's circuit-sharing and panel-sharing capabilities. Low rates of EV ownership among the multifamily residents, indicative of the current market, prevented some of the more advanced capabilities of the ALM-enabled low-power smart outlets, such as load sharing, from being fully realized and tested.

These findings are explained in further detail below.

Site Status Summary

This project included the installation of the evaluated EV charging technology at four multifamily sites in California. To enable more robust evaluation, the technology provider also provided utilization data from two multifamily installations that did not receive CalNEXT funding. A detailed summary of each site is provided below in Table 1: Site Summary.

Table 1: Site Summary

Site Name	Site Details	Site Status as of 10/23/23
Site 1 **San Jose, CA 95126**	75 units 83 parking spaces 2 known EVs 10 charging bases 8 charging units initially activated	This site has been fully operational since 12/22/22. The project was approved by the authority having jurisdiction (AHJ) and the utility company. There are two tenants who regularly park their EVs at this site. The project is running off its own dedicated electrical panel and electrical meter.
Site 2 **San Jose, CA 95126**	39 units 37 parking spaces 0 known EVs House Power Solution: 2 charging bases 2 charging units Full Install: 11 charging bases 4 charging units initially activated	This site is operational from the property's House Electrical Panel (aka House Power). To add a new meter and panel, the utility is requiring an infrastructure upgrade to the hardware providing electricity to the building. This can only be completed by the utility, and the technology provider cannot finalize the project until this upgrade has been made. 2 charging bases and 2 charging units are being powered from house power until infrastructural upgrades by the utility to the building's service equipment allow them to electrify the new electrical panel. There are currently no EV tenants who live at the property.

Site Name	Site Details	Site Status as of 10/23/23
Site 3 **Mountain View, CA 94043**	120 units 90 parking spaces 1 known EV House Power Solution: 3 charging bases 3 charging units Full Install: 12 charging bases 6 charging units initially activated	This site is operational from the property's House Electrical Panel (aka House Power). To add a new meter and panel, the utility is requiring an infrastructure upgrade to the hardware providing electricity to the building. This can only be completed by the utility, and the technology provider cannot finalize the project until this upgrade has been made. 3 charging bases and 3 charging units are being powered from house power until infrastructural upgrades by the utility to the building's service equipment allow them to electrify the new electrical panel. There is currently 1 EV tenant who lives at the property.
Site 4 **Redwood City, CA 94063**	12 units 18 parking spaces 0 known EVs House Power Solution: 2 charging bases 2 charging units Full Install: 10 charging bases 10 charging units	This site is operational from the property's House Electrical Panel (aka House Power). To add a new meter and panel, the utility is requiring an infrastructure upgrade to the hardware providing electricity to the building. This can only be completed by the utility, and the technology provider cannot finalize the project until this upgrade has been made. 2 charging bases and 2 charging units are being powered from house power until infrastructural upgrades by the utility to the building's service equipment allow them to electrify the new electrical panel. There are currently no EV tenants who live at the property.
Site 5 **Santa Clara, CA 95051**	2 known EVs	This site is not receiving funding from CalNEXT. Technology provider has agreed to provide the utilization data from this site to support this project.
Site 6 **Mountain View, CA 94043**	1 known EV	This site is not receiving funding from CalNEXT. Technology provider has agreed to provide the utilization data from this site to support this project.
Site 7 **San Mateo, CA 94403**	N/A	This project was removed from consideration by Technology provider due to water damage around the existing electrical load center. Technology provider did not believe their project would be approved upon inspection due to this damage.

Further site details, including site plans and installation photos as applicable, can be found in Appendix A: Site Details and Appendix B: Site Photos.

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Appendix A: Site Details and Appendix B: Site Photos.

Results

Research Questions

Question 1: What does a typical charging session look like? What does an ECO vs. AUTO vs. ASAP charge look like? What does a typical Level 1 charge session look like vs. a Level 2 charge session?

Electricity demand is highest between ~2—9 PM depending on one's geographic area and the time of year. In the figures below we can see that the installed chargers are very effective at shifting vehicle charging to off-peak hours. Across all time-of-use graphs, the highest demand is overnight from 9 PM to 7 AM.

Figure 3 and Figure 4 show the total kWh delivered over an average 24-hour period, broken down by the power mode (Figure 3) and voltage level (Figure 4) chosen. These graphs also provide an indicator of how much electric load the installed chargers put on the grid on an average day with the current rate of utilization. Users are most often plugged in to the chargers overnight, with most charging occurring in off-peak hours. The highest utilization rates are between around 8 PM and 6 AM.

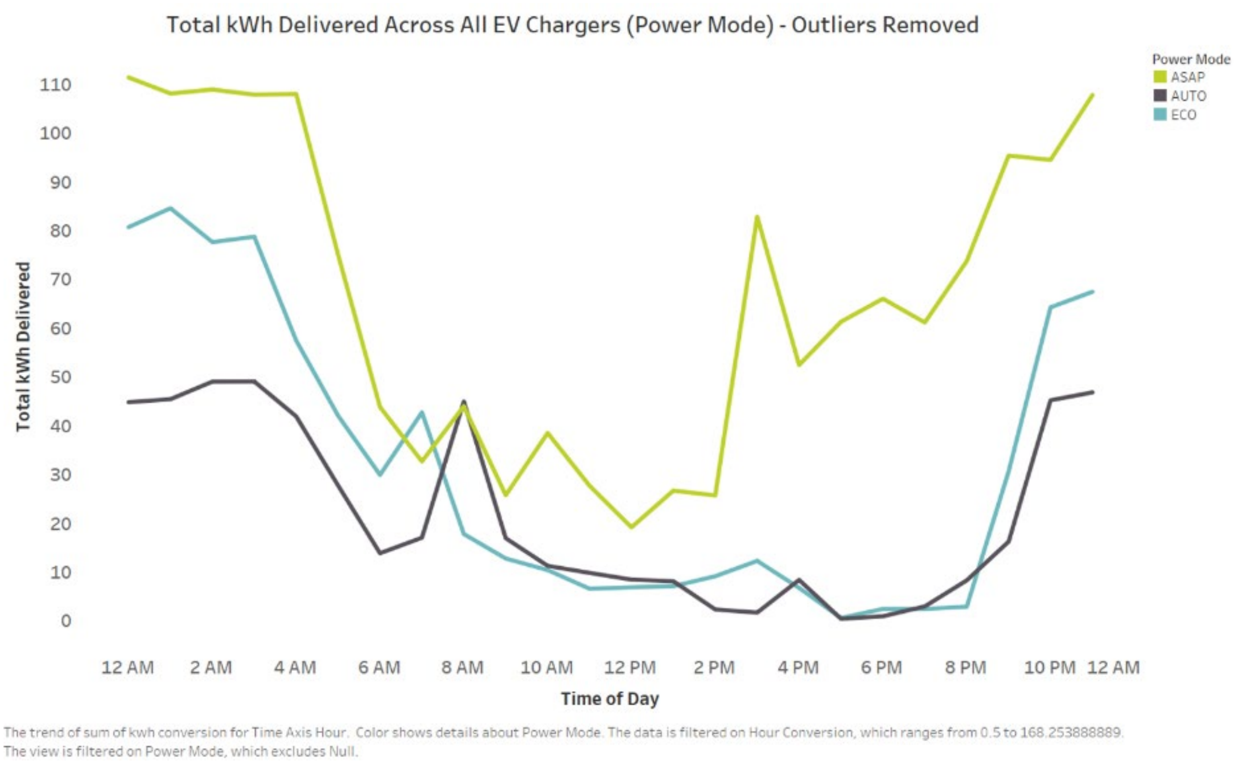


Figure 3: Average Total Daily kWh Delivered (by Charging Mode)

Figure 4 also shows that Level 2 ports are providing much more overall kWh than Level 1 chargers.

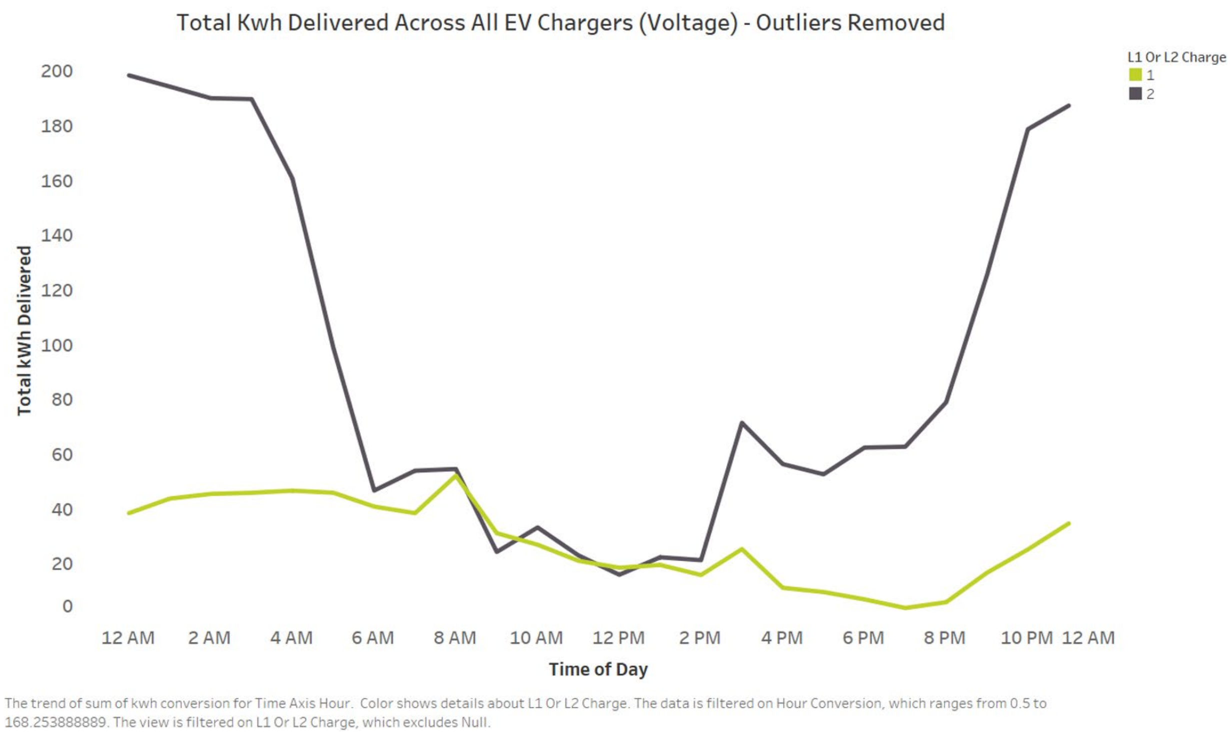


Figure 4: Average Total Daily kWh Delivered (by Voltage Level)

While Figure 3 and Figure 4 show total electricity draw across all sites within an aggregate 24-hour period, Figure 5 and Figure 6 illustrate power consumption at an average individual charger.

Figure 5 shows an average charge curve broken down by power mode. It appears that Auto and EC follow a similar usage pattern, whereas ASAP mode is drawing more power over longer periods of time compared to the other two modes. It also appears that ASAP mode is used more often throughout the workday, while Auto and ECO are primarily drawing kWh from around 8 PM till 8 AM.

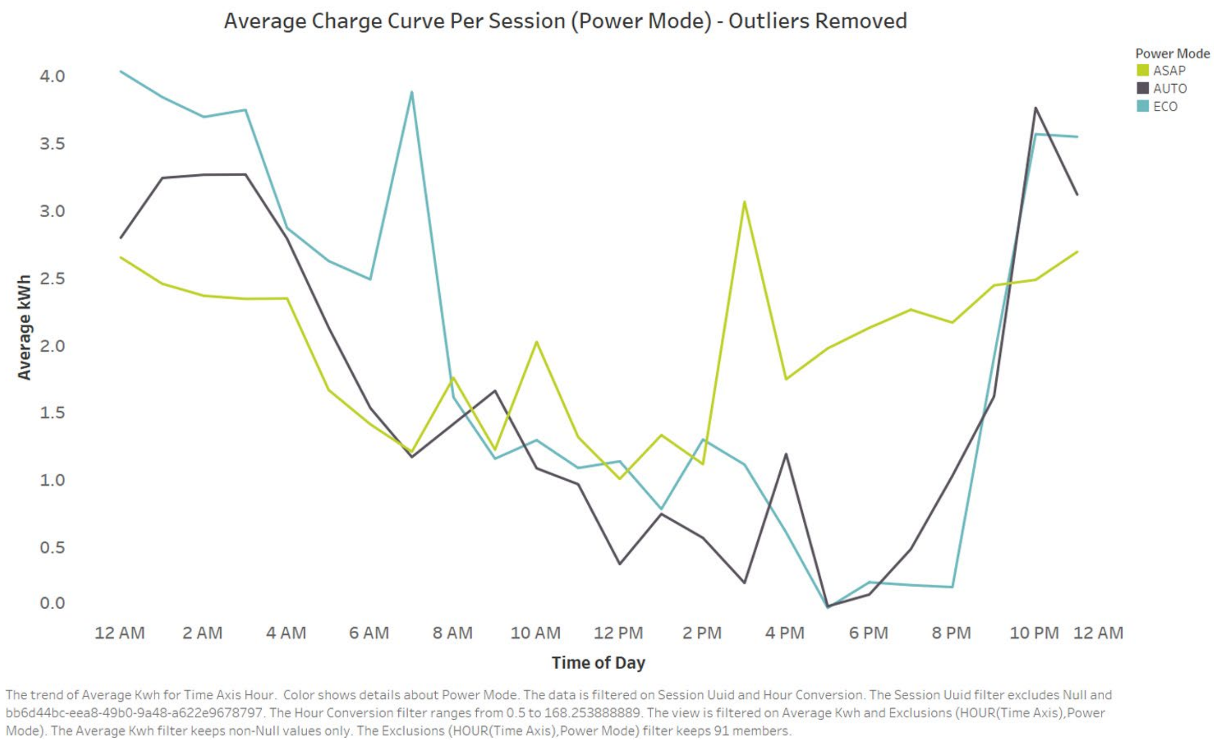


Figure 5: Average Charging Session Curve (by Power Mode)

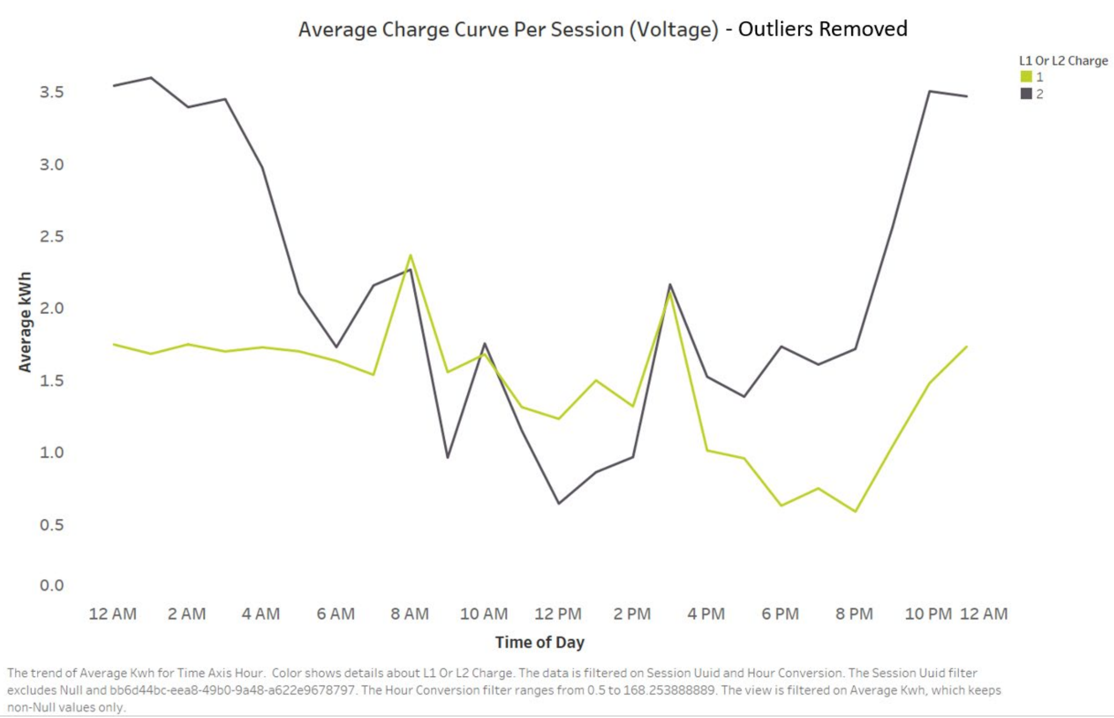


Figure 6: Average Charging Session Curve (by Power Level)

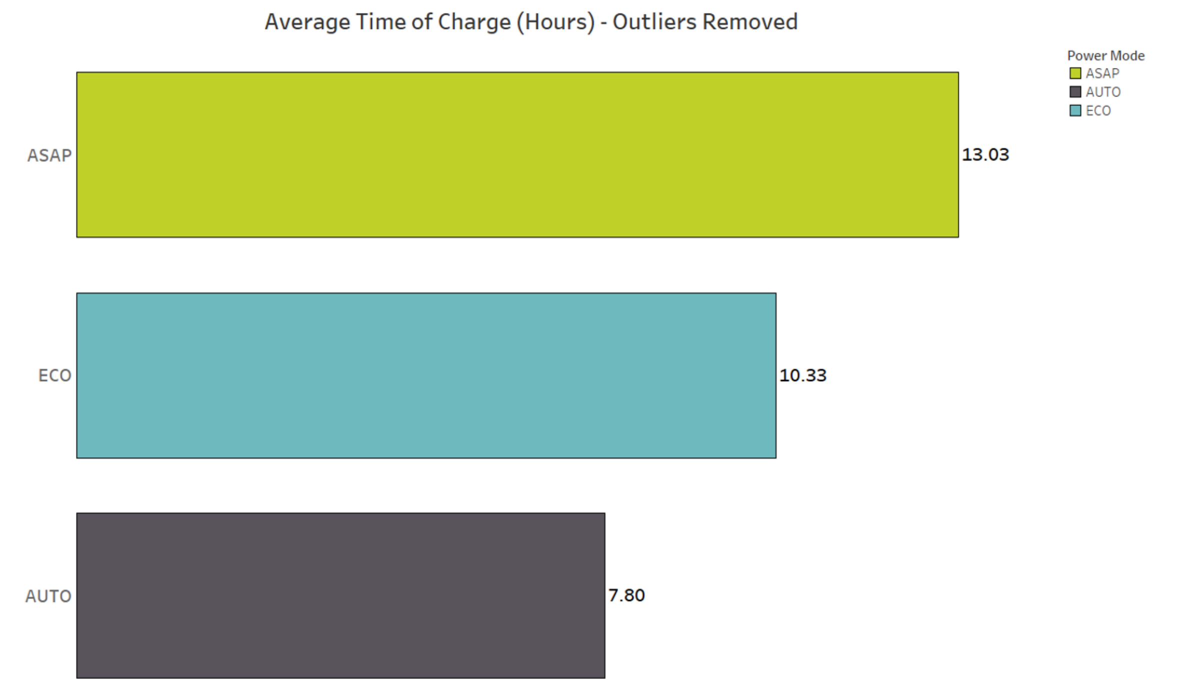
Figure 6 shows an average charge session for an individual user sorted by the voltage selected. Here we see that Level 1 can provide considerably more kWh overnight, with relatively similar kWh to Level 1 charging during the daytime.

Figures 3-6 show that the technology users are primarily charging at night from around 8 PM to 8 AM and the most electrical draw is coming from users plugged into a Level 2 port charging in ASAP mode. These findings are consistent with what the technology provider expected to find, based on how their algorithm delivers charge.

It is important to note that these sessions reflect the current state of market EV adoption, in which a multifamily property typically has few EV drivers, and each driver can have dedicated overnight charging access. Drivers can always opt for Level 2 if they wish, since they are very unlikely to pull into their parking space and find that a fellow EV driver is currently occupying the Level 2 port. Similarly, drivers can choose the charge mode that meets their needs, and the charging experience will not be impacted by the algorithm needing to allocate charge across multiple vehicles at one port. As more residents purchase EVs, they will be more likely to encounter these scenarios, and the potential impact on a typical charging session is uncertain.

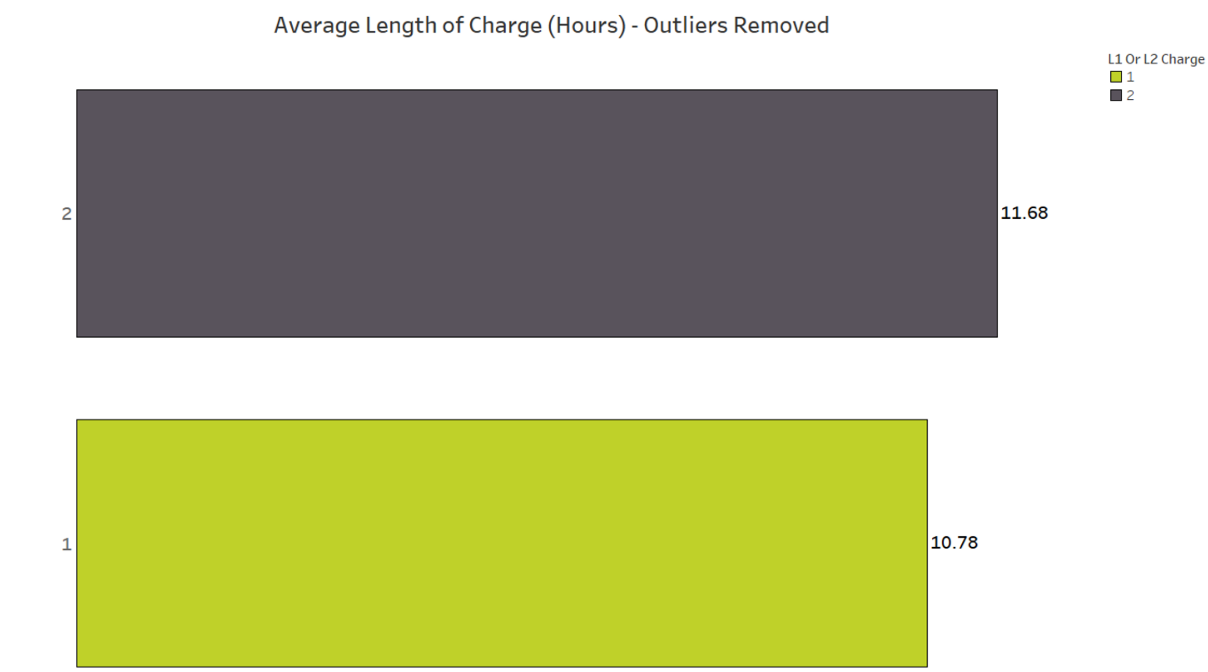
Question 2: What is an average charging session duration?

In the EV industry, the main concern with Level 1 charging is the limited amount of range that can be provided in a dwell session compared to Level 2. The ability of Level 1 to meet daily needs depends on how long a typical user is parked and plugged in. With the evaluated technology potentially splitting multiple Level 1 and low-power Level 2 charging sessions during one dwell session, this concern is particularly acute. Ideally, users are plugging their vehicles in overnight every night, and can receive more than 31 miles of range (the California daily driving average). Figure 7 and Figure 8 show the average amount of time customers were charging their vehicles, sorted by which power mode (Figure 7) or voltage Level (Figure 8) they chose.



Average of Hour Conversion for each Power Mode. Color shows details about Power Mode. The marks are labeled by average of Hour Conversion. The data is filtered on Hour Conversion, which ranges from 0.5 to 168.253888889.

Figure 7: Average Charging Session Duration (by Charging Mode)



Average of Hour Conversion for each L1 Or L2 Charge. Color shows details about L1 Or L2 Charge. The marks are labeled by average of Hour Conversion. The data is filtered on Hour Conversion, which ranges from 0.5 to 168.253888889.

Figure 8: Average Charging Session Duration (by Voltage Level)

In Figure 7 and Figure 8 we see that the technology users were plugged in to ASAP mode for the longest on average. This is not exactly what the technology provider had expected, as ASAP mode is the most expensive charge mode, ECO is the least. This may indicate that customers are not especially concerned about electrical costs, and instead are more interested in receiving the most amount of range. In Figure 8 we see users tend to stay plugged into Level 1 chargers for longer, which is consistent with what the technology provider expected, as Level 1 is cheaper than Level 2.

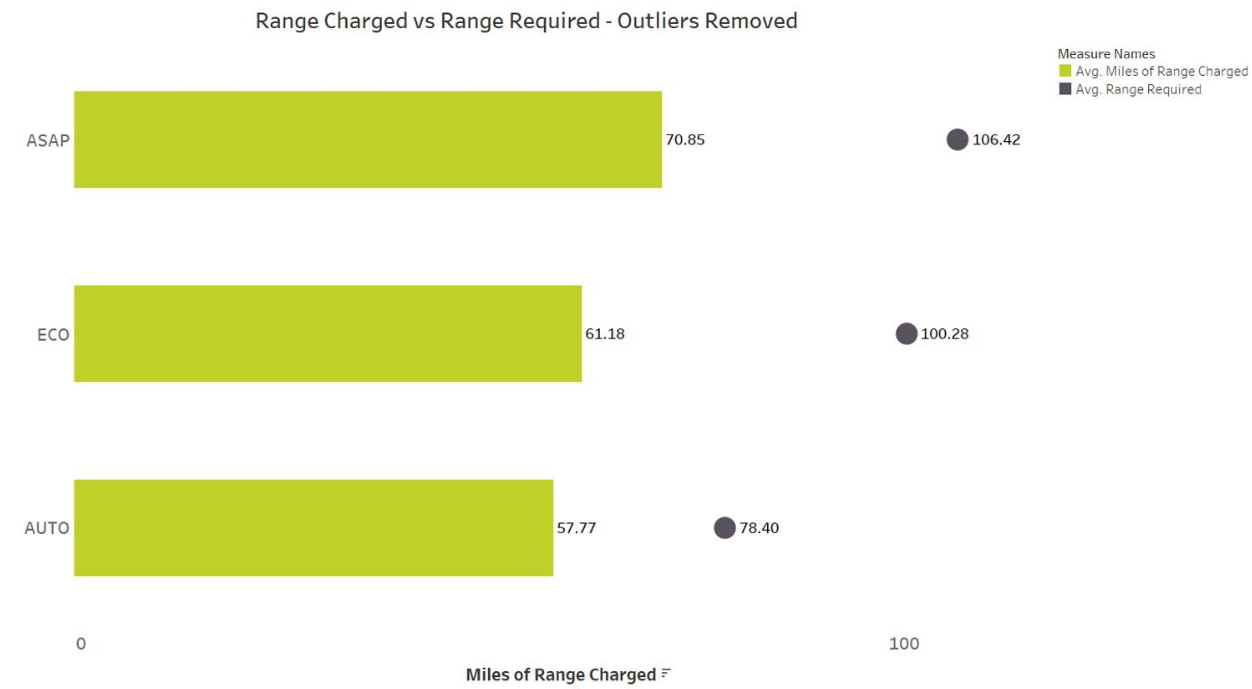
Question 3: How much range are users able to get?

EVs do not all charge at a uniform rate; some manufacturers design vehicles to accommodate high-power charging from 250 kW DC fast chargers that can provide hundreds of miles of range in minutes, while others have on-board chargers that must throttle the incoming power down to much slower speeds. As a result, there is no single formula that accurately captures the range delivered in a single charge session for all vehicles on the market.

The developer of the evaluated technology has plans to integrate a vehicle model-specific algorithm to calculate the range delivered, but this is not yet an available feature. Currently, the algorithm calculates how much range they deliver to the vehicle with the following formula:

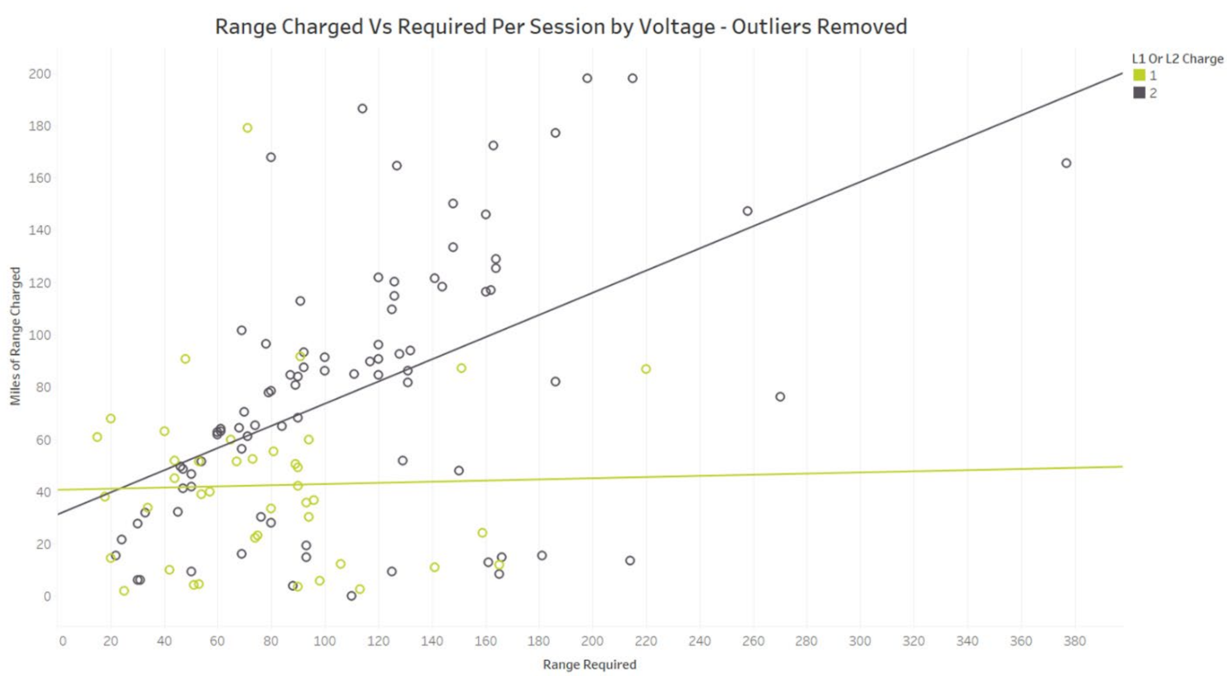
1. Users enter a departure_time. The max_session_duration is calculated as (departure_time - current_time)
2. Users select if they will charge on the Level 1 outlet or Level 2 outlet
    a. Level 1 outlets provide a maximum continuous power of 1.92kW
    b. Level 2 outlets provide a maximum continuous power of 3.84kW or 3.33kW, depending on if the property has 240V or 208V electrical service.
3. Users input their vehicle make / model, from which we will determine their miles_per_kWh. For now, we set an average of 3.5 miles_per_kWh for all vehicles.
4. Based on this information, the miles_per_hour_charged = (max_cont_power * miles_per_kWh)
5. The maximum allowable requested miles charged (maximum of the range slider) is calculated as (miles_per_hour_charged * max_session_duration)
6. Once a session is complete, and the actual kWh charged is known, the estimated miles of range charged = (kWh_charged * miles_per_kWh)

This formula allows us to ask two related questions: How much range did drivers think they need, and how much range did they actually receive?



Avg. Miles of Range Charged and Avg. Range Required for each Power Mode. Color shows details about Avg. Miles of Range Charged and Avg. Range Required. For pane Average of Miles of Range Charged: The marks are labeled by Avg. Miles of Range Charged. For pane Average of Range Required: The marks are labeled by Avg. Range Required. The data is filtered on Hour Conversion, which ranges from 0.5 to 168.253888889.

Figure 9: Range Charged vs. Range Required (by Power Mode)



Sum of Range Required vs. sum of Miles of Range Charged. Color shows details about L1 Or L2 Charge. Details are shown for Session Uuid. The data is filtered on Hour Conversion, which ranges from 0.5 to 168.253888889. The view is filtered on Session Uuid, which excludes 7 members.

Figure 10: Range Charged vs. Range Required (per Charging Session)

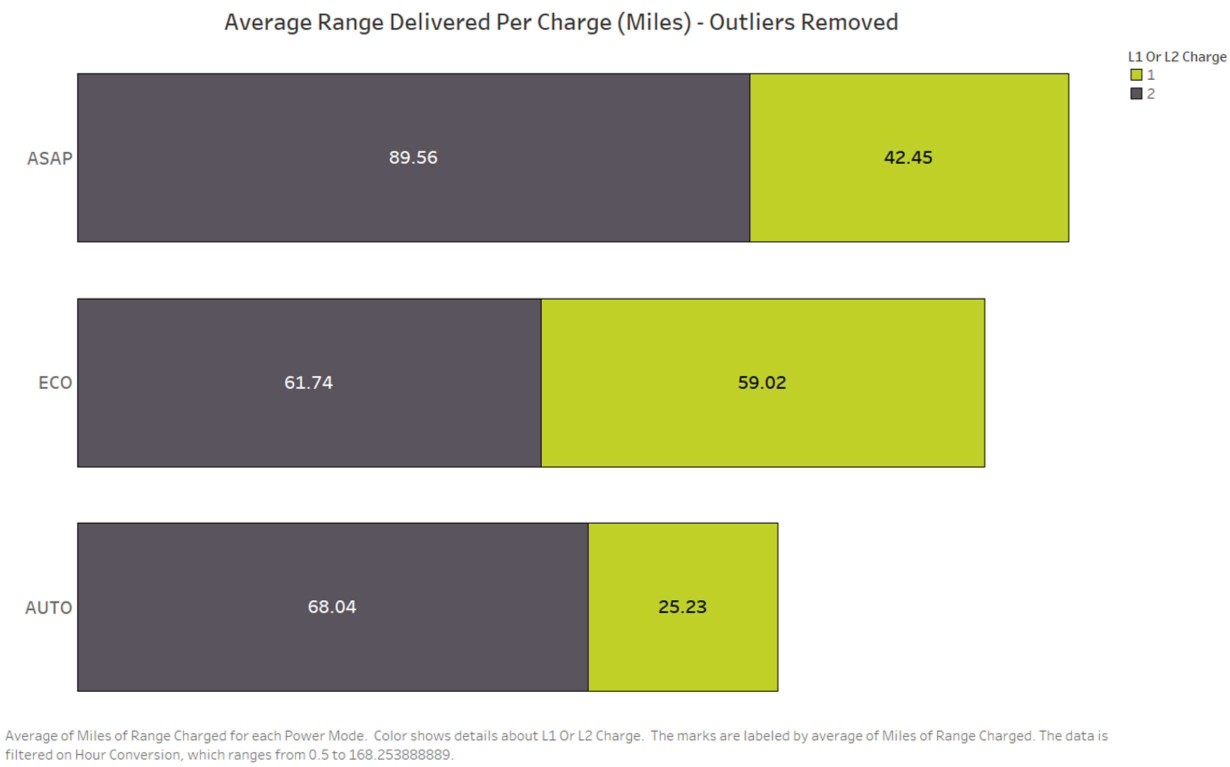


Figure 11: Average Range Delivered (by Voltage Level and Charge Mode)

These results reflect one of the major challenges in scaling EV adoption: The concept of "range anxiety" continues to be perceived as a major barrier to consumers buying EVs. Manufacturers continue to release models with larger batteries and significant investment continues to be made in expensive public charging stations. In reality, there is a significant disconnect between the amount of charge drivers feel they need, and the amount they actually need. This is reflected even in this small sample size: low power EV chargers were not always able to provide users with all the range they might want over a charging session, and in many cases users are requesting more range than they can receive. This mirrors a common concern that Level 1 charging will become even less capable of meeting driver needs as vehicle batteries extend to provide 400 miles or more on a single charge – despite the fact that home Level 1 charging is intended to meet daily needs, and just because a vehicle battery is larger does not mean an EV owner drives any further on a daily basis. It should also be noted that the design of the app user interface is such that users may default to setting the range request slider to the maximum, instead of trying to calculate what a reasonable range is for them. Additional user behavior study is needed to establish whether users selecting more range than necessary reflects any dissatisfaction on the part of the driver.

Regardless, despite concerns regarding potentially misaligned driver expectations, it is evident that users are receiving more than enough charge during an overnight session to provide sufficient range to cover the daily commute distance of the average Californian, even while using Level 1. Figure 11 shows that the average range delivered for a user in ASAP mode plugged into a 240 V charger is 91.35 miles. Customers can choose their own settings and address range anxiety by paying slightly more to prioritize range. Those who simply charge at the cheapest electrical rates – drivers using

Level 1 supply on Eco mode – still receive around 60 miles of range, nearly double the average daily driving total in California.

Table 1Table 2 below shows some of the key charge session metrics broken down by vehicle. These numbers do not include any charging sessions of less than half an hour, as those do not reflect the typical charging session use case for home charging. While no vehicles received the amount of range requested on average, all vehicles that used the chargers more than twice received an average range of 33 or more miles per charging session. As expected, the average miles delivered increases when looking at longer sessions – when filtering to only include sessions of 3 hours or more—a better representation of the overnight charging use case for which these types of technologies are designed—the average range achieved was between 39-108 miles per session.

Table 2: Charging Behavior by Vehicle

Vehicle	Total Charging Sessions	Average Session Duration (hrs)	Average Power Consumed (kWh)	Average Range Requested (mi)	Average Range Delivered (mi)	L1 vs. L2
1	2	3.4	0.19	172	1	L1: 0% L2: 100%
2	29	19.6	28.59	138	100	L1: 0% L2: 100%
3	2	0.8	1.88	109	7	L1: 55% L2: 45%
4	1	2.0	2.91	42	10	L1: 100% L2: 0%
5	15	12.3	25.70	114	90	L1: 56% L2: 44%
6	18	9.4	9.46	96	33	L1: 100% L2: 0%
7	15	10.8	10.68	59	37	L1: 70% L2: 30%
8	35	6.9	12.89	69	45	L1: 1% L2: 99%
9	1	2.5	0.03	12	0	L1: 100% L2: 0%

Energy Efficiency Results

While Level 1 and Level 2 EV chargers all provide power at similar levels of efficiency, ENERGY STAR has found that there are more significant variations in the standby power draw of various products. Figure 12 below compares the average no-vehicle standby power draw of 235 ENERGY STAR-tested Level 2 chargers, 4 Level 1 chargers, and 14 Level 1/Level 2 Dual Input chargers to the evaluated technology.

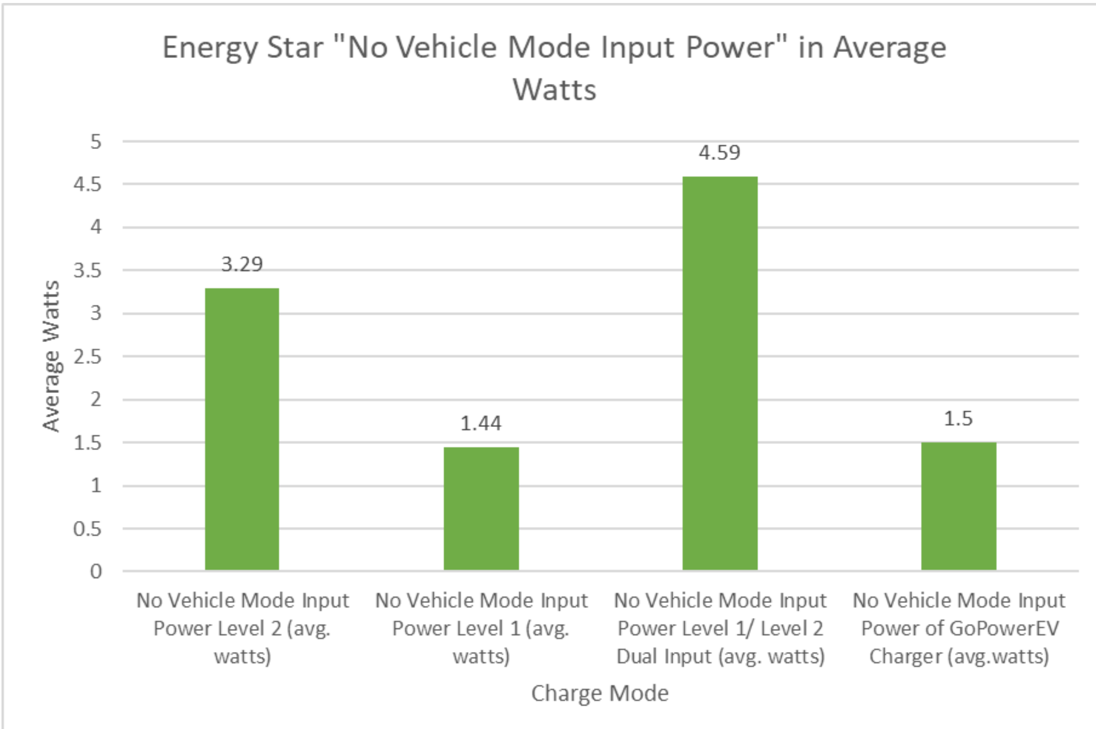


Figure 12: Standby Energy Efficiency with no Vehicle plugged in of evaluated charger compared to other EV chargers (EPA ENERGY STAR® n.d.)

This graph shows that although the evaluated technology is capable of charging vehicles at 240V for Level 2 charging, its standby electrical draw of 1.5 watts is lower than the average of other Level 1/Level 2 dual mode chargers, lower than the average Level 2 charger, and is nearly as low as the average Level 1 charger. These benefits may be greater in practice, wince a single charging base can provide charging access for more than one vehicle. A single port drawing power at 1.5 W can be considered the functional equivalent of two separate smart outlets from other manufacturers, which would draw at 2.88 W per ENERGY STAR. Despite these differences, however, the standby power draw in all EVSE products is so low that the energy efficiency savings from the evaluated technology are marginal.

Table 2 below shows the estimated annual energy provided to a single car via a full-power 40A Level 2 EVSE, a traditional 20A Level 1 EVSE, and the evaluated technology installed on a 20A breaker and operating at both Level 1 and Level 2. The annual charging time was based on the average hours spent charging at Level 1 in this project—the use case with the largest sample size—adjusted to reflect the shorter times needed to meet the same charge level with higher-power EVSE. The results show that the evaluated does not provide meaningful energy efficiency benefits. On its Level 2 mode the evaluated technology uses slightly less energy annually than a full-power Level 2 product and slightly more on its Level 1 mode. For context, the annual energy consumption difference between Level 2 and the evaluated Level 1 technology is about half the lifetime energy savings of a single 65W-equivalent LED light bulb (65-Watt Feit Electric BR40 n.d.)

The energy demand implications of the evaluated technology are more substantial. A single user will draw 1.92 kW at Level 1 and 3.84 kW at Level 2. Two drivers plugged into the same charging base will still only use 3.84 kW; two drivers at dedicated full-power Level 2 stations will draw 15.36. The difference is equivalent to the power draw of nearly 3.5 heat pump water heaters. Low-power EV chargers may not provide meaningful energy efficiency benefits, but by spreading out consumption over a longer period they provide opportunity for building electrification and grid management – not to mention the benefits of shifting demand to off-peak hours.

Table 3: Energy Efficiency Savings

	40A Level 2 EVSE	Level 1 EVSE	Evaluated Technology 20A Level 2	Evaluated Technology Level 1
Power Level / Max Demand	7.68 kW	1.92 kW	3.84 kW	1.92 kW
Annual Charging Time	246 hours[a]	982 hours	491 hours	982 hours
Annual Standby Time	8,490 hours	7,754 hours	8,245 hours	7,754 hours
Charging Efficiency	89.4%	83.8%	89.4%	83.8%
Avg. Standby Power Draw	3.29 W	1.44 W	1.5 W	1.5 W
Annual Charging Energy Consumption	2,109.46 kWh	2,250.43 kWh	2,109.46 kWh	2,250.43 kWh
Annual Standby Energy Consumption	27.93 kWh	11.17 kWh	12.37 kWh	11.63 kWh
Total Annual Energy Consumption	2,137.39 kWh	2,261.59 kWh	2,121.83 kWh	2,262.06 kWh

[a]This is calculated based on the estimated time needed to achieve a charge level equivalent to the average provided in this project. Drivers using the evaluated technology charged an average of approximately 12 hours per night using primarily Level 1. A full-power Level 2 station delivers power at 7.68 kW, four times the 1.92 of a Level 1 charger. Therefore a car could reasonably be assumed to charge to the same level as the evaluated technology's Level 1 ports in a quarter of the time at Level 2.

Equipment Maintenance

The EVSE industry has struggled to provide adequate uptime for charger fleets (J.D. Power 2023), drawing significant criticism in the press and creating a major challenge for EVSPs to cost-effectively service units dispersed across the country. The evaluated technology has several noteworthy features designed to minimize service requests and maintenance. During this project there were no instances of unit failure or other operational problems, so these capabilities were not tested. These features include:

1. Each smart outlet and each local control unit (LCU) sends a 'heartbeat' to the technology provider's servers so they can monitor when smart outlets or LCUs are 'down' (this covers major electronic or communications failures, power outages, etc.)

2. Each smart outlet performs health self-checks, so the technology provider can tell whether specific blocks within the hardware are broken, such as the relay to energize/de-energize the receptacle, or the energy metering hardware.
3. The ability to collect data for each requested session, including the requested range and how much energy was delivered, to identify instances when the technology is unable to meet user demand.
4. The ability to collect and log several other error types, allowing users to report errors directly through the app.

The smart outlet is the most complex element of the system and the most likely failure point. The technology provider has designed their system such that smart outlets can be swapped out by a layperson, meaning most issues can be quickly fixed without requiring an electrician. This design element should help directly address the challenge of limited electrician availability often leading to significantly charger downtime.

User Experience

EV drivers typically do 70-80 percent of their charging at home (Ricardo Inc 2021). Home charging is the most convenient and typically the least expensive option for charging an EV. As a result, the experience drivers have with their home charging solution is vitally important. This is especially key with lower-power solutions. The public is still learning the basics of EVs and the options to charge them. Those who do have some understanding of EV chargers are more likely to think of public DCFC or Level 2 chargers as a typical charging solution. As automakers pursue vehicles with longer and longer range, the idea of only being able to gain a relatively small fraction of that maximum range with an overnight charge may give potential drivers pause. Without setting appropriate expectations, Level 1 or lower-power Level 2 solutions are at risk of failing to meet the charging experience anticipated by most drivers, slowing the type of EV adoption needed to meet California's goals.

To understand how users feel about their experience using the evaluated technology, the project team relied on tenants surveys at properties where the technology was deployed. This included feedback from customers prior to installation and after they had used the equipment.

Pre-Installation Survey

The survey questions in Table 4 were provided to residents at Site 1 prior to the installation process. 32 residents were surveyed.

Table 4: Pre-Installation Survey Responses

Question	Answer
Do you currently have a car that you park at our property?	Yes, I have a car (100%, 32 Votes) No, I don't have a car (0%, 0 Votes)
Do you already have an EV or Plugin EV?	Yes, I already have an EV or PHEV (0%, 0 votes) No, I have a gasoline vehicle (no plug) (100%, 32 votes)
Do you have an assigned parking space at our property?	Yes, I have an assigned space (93.8%, 30 votes) No (6.2%, 2 votes)
If you had convenient EV charging capabilities for your own use, would you consider getting your next car as an electric or plug-in hybrid vehicle?	I would be interested in getting an EV (34.4%, 11 votes) I would be interested in getting a plug-in hybrid electric & gas vehicle (PHEV) (9.4%, 3 votes) No, I am not interested in EV/PHEV (56.3%, 18 votes)
If you had convenient EV charging, what timeframe would you consider getting an EV or PHEV?	During next 3 months (0%, 0 votes) 4-6 months (14.3%, 2 votes) 7-12 months (21.4%, 3 votes) 1-2 years (28.6%, 4 votes) More than 2 years (35.7%, 5 votes)
How many people with driver's licenses live in your apartment?	0 (3.1%, 1 vote) 1 (40.6%, 13 votes) 2 (56.3%, 18 votes) More than 2 (0%)
How many car/trucks do you currently have for all the people in your household/ apartment unit?	0 (0%) 1 (56.3%, 18 votes) 2 (40.6%, 13 votes More than 2 (3.1%, 1 vote)
Would it be more appealing to live in a property where convenient electric vehicle charging is easily available to everyone?	Yes (43.8%, 14 votes) No (25%, 8 votes) Don't have an opinion on this (31.3%, 10 votes)
Is an extra $20 per month a reasonable amount to have EV charging available in your own parking space at our property?	Yes (37.5%, 12 votes) No (34.4%, 11 votes) Not Sure (28.1%, 9 votes)

44 percent of respondents indicated interest in purchasing a battery EV or plug-in hybrid EV. This reflects broader attitudes in the market, as a 2022 Consumer Reports survey found that 36 percent of drivers were interested in purchasing an EV for their next vehicle (Consumer Reports 2022). The survey also found that while no residents owned an EV at the time of the survey, five tenants would consider getting an EV within a year given access to charging. This was proven out as two tenants have purchased EVs since Site 1 agreed to install the evaluated technology.

Post-Installation Survey

A post-installation survey was emailed out to the residents at all the locations included in this project, with ten total responses received. Nine responses were from people who did not own EVs and one respondent was an EV owner. Their responses are summarized in Table 5 .

Table 5: Post Installation Survey Results (All Respondents)

Question	Answer
1.) Are you aware that Electric Vehicle charging outlets have been installed at some parking spots in your building?	Yes (80%, 8 votes) No (20%, 2 votes)
2.) Please select your level of understanding of how the new Electric Vehicle charging outlets work.	I understand perfectly (30%, 3) I somewhat understand (40%, 4) I do not understand at all (30%, 3)
3.) How likely are you to purchase an Electric Vehicle or Plug-in Hybrid?	Very likely (0%, 0) Somewhat likely (30%, 3) Somewhat unlikely (20%, 2) Very unlikely (40%, 4) Already own one (0%, 0) Other (10%, 1): “A lot of people in our complex can’t afford one. Myself included.”
4.) Now that your apartment has EV charging access, are you more or less likely to purchase an Electric Vehicle or Plug-in Hybrid?	Much more likely (40%, 4) Somewhat more likely (10%, 1) No Change (20%, 2) Less likely (30%, 3) Other (0%, 0)

Question	Answer
5.) Approximately how many miles do you drive one way between home and work?	0 miles/ work from home (10%, 1) 1-10 miles (50%, 5) 10-20 miles (20%, 2) 20-30 miles (0%, 0) 30+ miles (10%, 1) Other (10%, 1): “currently bike to work”
6.) Do you have access to EV charging at work?	Yes (20%, 2) No (50%, 5) Unsure (10%,1) Not Relevant/ Work from home (20%, 2)
7.) Do you own or lease an Electric Vehicle or Plug-In Hybrid EV?	Yes (10%, 1) No (90%,9)

All the following questions in Table 6 were only administered to respondents who stated they owned an EV or PHEV.

Table 6: Post Installation Survey Results (EV and PHEV Owners)

Question	Answer
8.) How often do you plan on charging at home with the (installed) charger?	Every day (0) 4-5 days per week (0) 1-3 days per week (100%, 1) A couple times per month (0) Never (0) Other (0)
9.) Where do you typically charge your EV other than at home?	Work (0) Public Charging Stations (100%, 1) Other (0)
10.) How often do you charge away from home?	Every day (0) 4-5 times per week (0) 1-3 days per week (0) A couple times per month (100%, 1) Very rarely or never (0) Other (0)

Question	Answer
11.) Has the (installed) charger made owning an EV easier for you?	Yes (100%, 1) No (0) Other (0)
12.) What year, make, and model of EV do you drive?	No Responses
13.) Do you find the (installed) charger easy to use?	Yes (100%, 1) No (0) Other (0)
14.) Has the presence of (installed) charging increased your satisfaction with the apartment building?	Yes (100%, 1) No (0) Other (0)
15.) Do you find that charging with (installed charger) is reasonably priced?	It's cheaper than I expected (0) Yes, it's fairly priced (100%, 1) No, it's too expensive (0) Other (0)
16.) Does the (installed) charger provide enough overnight charge to meet your typical daily needs?	Yes (100%, 1) No (0) Other (0)
17.) If the (installed) Charger does not supply enough charge, please explain how much range the (installed) charger provides versus what you'd like.	No Responses

While this survey includes a small sample size, the results mirror the attitudes towards Evs observed elsewhere in the market – some residents are open to Evs and indicate they are more likely to consider one now that they have home charging, while others appear to be steadfastly opposed to Evs. Perhaps most importantly, this data supports the claim that most multifamily residents in California do not have long-distance commutes: 8 of 10 respondents indicated they commute 40 miles per day or less, and one of the other two is not a car driver at all. The one EV driver who responded indicated that their experience with the evaluated technology was primarily positive, increasing their satisfaction with their apartment building and making EV ownership easier.

Property Manager Interviews

The project team also interviewed two property managers about their experience in working with the technology provider. These interviews were conversational interviews based on the questions laid out below.

1. Do you drive an EV?
2. How would you describe your level of familiarity with electric vehicles and EV charging?
3. Why did you decide to install Level 1 EV Chargers at your property?
4. Why did you choose (the evaluated technology provider) for your charging solution?
5. Have you been satisfied with your experience with (the evaluated technology provider)?
6. Do you own other properties, and if so, would you consider putting Level 1 EV chargers there as well?
7. What do you see as the primary benefits of (the evaluated technology) charging at your property?
8. What concerns, if any, do you have with (the evaluated technology provider) charging technology at your property?
9. Have you received feedback from your tenants about the chargers? If so, what have they said?
10. Have you received feedback from your property managers about the EV chargers?
11. Have you needed to increase any fees for your tenants as a result of the installation of (the evaluated technology provider's) chargers?

The project team interviewed the property managers of Site 1 and Site 2. The full interview notes are included in Appendix E: Site Manager Interviews. Below are the main take-aways from each conversation.

Site 1

- Believes there is demand for EV charging at his property.
- Was drawn to the technology because of its price point and a personal connection to the founder.
- Likes the technology because of its ability to provide EV charging to multiple parking spots.
- Feels he can be helpful as a test site for the technology.
- Thinks the entire success of the project depends on the level of EV adoption; if more tenants do not start driving EVs and soon, it will not have been as worthwhile.
- Has concerns about current tenants not wanting to switch parking spots to accommodate EV drivers, and the possibility of fires due to vehicle battery malfunctions.

Site 2

- The primary motivator was the property manager's anticipation of this technology becoming increasingly in demand within the rental market.
- He cited customer demand and the ability to filter Craigslist for properties with EV chargers as motivating factors.

- He believes that the technology provider's business model is right for this property, but not necessarily for all properties. He said he believes in a "basket of solutions."
- They chose the technology provider because they would handle payments, provided a low-cost installation, and are providing a solution that did not require electrical upgrades at the property.
- The technology provider was able to electrify many more parking spaces than other charging solutions providers.

Software App

Complexity in EV charging products can lead to confusion, creating additional barriers to EV adoption and charger utilization, therefore considering the user experience is an important consideration in evaluating EVSE market potential. The evaluated technology users interact with two components of the product: the charging hardware and the software-based user interface. Appendix C: Software Application Interface includes screenshots of the app. These screenshots are from the portion of the app that will be used by tenants, in which they will specify how long the plan on leaving their car plugged in, which then informs the charging algorithm how it should schedule charging. The app works by using near-field communication (NFC) in which a user can tap their phone against the smart outlet to activate a session—the same functionality used by other common smart phone apps like Apple Pay and Samsung Pay. The technology provider is evaluating whether to also include a QR code as a backup. During this project, the technology provider did not receive any tenant complaints on the product. Further evaluation of the user experience is included in Lessons Learned.

Education & Training

Stakeholder education is a key element of any EV charging project, and doubly so for low-power projects. Property managers will be taking a bigger role than they are used to in parking-related administration and are likely to be on the front lines of answering tenant questions and dealing with potential complaints. Tenants may be familiar with traditional Level 2 or DC Fast Charging products at public or workplace settings but are far less likely to have used a smart outlet to charge their vehicle, particularly one with a unique form factor like the evaluated technology. Those residents experienced with EVs may also have preconceived and unrealistic expectations for the amount of charging that can or should be delivered in a single charging session.

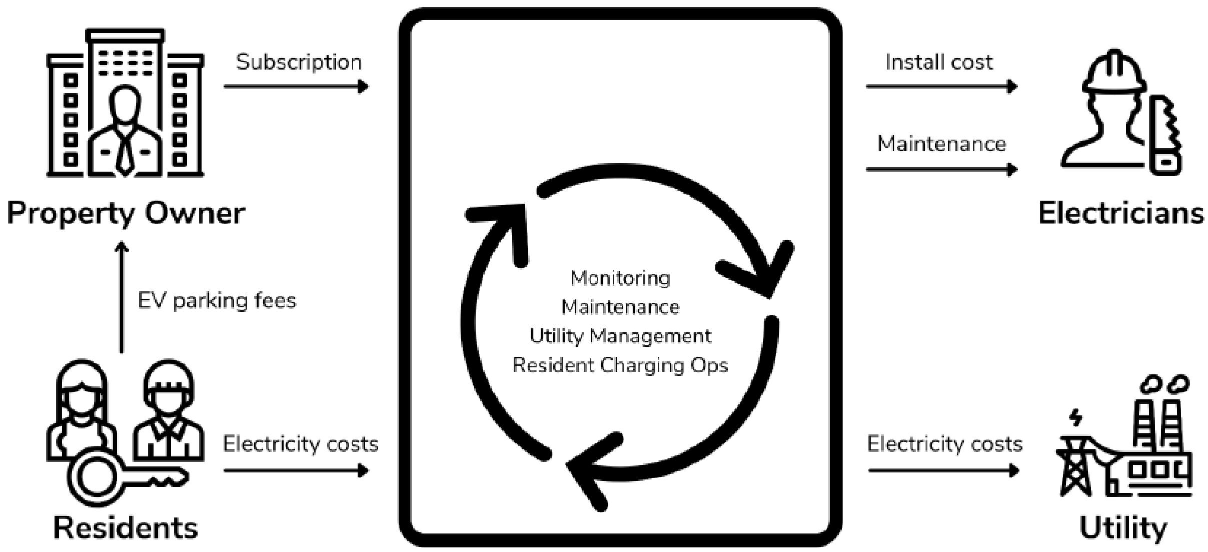
The technology provider uses the following process for onboarding new sites and training stakeholders:

1. Prior to the completion of installation and commissioning, a representative works with the property manager to deploy site-specific signage in the parking area of the building. A 'common space' poster is also displayed, typically in an elevator area or laundry room, to announce the new project, showcase potential benefits, and explain how the technology works.

2. As the activation date approaches, the customer success team sends an introductory email to the property manager and schedule a meeting to demonstrate the technology and train the property manager on their Property Manager Online Portal.

3. The provider electronically sends audience-specific guides to property managers and tenants (more detail below). There are two versions of the Resident Guide, one for current EV owners and one for prospective EV owners.
    a. The Property Manager Guide includes:
        i. A high-level overview of the solution ecosystem (Figure 13 below)
        ii. A description of the subscription model and parking fee collection
        iii. An overview of the Property Manager Online Portal
        iv. Guidance for adding additional powered spaces in the future
        v. Details on the installed hardware
        vi. An overview of the resident charging experience and a resident FAQ
    b. The Tenant Guide includes:
        i. Signup instructions with a QR code to the app
        ii. A basic description of Level 1 and Level 2 charging, with images showing which plugs on the charging unit provide which power level
        iii. Step-by-step instructions for initiating a charging session
        iv. EV educational information and resources for buying an EV, for tenants that are not yet EV drivers
        v. Resident FAQs
4. One week after the project is completed and the technology goes live, the technology provider follows up with the property manager to address any questions or concerns.

Figure 13: Technology Solution Ecosystem Overview



While the materials provided to the project facilities give a detailed walkthrough of how to use the technology, there remains room for improvement. Currently, tenants are first engaged just before the project goes live at their property, but the education process ideally starts much earlier. Tenants need time to get used to and excited about a new technology and the decision-making process to get a new vehicle can be a lengthy one. Providing earlier notice about the new planned amenity and materials on electric vehicles may help accelerate on-site EV adoption and EVSE utilization.

The documentation can also better prepare users for charging with the evaluated technology. The multiple modes (ECO, AUTO, and ASAP) may be appealing to tenants experienced with EVs and time-of-use electric rates, but new drivers may find them confusing and benefit from additional education. The current documentation is also very limited in educating customers on the expected user experience. The existing language primarily focuses on the cost benefits of low-power charging, although additional instruction on how to charge at the lowest rates would benefit users. The Resident Guide, for instance, details the cost difference between charging with the technology provider's unit compared to a public DC fast charging station, but does not speak to the expected rate of charge or daily range provided via an overnight charge session. In this project there were no complaints received from tenants and the lone EV driver respondent to the survey indicated satisfaction with the equipment; however, as EV ownership proliferates at these sites—and especially as drivers need to start sharing these charging stations--, it is more likely for users to have a poor experience if not educated on the Level 1 charging experience. The project team shared this feedback with technology provider.

Cost-Effectiveness

Cost information was provided by the technology provider and are reflective of the costs of the entire project, encompassing the temporary house panel install as well as the eventual full install. As the temporary install is a stopgap approach involving additional costs that the technology provider would like to avoid at future sites, so it is likely that these costs are slightly conservative. These numbers comes directly from the technology provider and therefore may be subject to speculation.

Table 7: Site Cost Summary

	Site 1	Site 2	Site 3	Site 4	*Average*
Labor, Materials, Signage	$25,148	$27,660	$57,891	$24,903	*$33,900*
Permits & Engineering	$5,000	$6,000	$6,400	$5,000	*$5,600*
Project Management	$7,500	$7,500	$8,000	$7,000	*$7,500*
Total Cost	$37,648	$41,160	$72,291	$36,903	*$47,000*
Cost Per Parking Space Enabled	$1,882	$2,058	$3,012	$2,050	*$2,250*

Table 8: Project Site Costs vs. Level 2 Project Costs

	Site 1	Site 2	Site3	Site 4	*Average*
Project Site Cost/Space	$1,882	$2,058	$3,012	$2,050	*$2,251*
PG&E EV Charge Network Avg. Cost/Space (PG&E n.d.)	$17,504	$17,504	$17,504	$17,504	*$17,504*
SCE Charge Ready Avg. Cost/Space (Southern California Edison 2022)	$14,209	$14,209	$14,209	$14,209	*$14,209*
Total Project Site Cost	$37,648	$41,160	$72,291	$36,903	*$47,000*

	Site 1	Site 2	Site3	Site 4	*Average*
PG&E EV Charge Network Est. Total Project Cost	$350,080	$350,080	$420,096	$315,072	*$358,832*
SCE Charge Ready Est. Total Project Cost	$284,180	$284,180	$341,016	$255,762	*$291,285*

Note: This report uses a Cost per Parking Space metric as opposed to the traditional Cost per Port. While each of the evaluated charging units can only actively charge up to two vehicles at once—akin to a traditional dual-port Level 2 charger—, up to three vehicles in separate parking spaces can plug in and receive charge over a single dwell session.

The evaluated technology is shown to be significantly more cost-effective than traditional Level 2 projects at providing access to EV charging in multifamily environments. The average cost-per-space of $2,251 is 87.2 percent lower than the per-port project costs PG&E has reported for its Level 2 EV Charge Network and 84.2 percent lower than those of SCE's Level 2 Charge Ready network. These numbers provided are similar to costs seen from other low-power EV charging companies. For example, Energy Solutions' pilot with Peninsula Clean Energy of Level 1 smart outlets on dedicated circuits had an average per-port cost of $4,191 (Peninsula Clean Energy Electric Vehicle (EV) Ready Program 2021). For cost-conscious multifamily property owners, low-power EV charging represents an extremely appealing option to add EV charging at a considerably lower price, with more of their tenants receiving charging than a traditional shared Level 2 charger approach.

Subscription Cost

The evaluated technology provider uses two different subscription models for the sites included in this project. Site 1, Site 2, and Site 3 are charged monthly fees at different rates for powered spaces (i.e., those that will have charging units installed and activated to provide EV charging) and unpowered spaces (i.e. those with charging units installed that will be electrified in the future as EV adoption increases among tenants). These costs are shown in Table 9 below. The technology provider has since changed its pricing model, which is reflected in the Site 4 project info and in Table 7and Table 8. The technology provider will now charge a facility fee and a price per powered space. The facility fee is intended to help cover the cost of the infrastructure installed at spaces that are not powered at initial launch. As the number of powered spaces increases (e.g., a prewired space is converted to powered), the amount paid in total will change accordingly.

All fees in the below table were provided by the technology provider. Recurring fees are based on the full installation of the systems, not on the house power phase of the program.

Table 9: Technology Provider Subscription Costs – Model 1

Facility Name[a]	Monthly fee per powered space	Monthly fee per unpowered space	Total cost per year assuming no change in # of powered spaces
Site 1	$15	$11	Total Monthly Cost: $284 Total Yearly Cost: $3,408
Site 2	$15	$11	Total Monthly Cost: $280 Total Cost Yearly Cost: $3,360
Site 3	$15	$11	Total Monthly Cost: $328 Total Yearly Cost: $3,936

[a] Note: These rates were agreed in Mar 2022 and are not offered to new customers as the technology provider's pricing has changed.

Table 10: Technology Provider Subscription Costs – Model 2

Facility Name	Monthly facility fee	Monthly fee per powered space fee	Total cost per year assuming no change in # of powered spaces
Site 4	$40	$5	Total Monthly Cost: $130 Total Yearly Cost: $1,560

Note: These are rates provided to low-income housing properties.

Lessons Learned

This project has resulted in valuable lessons learned about the appeal of and challenges facing low-power EV charging at multifamily properties, as well as some of the specific benefits and drawbacks of the evaluated technology.

Evaluated Technology

Deploying the evaluated technology at the four sites in this project provided the following insights into low-power EV charging options:

- Low-power EV charging solutions hold significant potential to increase EV charging access at a site without service upgrades or some of the more expensive infrastructure costs typically found in Level 2 charging projects. This project was able to add charging access for more parking spots, both in the initial project phase in which only the existing panel capacity could be used as well as the eventual approved project design, than would be possible for a traditional Level 2 project. For instance, Site 2 was found to have 200 amps of available power, which would allow for 5 full-power Level 2 chargers without increasing the utility service level and installing larger panels (and potentially larger gauge cables and other associated infrastructure that typically requires expensive trenching). When all utility infrastructure upgrades are completed and all installed ports are activated, the low-power project at that site will provide charging access to 20 parking spots trenching while avoiding those costs. These results are in line with other deployments of low-power EV charging technology in California.

- While low-power solutions can help avoid service level increases and major project expenses, the evaluated technology's design is particularly impacted by utility service planning requirements. Other low-power solutions are often designed to leverage the available capacity in an existing electrical panel, the evaluated technology provider prefers to install a new, separately metered panel to make charging administration and billing easier for property owners. The additional technical requirements associated with this business model mean that the technology provider is more dependent on the local electric utility than many of its competitors. As a result, installations such as those in this project are at greater risk of delays from transformer upgrades and other infrastructure requirements. These typically do not add additional customer cost as the site service level remains the same, but do impact project economics. Once upgrades are complete, however, the evaluated technology is not limited by the available capacity in the house panel but by the overall facility capacity, and therefore can typically add much more overall charging access. The utility service planning barrier is detailed further below.

- Low-power EV charging solutions are significantly more cost-effective than traditional Level 2 EV chargers. While the costs in this project were provided by the technology provider and could not be verified by outside contractors, the costs are comparable to other low-power deployments. A report by Ecology Action for Ava (formerly East Bay Community Energy) provided an estimated cost of $5,000 per port for a no-cost low-power multifamily EV charging program (Ecology Action 2020). This included no cost share from the property owner via up-front investment or subscription nor any of the potential circuit-sharing benefits of the evaluated technology. If real world costs indeed include expenditures in excess of those accounted for in this report, low-power solutions still represent a significantly more cost-effective investment for many multifamily properties.

- Low-power solutions do not provide significant energy efficiency savings but do offer substantial demand benefits. The ultimate energy consumption between Level 1, Level 2, and combination EVSE has minimal variation when providing the same amount of vehicle range. By spreading that consumption over a longer period, however, the evaluated technology and similar low-power solutions cut peak demand by two to four times that of full-power Level 2. The ability to shift load to off-peak hours was also shown in this project and provides additional grid benefits.

- Some of the most innovative features in the evaluated technology, including the ability to share a single circuit among 2-3 parking spots, the potential for actively monitoring overall panel capacity and modulating charge to add even more charging at a site, and the electrician-free maintenance of the charging ports, remain appealing features but cannot be fully evaluated until greater on-site EV adoption is achieved and the sites experience greater utilization.

User Experience

While the evaluated technology hardware is designed to enable cost-effective maintenance and maximize access to EV charging, there are elements that raise questions on how well the current iteration of the technology is designed to provide an intuitive user experience to the broader EV market. To date, EV owners are mostly early adopters, a segment of the market that is typically more able and willing to invest the time in understanding the technical elements of EV ownership and operation. This population likely understands Level 1 vs. Level 2 chargers, from the charging experience to which outlets support which charge level. They are more likely to understand time-of-use pricing and how electric bills and vehicle refueling are linked when you purchase an EV. The evaluated technology provider's app provides some excellent features for these customers – namely the flexibility to choose Level 1 vs. Level 2 and select among AUTO, ECO, and ASAP modes. As EV ownership expands to new users, customizability of charging experience may create barriers of entry for those unfamiliar with these concepts. The current iteration of the hardware and software provides relatively limited signage or education on these topics and relies on the knowledge of the user. That said, this is a new technology and the technology provider will certainly iterate on its current product. As EV adoption increases and the needs of new types of drivers are better understood, technology providers should adapt their products accordingly.

Permitting

While the need to pull any permits required by a local Authority Having Jurisdiction (AHJ) is not unique to the evaluated technology or any EVSE multifamily project, the length of time between permit submission and permit approval remains a barrier. The technology provider found that it can take six weeks or more just to have a permit application reviewed, much less approved. The challenge of EVSE permitting is well-recognized – in 2021 the California Governor's Office of Business and Economic Development (GO-Biz) launched the "Permitting Olympics" to encourage local governments to comply with streamlined approval requirements for EV charging stations. Yet only 11 California counties received Gold, Silver, or Bronze designations[4] so there is still work to do (California Governors Office of Business and Economic Development n.d.) The features that make the evaluated technology so promising for expanding EV charging access – circuit-sharing and panel-sharing capabilities that allow the installation of more EV charging than would traditionally be allowed in a panel –add complexity to project review and can give permit reviewers pause. This barrier, however, remains less an EVSE technology issue, particularly in areas like the Bay Area, where more EVSEs are permitted than elsewhere in the country, than a resourcing issue as AHJs struggle with budget and staffing challenges following the COVID-19 pandemic. While getting a permit issued in a timely manner is a challenge, project inspections were relatively prompt. For

[4] San Mateo and Santa Clara, home of the four sites in this project, were not recognized for having streamlined EVSE permitting.

instance, in the case of Site 1 the project completed installation on October 18 and was inspected on October 26.

Utility Service Planning

The primary barrier the project faced during the permitting process was getting approval from electric utilities. Most Level 1 and Level 2 solutions in multifamily environments are wired to the house panel or a subpanel off the house panel of the building. Sites can install as much EVSE as the house panel has available capacity or upgrade the service level to the building and the size of the house panel to add further EVSE. The evaluated technology provider, however, installs a new meter and panel to provide power to its EVSE. This approach has clear benefits – a separate panel makes it easier to scale deployment of further EV charging access at a site, for instance. A dedicated meter also solves the "split incentive" challenge that plagues most EVSE, where the equipment benefits tenants but increased electric bills are borne by the property owner. A separate meter allows the evaluated technology provider to allocate electricity costs among users, removing a key administrative barrier. The addition of a new meter, however, also creates complexity in the project as electric utilities view the installation of a new meter and panel as having a potential impact on the local distribution system to a greater degree than utilizing an existing house panel. Three of the four sites funded by this project have hit unexpected delays from coordinating with the utility around service planning. In all cases, the utility required that the electrical service to the building be upgraded which caused an unforeseen delay of more than 6 months to the projects. There is also very little information coming from the utility about when this upgraded service may be installed.

Clear direction on the service planning process and required application information was not available, and new issues continued to crop up for each site. For instance:

- At Site 2, the evaluated technology provider performed a load study, determined that plenty of power was available to support EV charging, and submitted a design for a permit with the City of San Jose and a new meter with the utility. In the process of working with the utility, they were informed that utility would not allow additional load to be placed on the existing overhead drop, despite the 'headroom' available, and cancelled its application. The technology provider was instructed to apply for a new electrical drop. Emails from PG&E shared with Energy Solutions demonstrated ambiguity whether this decision was related to the specific conditions of Site 2 or if this is a general policy. As a result of the lack of clarity provided by this process or the utility Greenbook, the technology provider decided to only request the addition of load for an underground service drop; they will apply for a new drop for all aerial configurations.
- At Site 1, the evaluated technology provider performed a load study, was issued a permit by the City of San Jose, completed installation, passed inspection by both the utility and the City, and received a meter release. However, when the technology provider requested installation of the meter, they were informed that they would need to apply for a new residential address to be registered with the city, a process that would take several weeks just to get started and incur additional cost. The reason provided for this decision was that the new meter was to be installed at an address that already had an existing house meter, and the utility's software systems would not allow multiple meters at the same address. While PG&E may be able to add a suffix to differentiate a separate meter at a single-family home address (i.e., "123 Sesame Street A" vs. "123 Sesame Street"), the system does

not allow that for a multifamily property due to multiple units already sharing the same address. This process created significant confusion, delay, and cost for the Site 1 project, and there is still some confusion over whether this will be required for other project sites and at what stage the technology provider can make these requests to avoid further delays in the future.

The biggest and most common barrier to the evaluated technology provider's desired approach to project design, however, was grid capacity constraints. Even in instances where the overall building service level was not increasing, the utility would not approve the installation of a new meter with larger numbers of EV chargers unless hardware was installed by the utility providing the property with more capacity. Due to supply chain issues resulting from the pandemic, this would often delay a project indefinitely. This barrier deserves further exploration among California's electric utilities. Utilities are used to new electric loads at a facility coming online all at once, and in that paradigm, it makes sense that the distribution system be upgraded to handle the entire new load before that load is activated. For EV charging, however, activation and utilization of the end use can be much more gradual. In the case of many of the project sites, it is true that if every charging port installed were to go into use at the same time, the local transformer may not have available capacity to serve that new load. But as the project team has seen, EV adoption follows access to charging, but not immediately. Ideally a utility would provide a process whereby an EVSE provider, like evaluated technology's, could install the full intended complement of chargers at a site at the same time—by far the most cost-effective approach—and activate a smaller subset of those chargers while the utility pursues whatever upgrades are necessary for the full project concurrently. Currently, it seems to be that electric utilities' system planning processes do not have this level of flexibility and as a result the evaluated technology provider was unable to install chargers even at sites that had only one or two current EV drivers.

The solution that the technology provider found to get around these extremely long delays was to install all their charging hardware according to their original plan, but not make the final connection to a new metered panel. Instead, a handful of the chargers in that deployment were wired to the facility house panel using whatever free capacity was available. The evaluated technology provider submitted another permit request, incurring additional time and cost in the process, to power 3 or 4 chargers from the existing house electrical panel billed to the building owner, which also complicates the value proposition of administratively easy billing for site hosts. This permit type proved much easier for the AHJ to approve and did not require inspection from the utility as long as it met the electrical code's load requirements. These allowed some of the chargers to be energized much more quickly and meet the immediate need of the tenants. As most properties have only 0 to 2 current EV drivers, and each charging unit has 3 ports, 3 chargers could theoretically support up to 9 EV drivers, more than meeting the current need. As the permits for the full system wind their way through the utility and AHJ, this house panel solution is sufficient. Once the full permit is approved, all the infrastructure will have been installed, and it will simply be a matter of rewiring the chargers to become fully electrified.

Recommendations

The following are recommendations to scale commercialization of low power EV charging at multifamily properties in California.

Include low-power load management solutions in EVSE programs. For many IOU programs, Level 2 remains the standard for eligible EVSE equipment. This limits the financial resources that can be leveraged for low power EV charging and signals to the market that Level 2 products provide the only acceptable user experience. The results from this project support studies and pilots completed elsewhere that demonstrate Level 1, low-power Level 2, and load-managed EVSE products can provide a positive driver experience for many more drivers per site at a significantly lower cost. Utility-sponsored programs could realize significant cost savings and dramatically increase access to home EV charging by including and emphasizing these products.

Clarify IOU metering & service requirements for EVSE. To scale low power EV charging, the time between customer agreement and project completion must be reduced. Developing a stronger understanding of the IOU requirements for installing new meters and adding new or additional load to a building service is essential for avoiding future roadblocks. As low power EV charging companies complete projects at more and varied locations throughout California they will gain a stronger understanding of the IOU processes and requirements; however, without better collaboration and greater consistency across projects, delays and their financial toll become inevitable. The California IOUs can provide additional resources for helping companies navigate service planning. Startup EV technology providers are far more likely to be familiar with the behind-the-meter requirements of the National Electrical Code than those of the local distribution system. While the PG&E Greenbook and its analogues at other IOUs are comprehensive documents that apply to a wide variety of customers and facilities, they can be prohibitively difficult to navigate for entities inexperienced with system planning. The IOUs could take inspiration from the California Governor's Office of Business and Economic Development (Go-Biz) "ZEV Permitting Olympics" effort to streamline permitting[5] and develop resources to educate EVSE providers on the requirements for installing EV charging technology at multifamily properties. In the meantime, low power EV technology providers should continue to proactively engage the IOUs and identify and communicate as many potential project delays to property owners seeking to install these solutions.

Build a network of qualified installers. Befitting its status as an early technology startup, the evaluated technology provider leverages a handful of electrical contractor relationships to complete installations. Scaling beyond the startup geography will require a significantly expanded network of qualified installers. Networked Level 2 providers have been very effective in building out installer networks, however Level 1 and non-networked Level 2 products, with lower profit margins, often do not yet have comparable distribution channels.

Smart outlet products have some inherent advantages over "true" EVSE, as they can be installed by any licensed C-10 contractor and do not require Electric Vehicle Infrastructure Training Program (EVITP) certification. The pool of C-10 contractors that also have EVITP certification is currently small, in part due to administrative challenges with the availability of EVITP testing. Low power smart outlet

[5] https://business.ca.gov/industries/zero-emission-vehicles/plug-in-readiness/permitting-olympics/

technologies, like the one evaluated, should not be held back by these growing pains. Additionally, building products that can be maintained without an electrician, such as making the charging unit modular and able to be swapped out without an electrician, will make low power smart outlets easier and less expensive to maintain than traditional Level 2 solutions, enabling them to maintain high uptime cost-effectively.

Explore rideshare partnerships. The evaluated technology, like all EV charging providers serving the multifamily space, faces the "chicken and egg" problem in which tenants will not purchase EVs until they have access to convenient charging, but property owners are not motivated to install charging until tenants buy EVs. While the per-space subscription model helps better align capital and operational costs with utilization, low-power smart outlet providers should continue to explore alternatives to drive utilization. Ridesharing solutions and partnerships with ridesharing companies may provide an opportunity for residents to test out an EV and the low power smart outlet chargers. This could help reassure drivers that on-site charging can meet their daily needs and encourage EV adoption.

Utility service planning modifications. To streamline the approval process of EV charging infrastructure, and specifically low-power and power-managed solutions such, utilities may consider the following changes to their service planning process at multifamily buildings:

- Utilities currently calculate the load posed by new EV chargers as though all the EV chargers in a project would be simultaneously charging at full power – even if that scenario is months or years away based on the EV adoption at a property. When analyzed this way, utilities are often forced to upgrade the infrastructure delivering electricity to the building as the full complement of new EV chargers impose too much load for the existing infrastructure. This often imposes a huge delay to the project's completion. By exploring a provisional construction authorization in which projects are allowed to complete construction of a full EV charging project but only electrify chargers up to an approved maximum allowable amperage, utilities could balance distribution system concerns with a more project- and customer friendly approach. In that scenario, a project could complete all electrical work at once but use built-in EVSE software to limit the electrical draw and prevent overtaxing of the building infrastructure. Then, once the utility upgrades the necessary infrastructure, the EV charging company could unlock all chargers for operation without the expense of sending an electrical team to re-wire chargers. This approach would also allow the limited number of current EV drivers at a property to have immediate charging access, with additional charging access catching up when upgrades are completed and more tenants purchase EVs.
- By reviewing the information being provided to customer-facing staff on EV charging service planning, utilities could limit customer and vendor confusion and conflicting advice. The installation team experienced conflicting direction from different regional engineers and managers within the same utility, causing additional cost and delays.
- Clarification on multifamily project classification would also provide additional clarity for EVSE vendors. The technology provider was informed by PG&E that the multifamily sites in this project were classified as 'commercial' sites. The PG&E Greenbook, on the other hand, indicates that a 'residential' classification may be more appropriate. The 'commercial' classification imposes much stricter requirements exacerbated by a severe

shortage of electrical panels for commercial installations. The California Governor's Office has put forward instructions to increase EVSE and states that one strategy is to avoid treating multi-family locations as commercial. Revisiting this question could help streamline the project process and result in greater deployments of multifamily EV chargers.

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Appendix A: Site Details

Site 1

Building Overview

Site 1 is a two-building apartment complex in San Jose, California. It was built in 1970, the building has 75 units, and 83 total parking spaces. The property has two feeder locations, an 800A feeder for one building and a 1,000A feeder for the other. A load study confirmed 400A of available power in the existing infrastructure.

Project Scope

The technology provider will enable 20 parking spots for EV charging, representing 24 percent of total garage spaces and 27 percent of building units. This will include the installation of a new meter and panel of the main service, 10 charging bases, associated conduit, and wiring. Initially, ports will be installed at 6 of the 10 charging bases to provide immediate EV charging access to 12 parking spaces. An additional 8 spaces will be activated with the installation of ports on the four remaining charging bases as site demand increases.

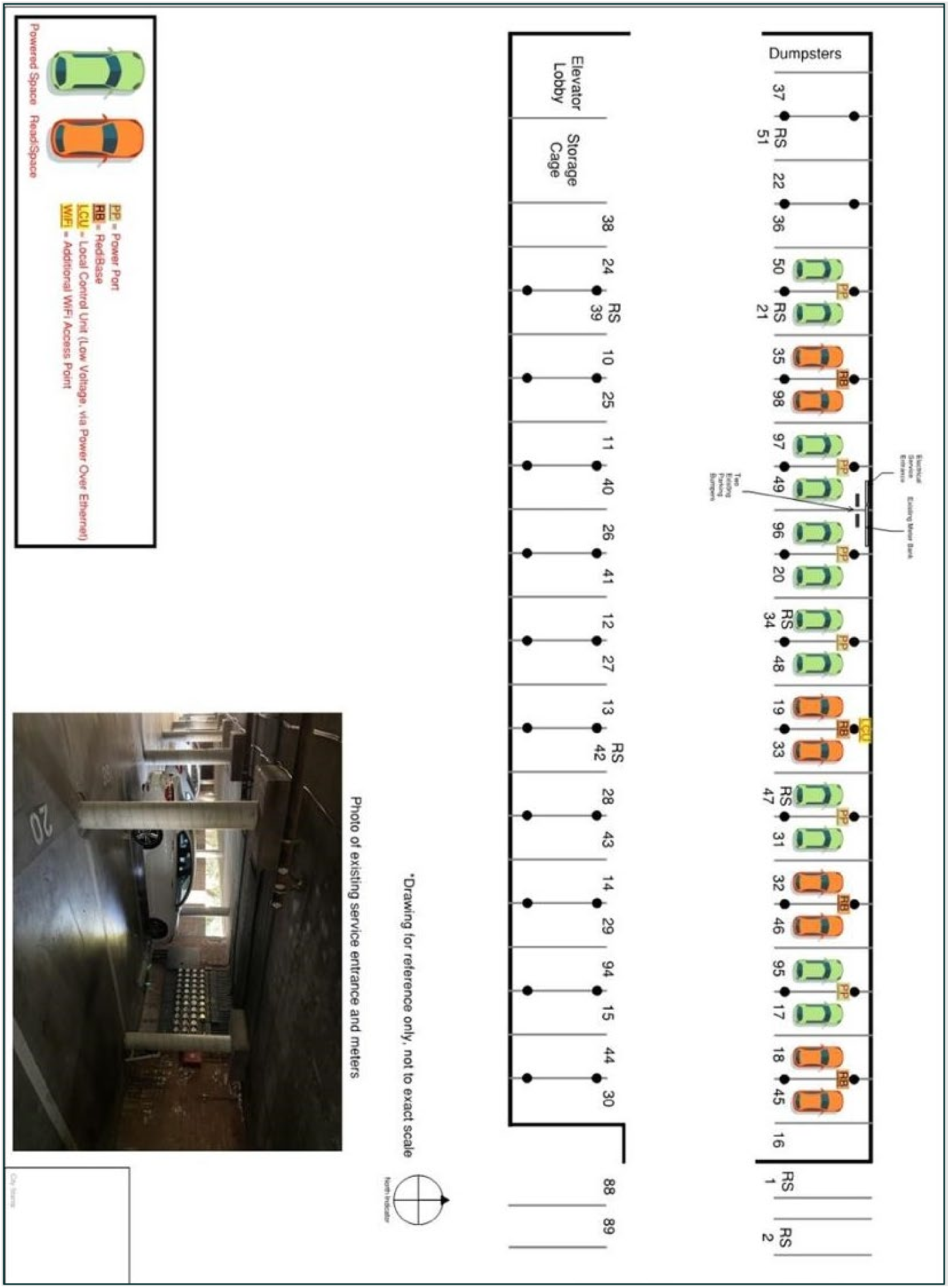


Figure 14: Site 1 Site Plan, Source: Evaluated Technology Provider.

Site 2

Building Overview

Site 2 is a 57-year-old two-building apartment complex in San Jose, California. It contains 39 units and 37 under-building garage parking spaces. Like Site 1, the property has two PG&E feeder locations, one for each building. The main breakers are 800A and 400A. A load study of this property found 200A available in the existing infrastructure.

Project Scope

Evaluated technology provider will enable 20 parking spots for EV charging, representing 54 percent of the covered parking on site and 51 percent of apartment units. This is significantly more than the amount of EV charging required under the Title 24 CALGreen building code for new multifamily properties, an ambitious goal for an existing multifamily property. Upon final installation, the technology provider will install 11 charging bases with 4 ports initially installed to provide active charging to 9 parking spaces. When demand increases on site, the technology provider will install the remaining ports to activate the remaining 11 spaces.

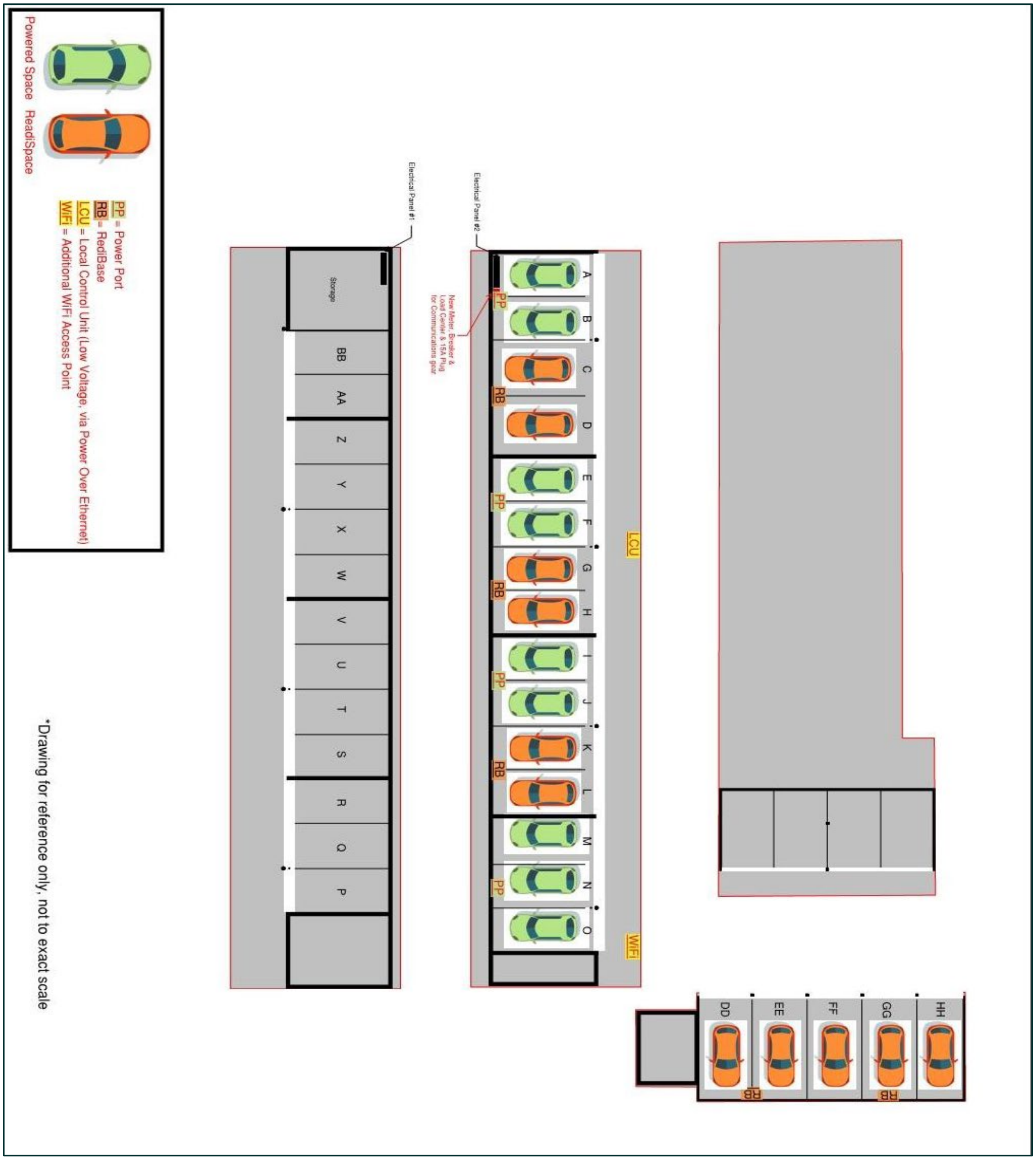


Figure 15: Site 2 Mockup, Source: Evaluated Technology Provider

Site 3

Building Overview

Site 3 is a six-building apartment complex in Mountain View, California. It has 120 units and 90 under-building parking spaces and was built in 1960. There are six PG&E feeder locations, one for each building, and each with a 600A main breaker.

Project Scope

Evaluated technology provider intends to install 12 charging bases which would enable 24 parking spots at the Site 3 complex. This would serve 20 percent of units and represent 22 percent of under-building parking. The project will entail the installation of a new meter and 200A panel to each 600A main service where chargers are to be added.

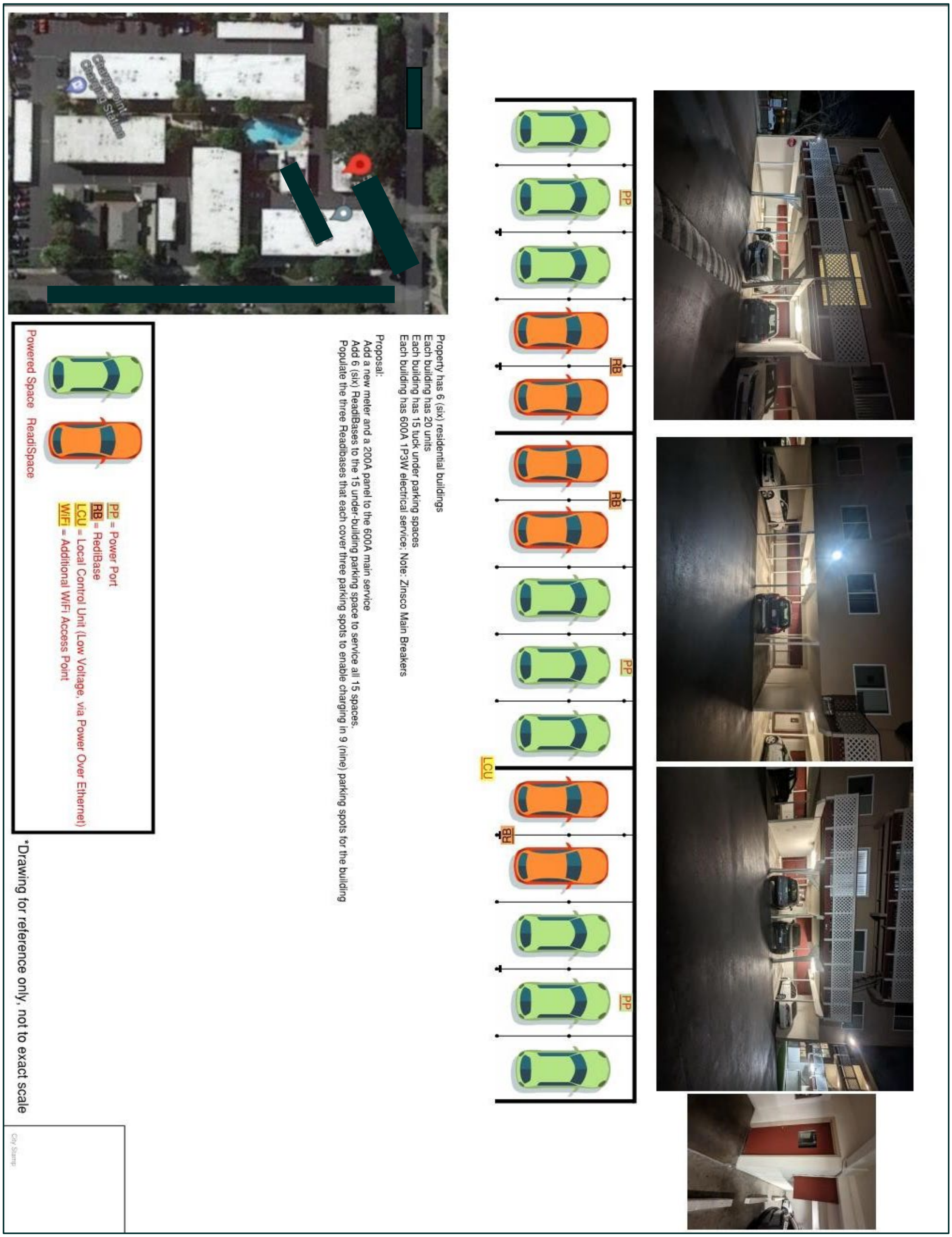


Figure 16: Site 3 Mockup, Source: Evaluated Technology Provider

Site 4

Building Overview

Site 4 is a 12-unit low/medium income (LMI) housing apartment complex in Redwood City, California.

Project Scope

Evaluated technology provider intends to install 10 charging bases which would enable 18 parking spots at Site 4. Five charging bases will receive charging units upon installation. The lower number of parking spots enabled per charging based compared to Site 1 is due to the garage layout at Site 4; additional charging bases were required such that charge cords would not cross pathways when in use.

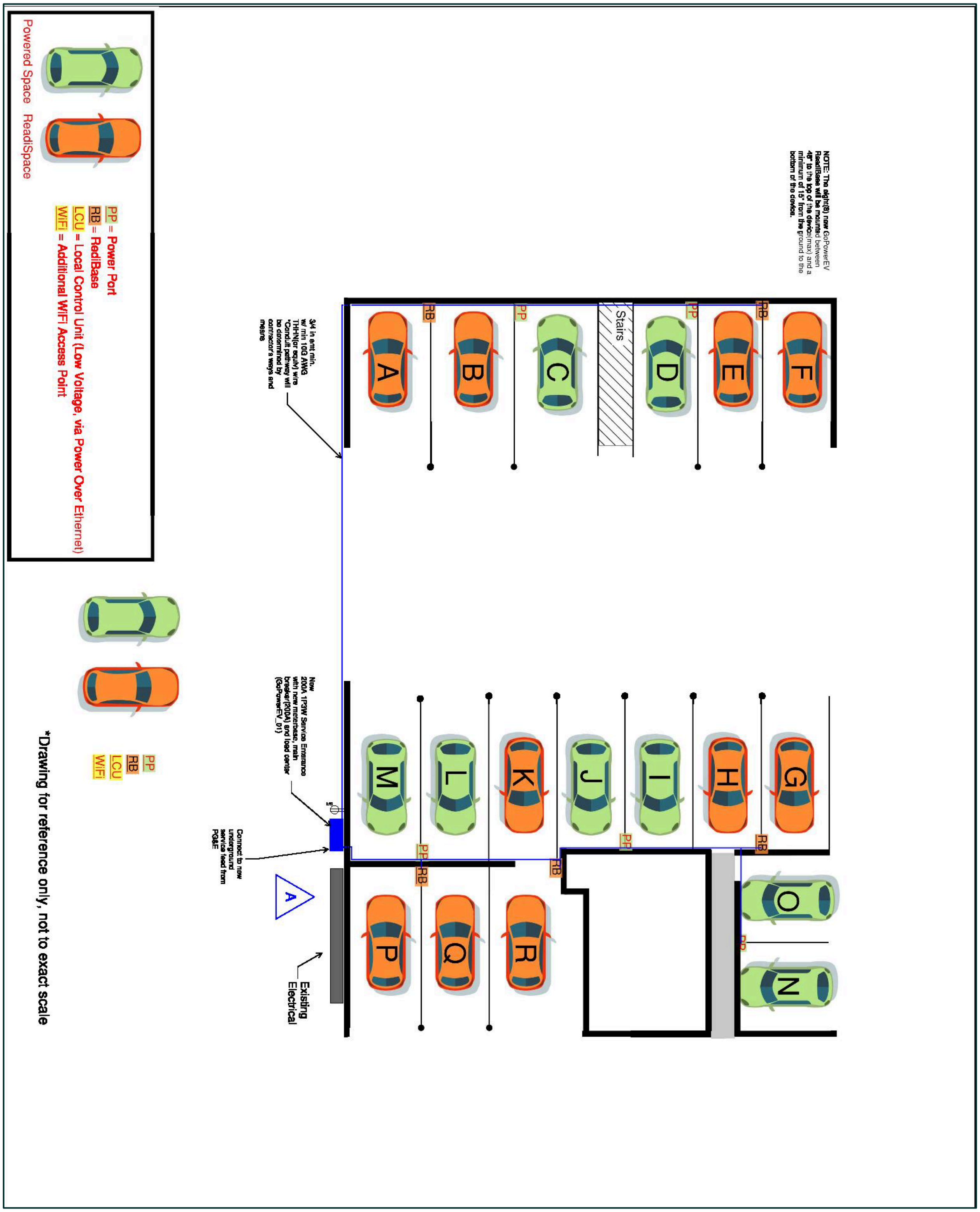


Figure 17: Site 4 Mockup, Source: Evaluated Technology Provider

Appendix B: Site Photos

Site 1

Figure 18: Charging Base Installed at Site 1

This is one of 10 charging bases installed by the technology provider at Site 1. The charging bases are fully wired and only require a charging unit to slip onto them to be ready for charging. This allows the landlord to be able to increase capacity without needing to involve an electrician.

Figure 19: Charging Unit at Site 1

This is a charging unit being held above a charging base to simulate what it would look like when fully installed. The two 120 V outlets and the central 240 V outlet are clearly visible. Around the outlets is an LED ring which indicates charging status. In the top right corner of the box is the wireless payment area, and in the top left corner is a camera which takes a photo each time the charger is used.

Figure 20: Local Control and Uplink (LCU) at Site 1

This is the local control and uplink unit (LCU), that controls all of the charging units through Wi-Fi. This LCU dictates how much power each outlet outputs based off the number of vehicles already plugged into the charging unit, and the duration of time each driver specified they could remain plugged in for. It can also be programmed to schedule the bulk of charging during off peak times. On the right side of the image, you can see the conduit heading to all the charging bases.

Figure 21: Evaluated Technology Provider Electrical Panel at Site 1

This image shows the interior of the dedicated panel installed by the evaluated technology provider powering all the charging bases. Inside you can see ten 20 Amp GFCI breakers, one for each of the charging bases. On the left-hand side of the panel is where the new PG&E meter will be installed.

Site 3

Figure 22: Site 3 Garage

This is the Site 3 garage prior to installation.

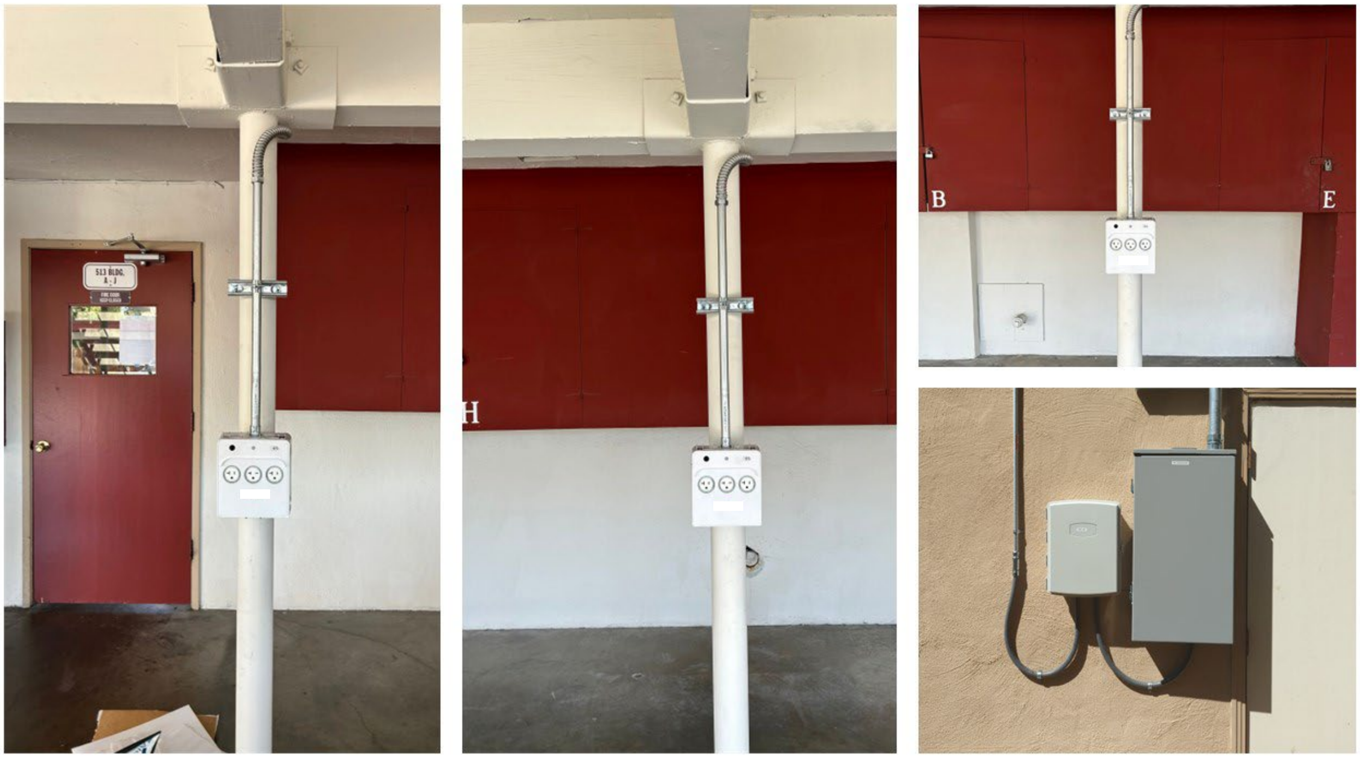


Figure 23: Site 3 chargers installed off the house panel, and the dedicated electrical panel installed by the evaluated technology provider that will be power the full installation once the utility upgrades the building's service.

Site 2

Figure 24: Installed chargers at Site 2 wired from the house panel, and the dedicated electrical panel which will power the full installation once the utility upgrades the service.

Figure 25: This is the aerial drop which the utility stated cannot handle any more electrical load at the building. The utility must upgrade it before the full installation can be finalized.

Site 4

Figure 26: Installed chargers at Site 4 wired from the house panel and images of the LCU apparatus for the installed chargers.

Appendix C: Software Application Interface

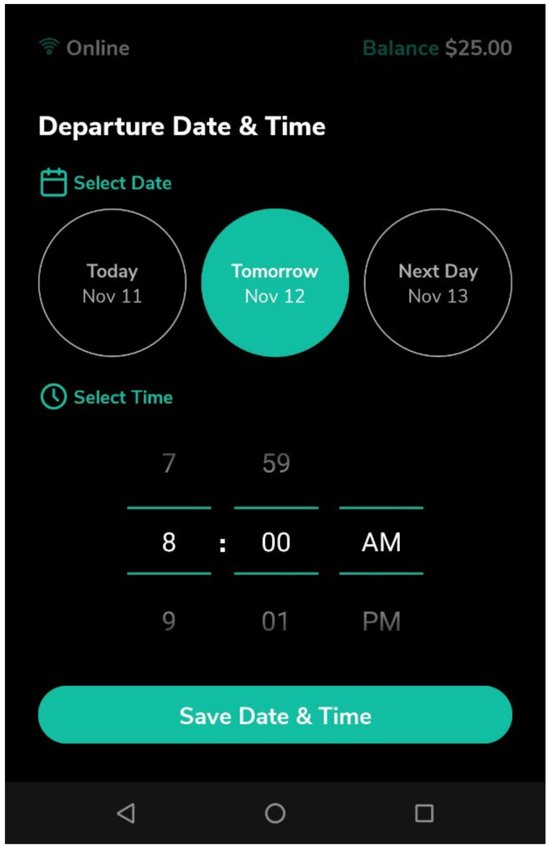


Figure 27: Tenant View Screenshot

This is the screen tenants will see when they plug their vehicles in to charge. Here they set how long they intend to leave their vehicle plugged in, which the charging algorithm then uses to determine what is the most efficient way to charge their vehicle. Notice in the upper right-hand corner, the user's charging balance is listed.

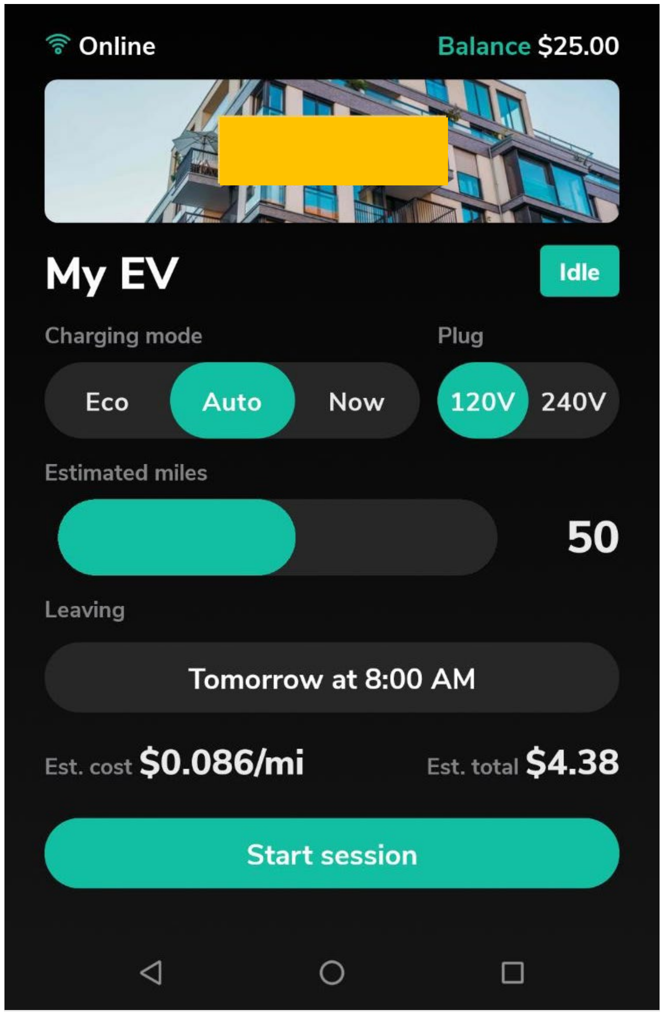


Figure 28: App Confirmation Screen

This is the confirmation screen. It is the step summarizing the charging session, and from which the tenant can fully initiate their session.

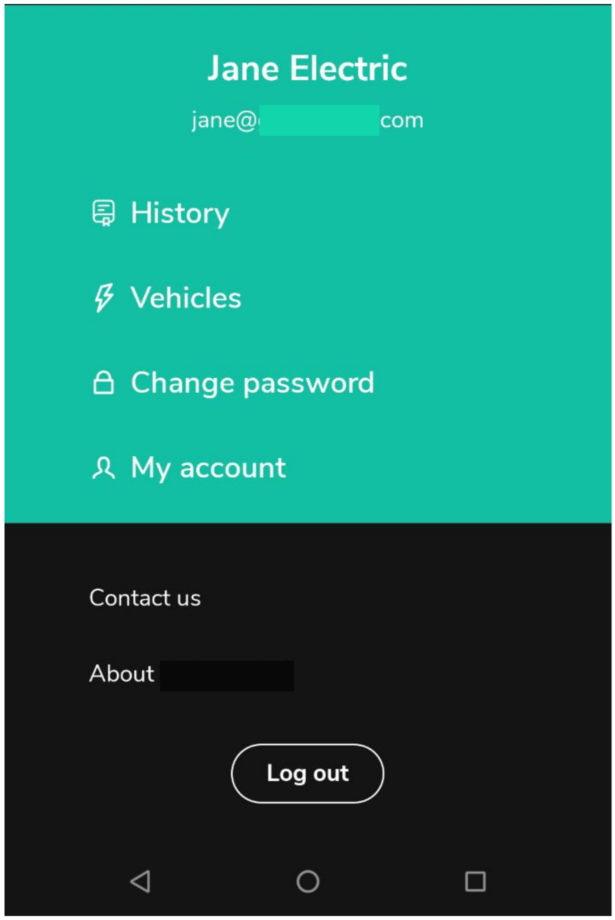


Figure 29: Tenant Drop Down Menu

This is the tenant's drop-down menu, from which they can see their past charging sessions, which vehicles they have registered, change their password, and edit the rest of the account details.

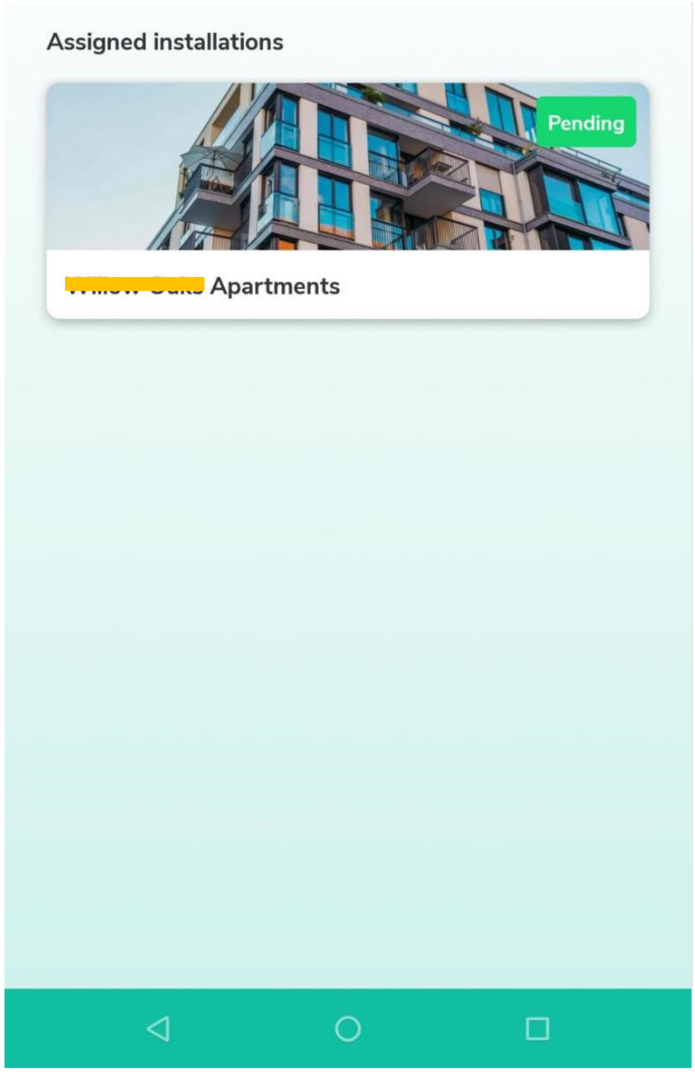


Figure 30: Installer App Home Site Menu

The installer app is used by the electrical contractor commissioning and configuring the hardware in the field. It essentially tells the technology provider's cloud software which specific pieces of hardware are installed at which specific property. It is also used to tell that specific hardware how to connect to the LCU Wi-Fi.

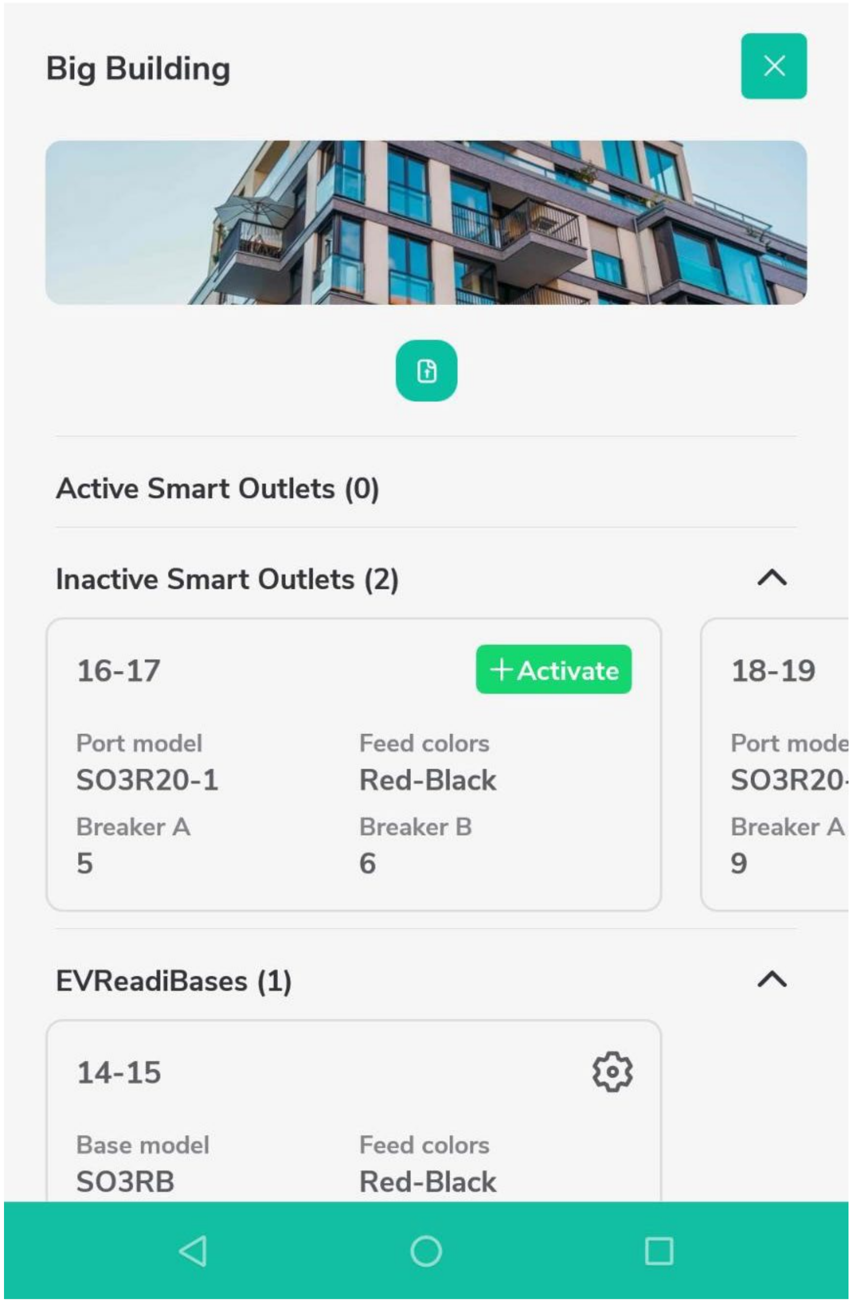


Figure 31: Installer App Site Installations Menu

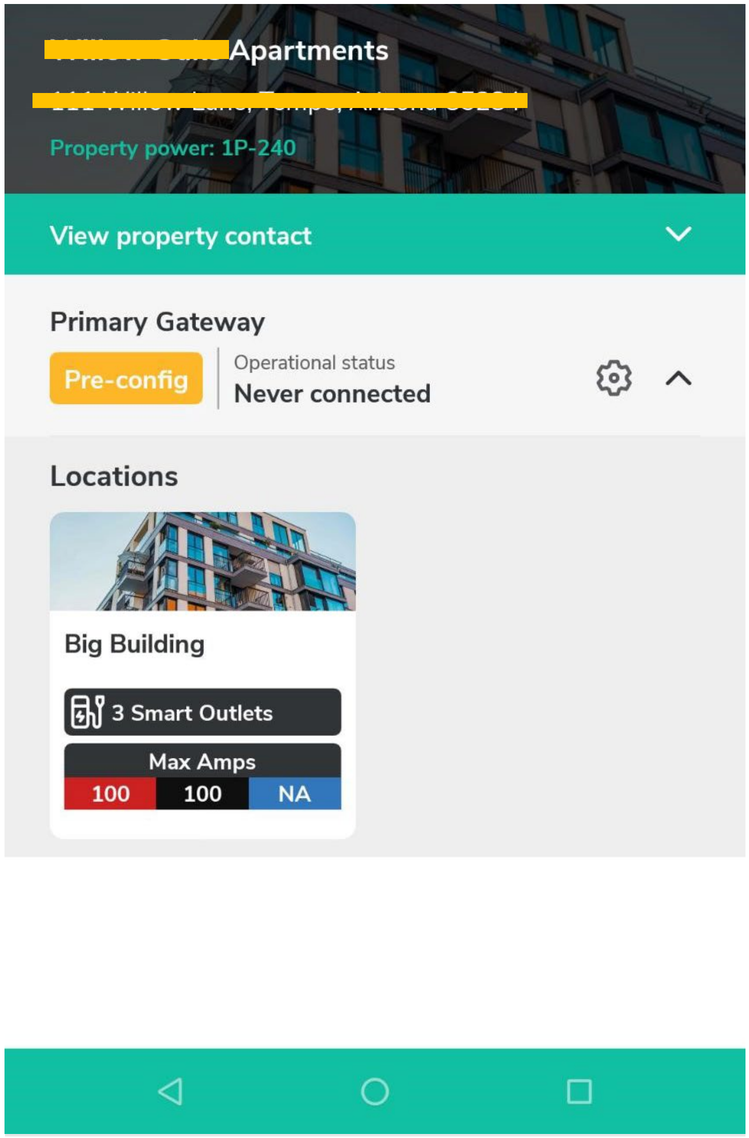
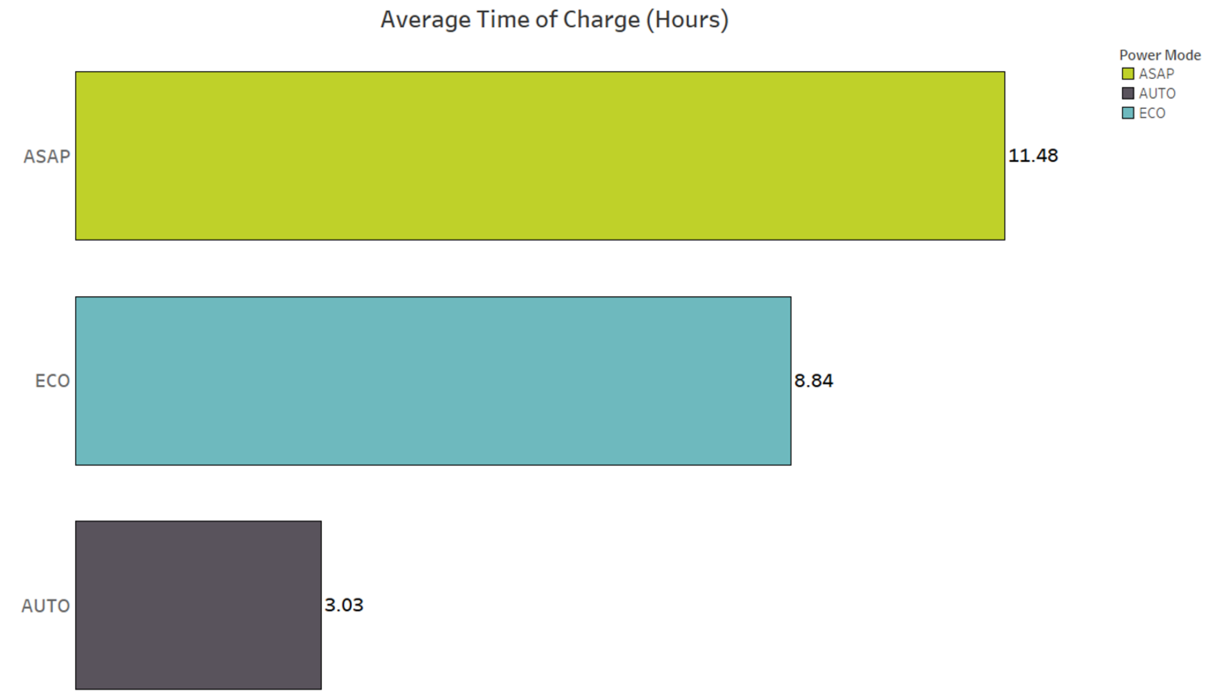


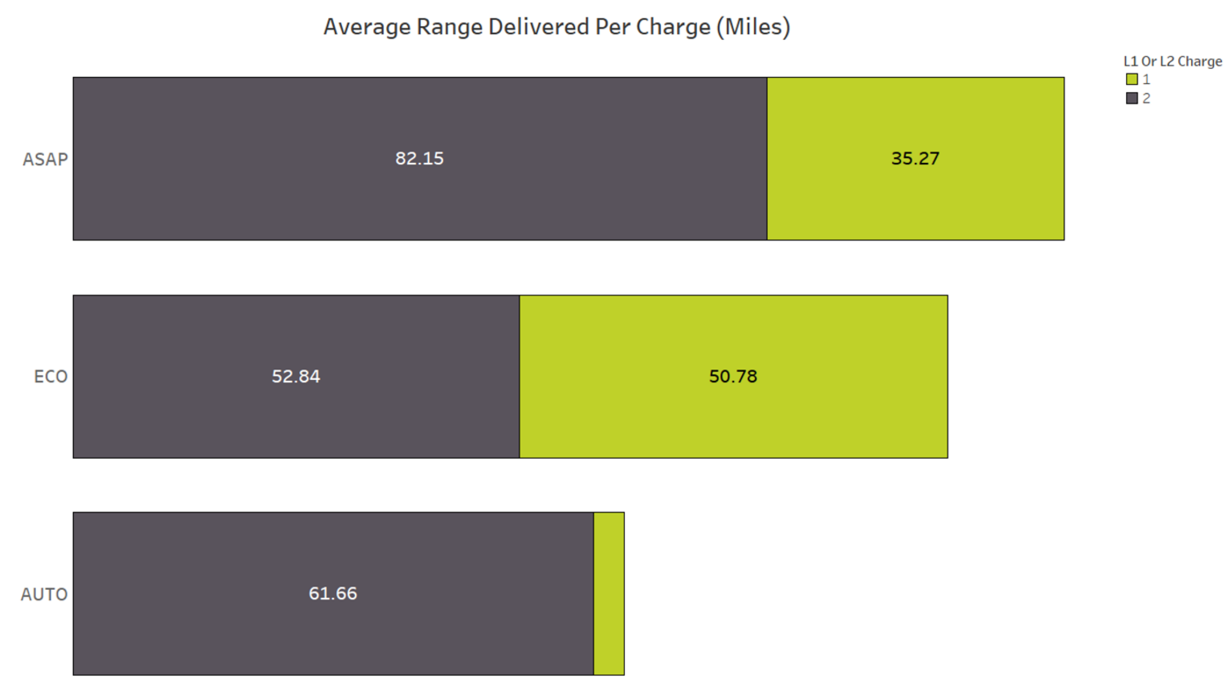
Figure 32: Installer App Gateway Menu

Appendix D: Utilization Data Containing Outliers

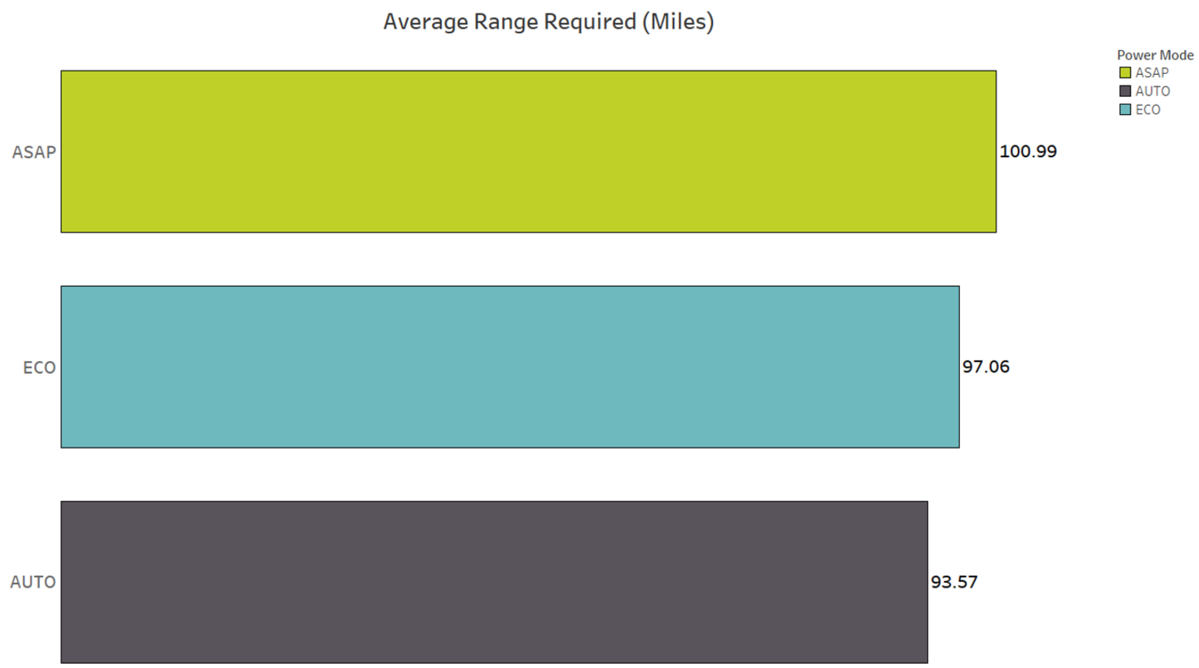
The below graphs utilize the same analysis techniques used in the graphs in the Findings section above, but they contain all 182 sessions logged by the technology provider including the 55 sessions that were skewing the data due to being very short duration.



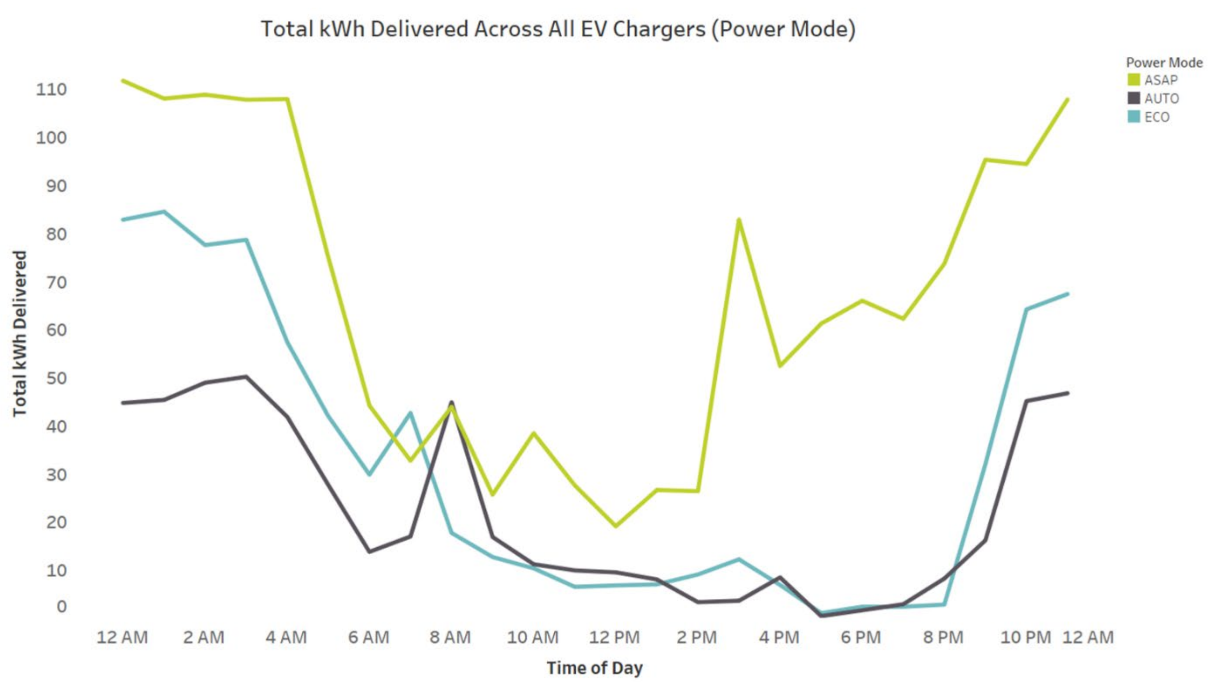
Average of Hour Conversion for each Power Mode. Color shows details about Power Mode. The marks are labeled by average of Hour Conversion.



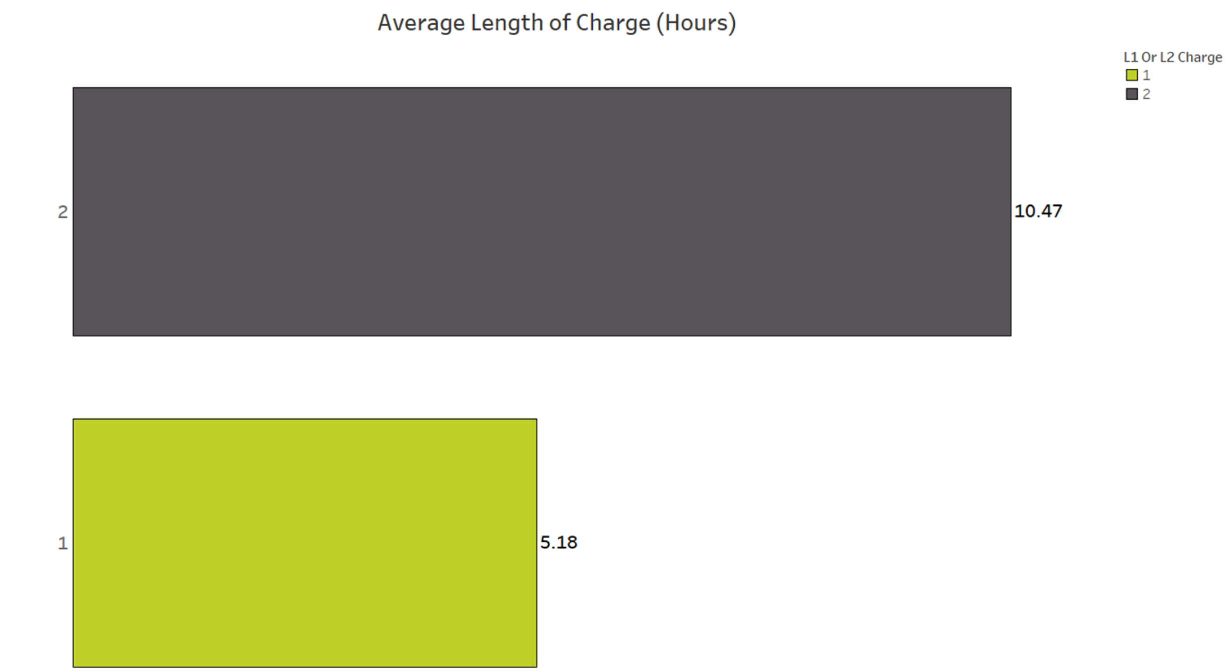
Average of Miles of Range Charged for each Power Mode. Color shows details about L1 Or L2 Charge. The marks are labeled by average of Miles of Range Charged.



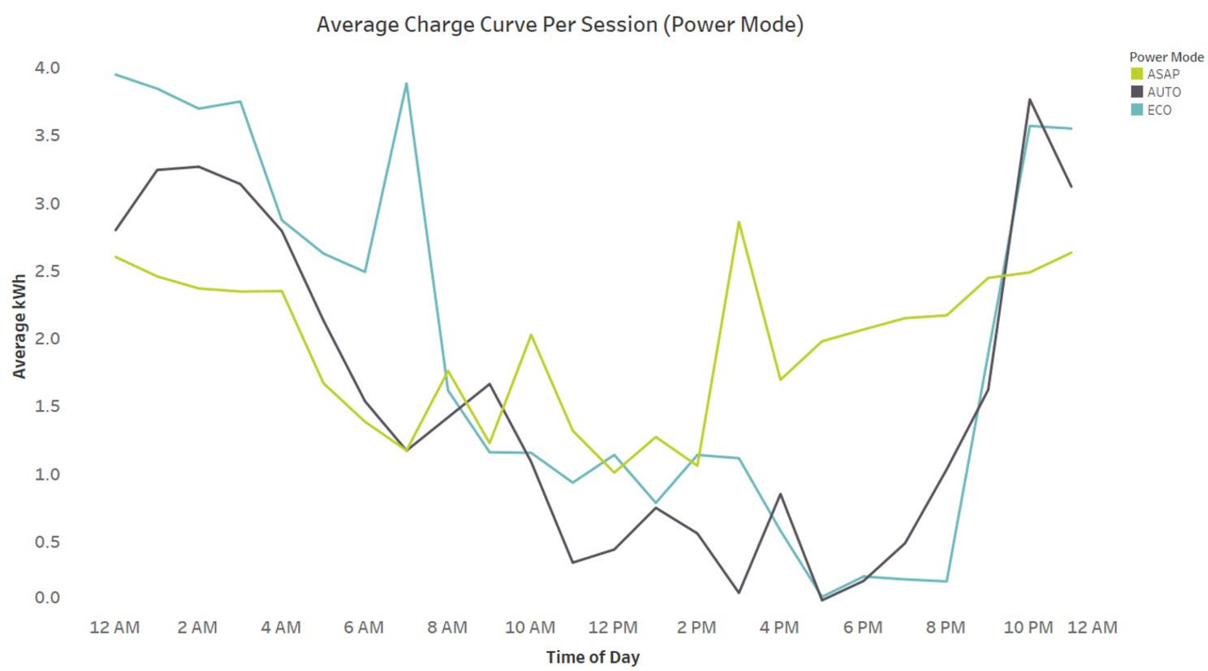
Average of Range Required for each Power Mode. Color shows details about Power Mode. The marks are labeled by average of Range Required.



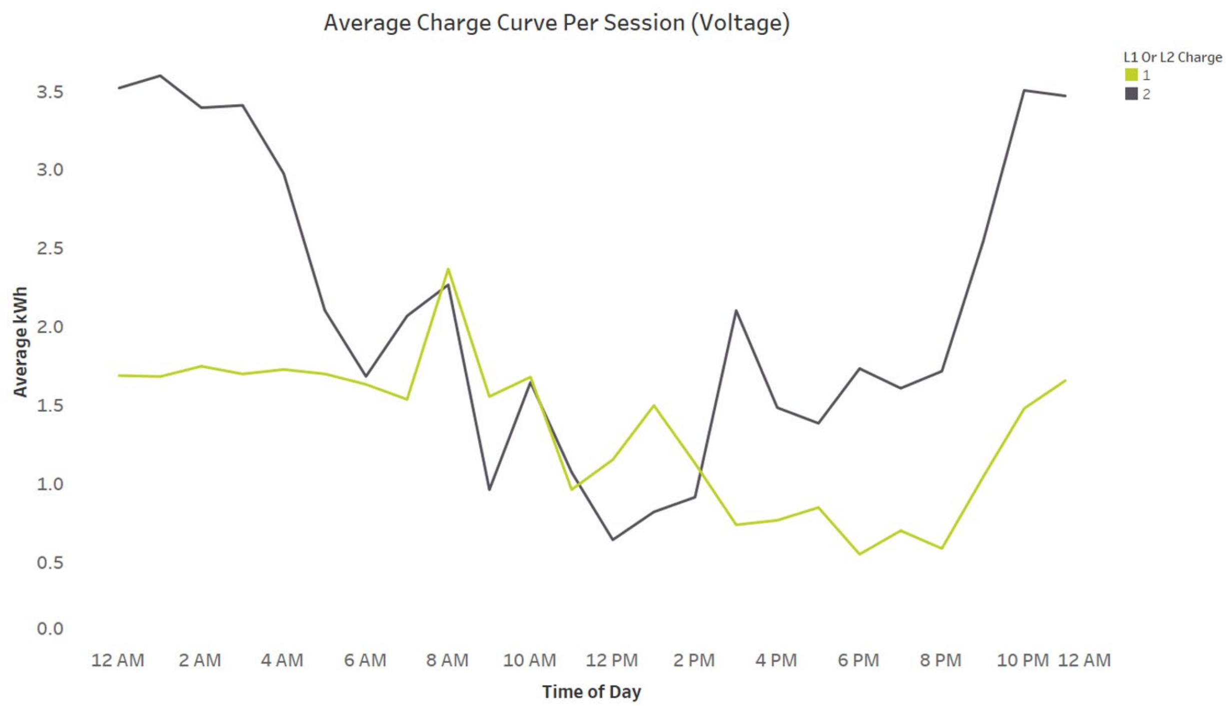
The trend of sum of kwh conversion for Time Axis Hour. Color shows details about Power Mode. The view is filtered on Power Mode, which excludes Null.



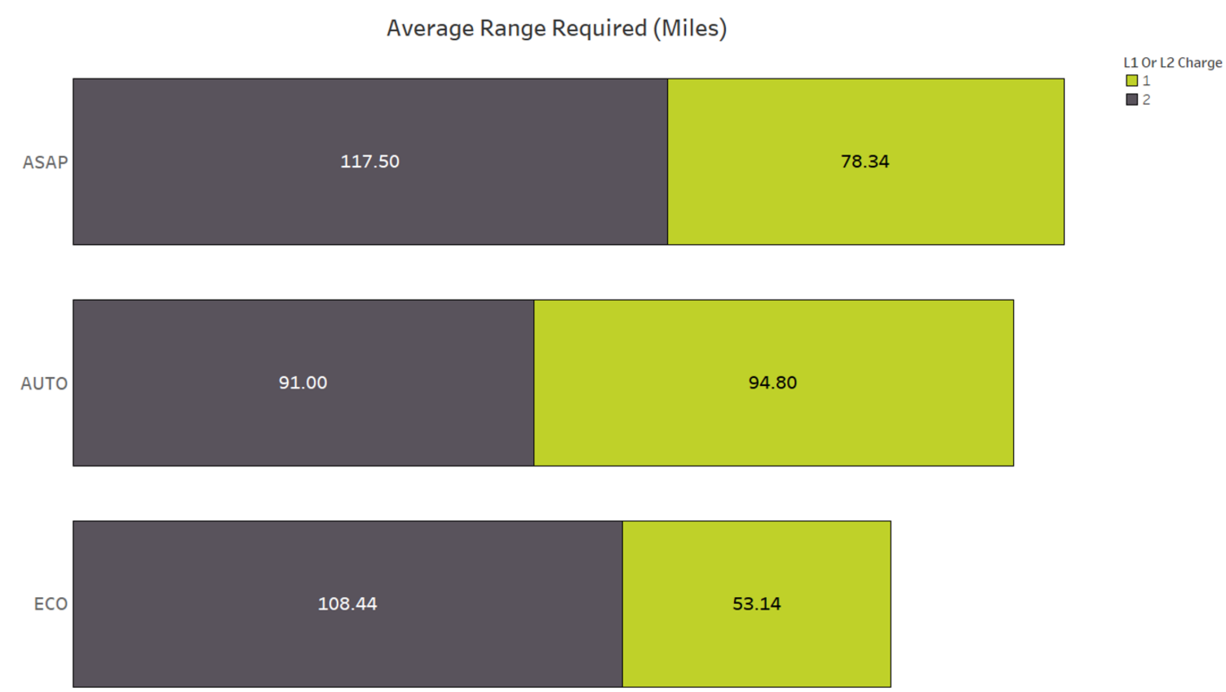
Average of Hour Conversion for each L1 Or L2 Charge. Color shows details about L1 Or L2 Charge. The marks are labeled by average of Hour Conversion.



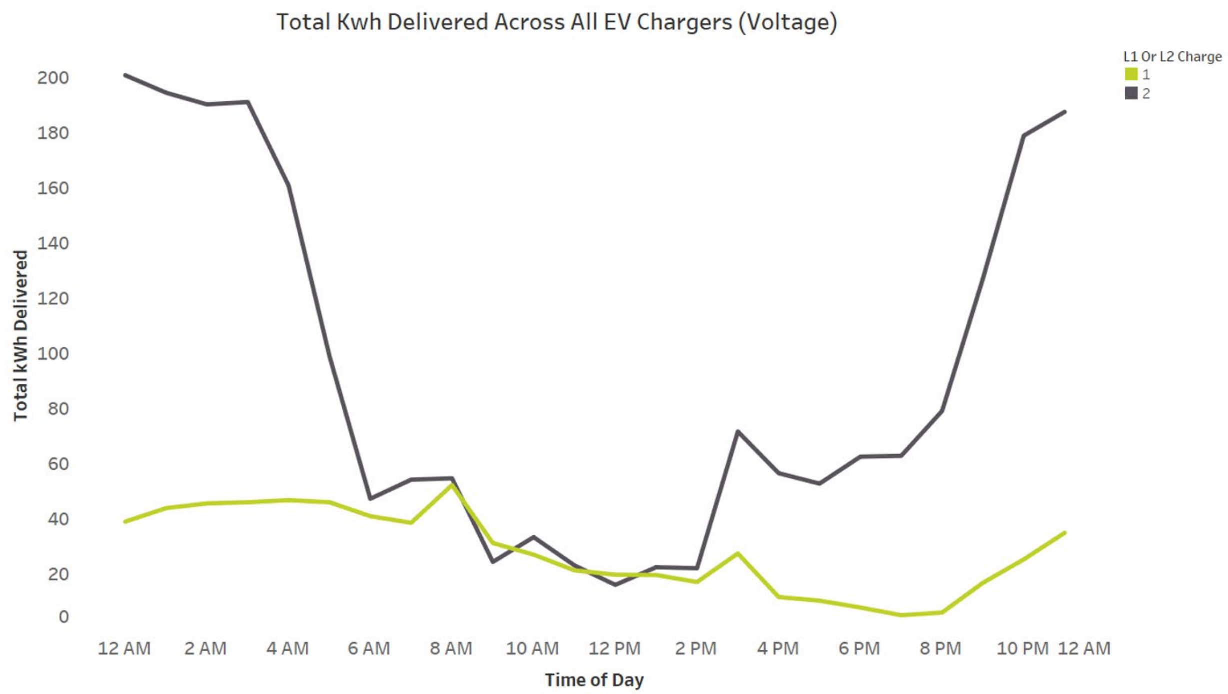
The trend of Average Kwh for Time Axis Hour. Color shows details about Power Mode. The data is filtered on Session Uuid, which excludes Null and bb6d44bc-eea8-49b0-9a48-a622e9678797. The view is filtered on Average Kwh and Exclusions (HOUR(Time Axis),Power Mode). The Average Kwh filter keeps non-Null values only. The Exclusions (HOUR(Time Axis),Power Mode) filter keeps 91 members.



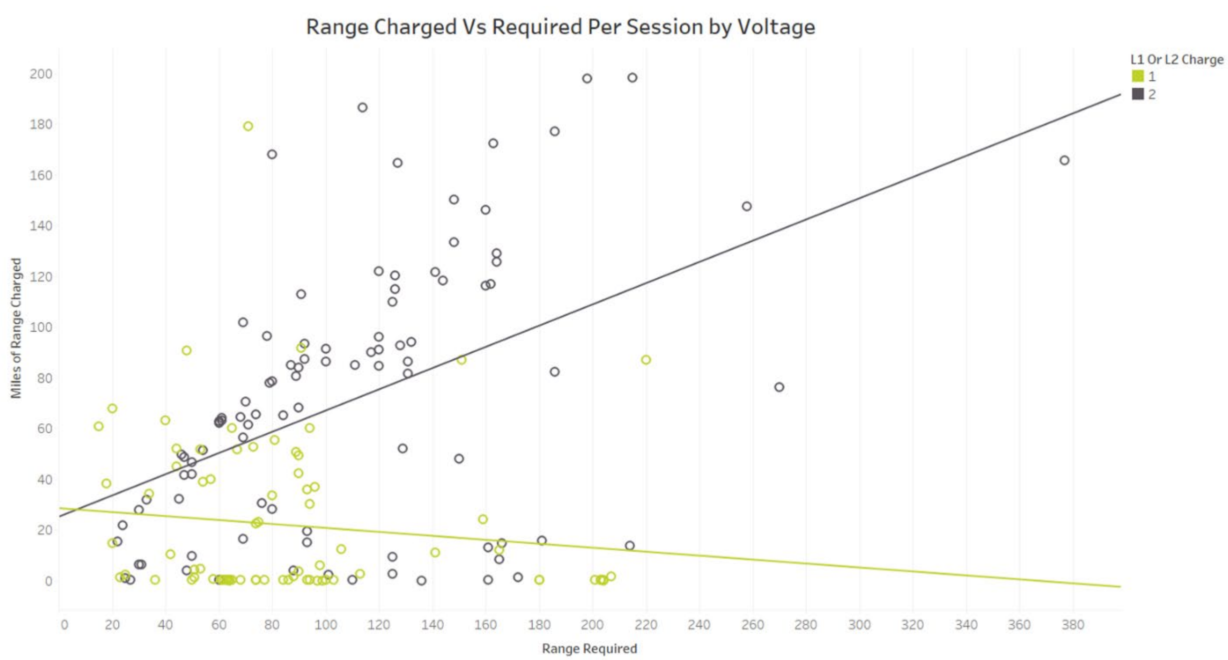
The trend of Average Kwh for Time Axis Hour. Color shows details about L1 Or L2 Charge. The data is filtered on Session Uuid, which excludes Null and bb6d44bc-eea8-49b0-9a48-a622e9678797.



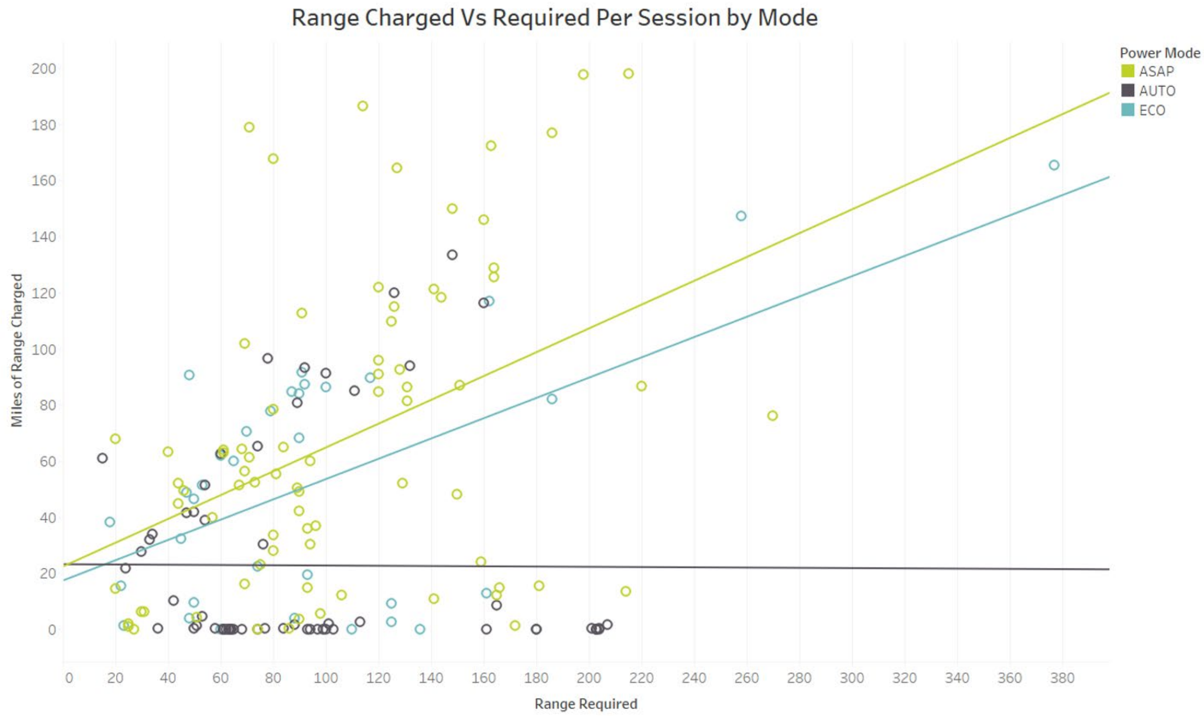
Average of Range Required for each Power Mode. Color shows details about L1 Or L2 Charge. The marks are labeled by average of Range Required.



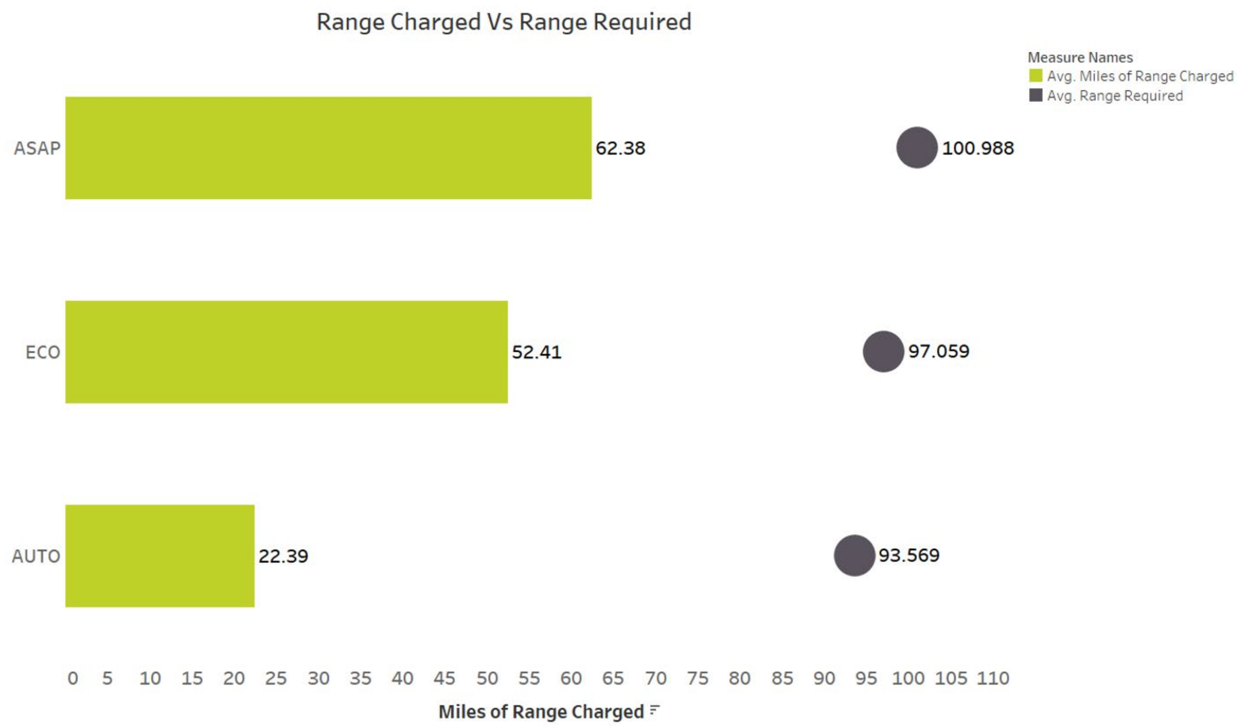
The trend of sum of kwh conversion for Time Axis Hour. Color shows details about L1 Or L2 Charge. The view is filtered on L1 Or L2 Charge, which excludes Null.



Sum of Range Required vs. sum of Miles of Range Charged. Color shows details about L1 Or L2 Charge. Details are shown for Session Uuid. The view is filtered on Session Uuid, which excludes 7 members.



Sum of Range Required vs. sum of Miles of Range Charged. Color shows details about Power Mode. Details are shown for Session Uuid. The view is filtered on Session Uuid, which excludes 7 members.



Avg. Miles of Range Charged and Avg. Range Required for each Power Mode. Color shows details about Avg. Miles of Range Charged and Avg. Range Required. For pane Average of Miles of Range Charged: The marks are labeled by Avg. Miles of Range Charged. For pane Average of Range Required: The marks are labeled by Avg. Range Required.

Appendix E: Site Manager Interviews

Interview #1 with Property Manager of Site 2

Do you drive an EV?

- Not an EV driver, don't know if he will ever be, doesn't have the fascination with it that many people do.
- Have been thinking about EV charging for quite a few years… they know there is a readiness issue that needs to be addressed across properties
- Put in system in Scotts Valley 4 years ago, put one in in Mountain View 1.5 years ago, and recently in Palo Alto
- He thinks a "basket of solutions" is needed; different owners have different needs
- Needs differ because owners have different willingness to invest capital on their own - some want to own & control whole thing, some want to do least capital outlay on their part… they have been looking at different options
- They do fee management (manages 4000 units in Bay Area "Silicon Valley extended"
- Getting more requests from residents, so they are pitching owners on the need to deal with this
- Don't have infrastructure at most buildings to support load that is needed - looking for innovative solutions. This attracted them to the technology provider
- Load management overlay of the evaluated technology and the provider's willingness to make capital investments and bring in a separate meter was big
- Most apartment stock is 50s/60s/70s… electrical infrastructure can't support 100 percent of spots
- They want to eventually add solar on carports & roofs to support charging
- Craigslist - you can filter rentals for EV charging access… a signal for how market is changing

How did you first hear about the evaluated technology provider?

- When they were at early stage, they were looking for contacts, somebody put them in touch
- Likes the ability to have electric ready space and then plug in modules
- Other big problem they see - even if they have the right to move people from one parking space to another it will ruffle feathers - Traditional approach (shared L2):
    - Looking at a shared Level 2 charger depending on parking environment… many older sites have few spaces. Some have a ton of parking where it is easy to carve out space for L2 hoteling… much harder with smaller number of spaces (fewer visitor parking spaces, etc. that impact tenants)
    - Also, from operator standpoint - if they do spaces out in the public, they might have to add additional ADA-enabled spaces… could lead to a net lower number of spaces for the tenants to park in.

Are they solving for next 5 years? 3 years? 10 years?

- Depends on the site, impacts whether shared L2 makes sense. Ideally would like to be able to electrify every space and every site… no need for hoteling (surcharges create dissatisfaction, people are waiting, no fun)

How has Level 1 charging been for your property?

- Still waiting for go-live… their model was appealing because it had both L1 and L2 and user can indicate how much charge they need.
- May have a case down the road where both people side by side want L2… will have to work through that matrix later… the technology provider could always develop a new device later that just gets plugged in to their charging bases.
- Future proofing was very appealing… in other properties they're looking at prewiring with larger gauge wire.

Any concerns about the evaluated technology provider?

- Their solutions isn't appealing to some owners - their model has ongoing fee. Owner has to balance spending capital and owning outright vs. preserving capital to pay in pieces going forward
- From an investment standpoint buildings are valued based on Net Operating Income… ongoing cost reduces that NOI… they believe they will be able to offset payments to the technology provider by charging tenants slightly more via rent for electric-ready sites… aiming for being revenue neutral
- One of the solutions in Mountain View did hoteling concept… had a ton of surface parking and that client wanted to own the charger
- Appeal of the approach depends on both the building (amount of available parking) and personal preferences of owner… need to look at each unique site and what those dynamics are like
- Part of process is doing a load study and results might scuttle some options

How willing are property owners to upgrade electrical infrastructure?

- Very little appetite to do that
- Ex: how many people will replace roof before it needs to be replaced
- It isn't just the hardware… sometime if you are modifying things like that you need to tear up drywall, huge inconvenience to tenants, etc.… same issues with replumbing buildings
- Encouraged about adding solar PV to buildings to supplement - innovation coming in that space (thin film panels, Tesla roof, etc.)
- Solar is currently standalone with export to grid, as Net Energy Metering changes they will look at batteries

How are you thinking about success?

- Tenant response - are they happy, does it deliver what they promise to deliver?
- They need solutions in place to be able to convince other owners

- Other solutions - (Scotts Valley, they can make it public or private… slow adoption at first but usage has climbed over the last two years… hoteling approach… electrifying all spaces was too big a leap early on but may revisit that in the future); in Mountain View did another approach with Marin-based company… trenching vs. overhead vs. whatever also guides solution identification… they have L1 charging at Mountain View (and they are being used)

Interview #2 with the Property Manager of Site 1

When did you first decide to consider a project like this?

- As a businessman knows, there have been great strides with these types of vehicles and there will be more; at multifamily properties (he manages several) residents don't have EV cars for many reasons, but one is they don't have the ability to have a convenient and satisfying charging experience
- Considering all cars will be EVs (he seems skeptical) it will be part of the market (and environmentally good)
- Knows few Multi-family properties are involved with this
- Was asked to help out by way of a good friend of his in personal life - asked him to speak to the evaluated technology provider's founder. Thought it was worth the inquiry and he could add value as a test facility

Have you looked at any other solutions?

- Had talked to several other EV charging companies… wasn't really too impressed with what they were saying and what their costs were… had been working on this for 1-1.5 years

What was the primary differentiator of the evaluated technology?

- #1 - had homes/intentions/wishes/capabilities to bring charging station to every single parking space within property… that was so much better than all the other providers who were interested in putting in 2-4 on the property and it would be like a carwash area… concerns over constant rotation of vehicles where residents would have to keep an eye on the space and manage that
- Had a way of bringing a charging station to everyone's parking spot
- Intuited this would be a problem and that other solutions would be inadequate
- Not interested in monitoring the solution, doesn't want a signup sheet or anything like that… too busy as it is, didn't need those headaches
- Doesn't believe other solutions are as convenient

Any concerns with the solution/experience?

- Concerns with lithium batteries and how they can catch fire… but those happen more so on fast charging equipment rather than slow charging equipment
- They have podium parking (building is on top of parking) … right now there is almost no chance of a fire down there but one day when there are 75 vehicles down there…
- He is always willing to explore any new technology

Is there potential to expand?

- Success of this program would determine whether he does other properties
- Success depends on resident's experience in using the program... also there are costs associated. He is used to revenue sharing situations (e.g. someone needs property to implement an idea, they charge the residents and the property manager gets a cut of revenue) but in this case he is paying for these spaces and doesn't have users for them... one of the other differentiators was in promoting EV cars through educational or promotional process to get more people to use/consider EV cars... they will initially have 20 parking spots but currently only 1-2 EV cars on the property. Through the promotions and encouragement of people they hope to bring another 18 EV cars to the property where they can use spots and pay small fee to property manager... otherwise if years go by and folks do not occupy those spots then he will be paying for something that isn't used - far from revenue sharing. Willing to do that for a few years in the interest of the overall success of the project. Even through education and promotion you may not be able to influence people to make a major capital purchase... will be very interesting what participation rates they see within the next 12 months. If they could get 20 EV cars in there to use spaces within 12 months that is an A... now he is in the business of trying to convince 24 percent of his property to buy a new vehicle

Where do you think you could achieve a marketing edge?

- They are going to start promoting these EV capabilities and will hopefully attract a higher grade of resident that will hopefully stay with them longer.
- This is all exploratory

Do you have any feedback for the technology provider?

- He is primary contact person (doesn't want to bog down other staff with this), is very impressed with what they have done, the provider's founder is a very good, smart guy, working at his best possible pace considering his own obstructions (personnel, capital) ... has been a very pleasurable experience, has enjoyed it. Pleased with how they have delivered on their word to this point. Nothing would thrill him more than to see the technology provider be successful.

Have you received any tenant feedback?

- Nothing yet, a little too early for them to be involved. They did take a survey about a year ago and John summarized results - there was an interest in EVs, to learn more, to be open minded

Why Site 1?

- It has underground parking - not exposed to weather. Most other properties there is tucked under parking or parking lots or street parking; this is kind of half inside/half outside - better test facility