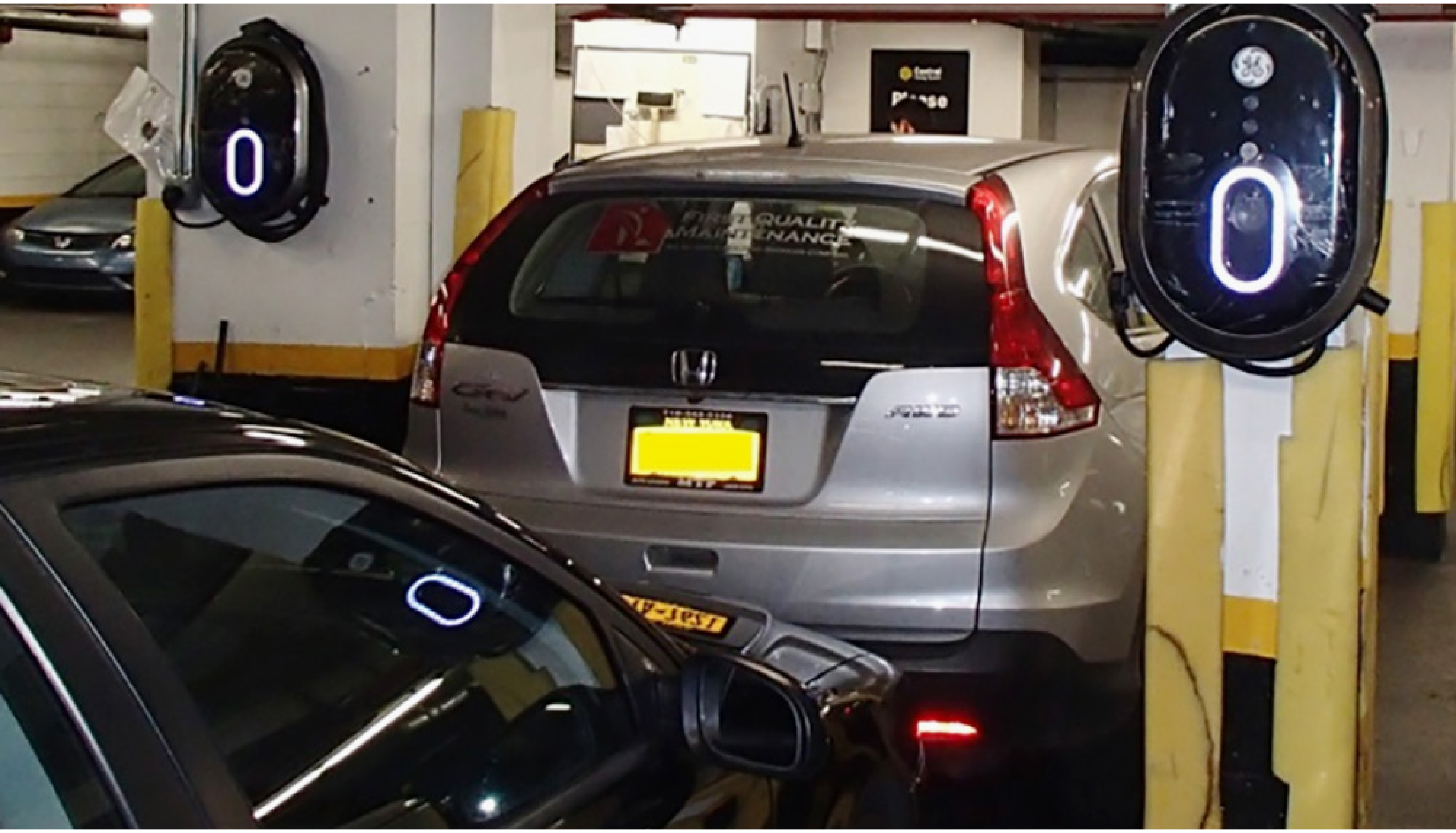
Strategies and Techniques for Reducing the Installation and Operating Costs of EVSE



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Strategies and Techniques for Reducing the Installation and Operating Costs of EVSE

Final Report

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Notice

Abstract

Available plug-in electric vehicle (EV) charging technologies and strategy options were developed to be lower-cost options for "long-dwell" or "long duration" public/shared parking venues to decrease the cost barrier to increased EV charging infrastructure. (EV includes battery-electric and plug-in hybrid-electric vehicles.) Long-dwell is defined here as six or more hours per day per parking event. Long-dwell public/shared parking venues include (but are not limited to): long-term airport parking, multifamily dwellings (e.g., condominiums and apartments), park-and-ride commuter parking, transit (e.g., bus and train), workplaces, and hotels. (Shorter duration parking and higher rate charging are not included.) The lower cost and/or lower power charging technology and strategy options described provide options for facility operators to install more cost-effective EV charging to meet parking users' charging needs for both new installed and upgraded and expanded existing EV charging installations. A companion technical primer document summarizing this detailed report was developed to quickly educate long-dwell parking operators on the technologies, options, and process to narrow in on a solution(s) that could work for their facilities.

Keywords

Long-dwell EV charging, long dwell EV charging, low-cost EV charging, low cost EV charging, low power EV charging, EV charging demand management, EV charging optimization, EV charging infrastructure expansion

Acknowledgments

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Acronyms and Abbreviations

A	amp
AC	alternating current
BEV	battery-electric vehicle
DC	direct current
EV	plug-in electric vehicle
EVSE	Electric Vehicle Supply Equipment
GFCI	ground fault current interrupter
kW	kilowatts
kWh	kilowatt-hour
NYC	New York City
PHEV	plug-in hybrid electric vehicles
VAC	volts-alternating current

Summary

The plug-in electric vehicle (EV) charging technologies and strategy options described were developed to be lower-cost options for “long-dwell” or “long duration” public/shared parking venues to decrease the cost barrier to increased EV charging infrastructure. (EV includes battery-electric and plug-in hybrid-electric vehicles.) Long-dwell is defined here as six or more hours per day per parking event. Long-dwell public/shared parking venues include (but are not limited to): long-term airport parking, multifamily dwellings (e.g., condominiums and apartments), park-and-ride commuter parking, transit (e.g., bus and train), workplaces, and hotels. (Shorter duration parking and higher rate charging are not included.) The lower cost and/or lower power charging technology and strategy options described provide options for facility operators to install more cost-effective EV charging to meet parking users’ charging needs for both new installed and upgraded and expanded existing EV charging installations. A companion technical primer document summarizing this detailed report was developed to quickly educate long-dwell parking operators on the technologies, options, and process to narrow in on a solution(s) that could work for their facilities.

S.1 Electric Vehicle Charging Technology Options

S.1.1 Electric Vehicle Supply Equipment Options

A range of Electric Vehicle Supply Equipment (EVSE; i.e., charging station) technology options are available for long-dwell parking. All use the SAE International J1772 standard vehicle charging connector. The lowest cost option is an alternating current (AC) Level 1 outlet that the EV connects to the outlet using the AC Level 1 EVSE cordset that comes with the vehicle. A rugged commercial 120 volts-alternating current (VAC) ground fault current interrupter (GFCI) outlet on a dedicated 15-amp (A) circuit is used. They provide up to 1.4 kilowatts (kW) of power and provide approximately 5.0 miles of driving range per hour of charging (approximately 30 miles in a six-hour charge).

An AC Level 1 EVSE has more functionality and convenience, for a somewhat higher cost. They are powered by 120VAC a 20 A circuit and provide up to 1.9 kW. They provide approximately 7.0 miles of driving range per hour (approximately 42 miles in a six-hour charge).

Low power AC Level 2 EVSE are standard AC Level 2 EVSE powered by 240VAC on a 20 A circuit (lower than the maximum allowable) and provide up to 3.3 kW. They provide approximately 10-12 miles of driving range per hour (approximately 60-72 miles in a six-hour charge).

A typical AC Level 2 EVSE uses 240VAC or 208VAC input power on a 40 A circuit to provide up to 6.6 kW. They provide approximately 20-25 miles of range per hour of charging (approximately 120-150 miles in a six-hour charge).

EVSE costs vary based on the power level, features, and whether the stations are networked. Charging infrastructure installation costs vary widely by location depending on the site configuration. Various factors influence installation costs (wire run length, obstacles to routing wires, trenching length, pavement/concrete repair, etc.), as well as any needed utility infrastructure upgrades. Installation costs often exceed the charging station hardware costs. Because of this, the total installed costs are difficult to accurately estimate, so the costs shown in Table S-1 are representative range examples to guide the charging infrastructure design development.

Table S-1. EV Charging Infrastructure Specifications, Performance, and Cost Characteristics

Type	Charging Infrastructure Cost	Installation Cost	Input Power	Maximum Output Power (kW)	Maximum Driving Miles per Hour Charge	Maximum Driving Miles per Six Hour Charge
AC Level 1 Outlet	$100	$100-$1,000	120VAC, 15-20 A	1.4	5	30
AC Level 1 EVSE	$300-$1,500	$300-$5,000	120VAC, 20 A	1.9	7	42
AC Level 2 EVSE (low power)	$300-$1,500	$500-$8,000	240VAC, 20 A	3.3	10-12	60-72
AC Level 2 EVSE	$400-$6,500	$1,000-$10,000	240VAC or 208VAC, 40 A	6.6	20-25	120-150

S.1.2 EVSE Power Management Options

Simple power sharing dual-port AC Level 2 charging stations are powered by the same input power as a standard single charging station. These charging station share the power between the two connected vehicles based on need. When one vehicle is connected, the charging station functions as a standard charging station. When two vehicles are connected, internal hardware shares the available power between the two vehicles based on need. The hardware costs are somewhat (~25-30%) higher than two standalone EVSE, but the electrical infrastructure costs and system demand charges will be lower.

Automated power management systems actively control/manage the power among multiple charging stations at a facility to minimize the system-level electrical demand and cost impacts by optimizing charging times and rates. Some systems communicate with the grid and incorporate pricing signals in the management algorithms. System costs (initial and monthly) can be high but can still be a cost-effective solution for long-dwell parking situations where the AC Level 2 charging is needed; however, there is limited available electrical service capacity or minimizing demand charges is critical.

S.2 New York State Long-Dwell EVSE Utilization

Each EV charging venue type has unique operating circumstances. So lower cost charging installation and operations solutions should be evaluated on a per-site basis.

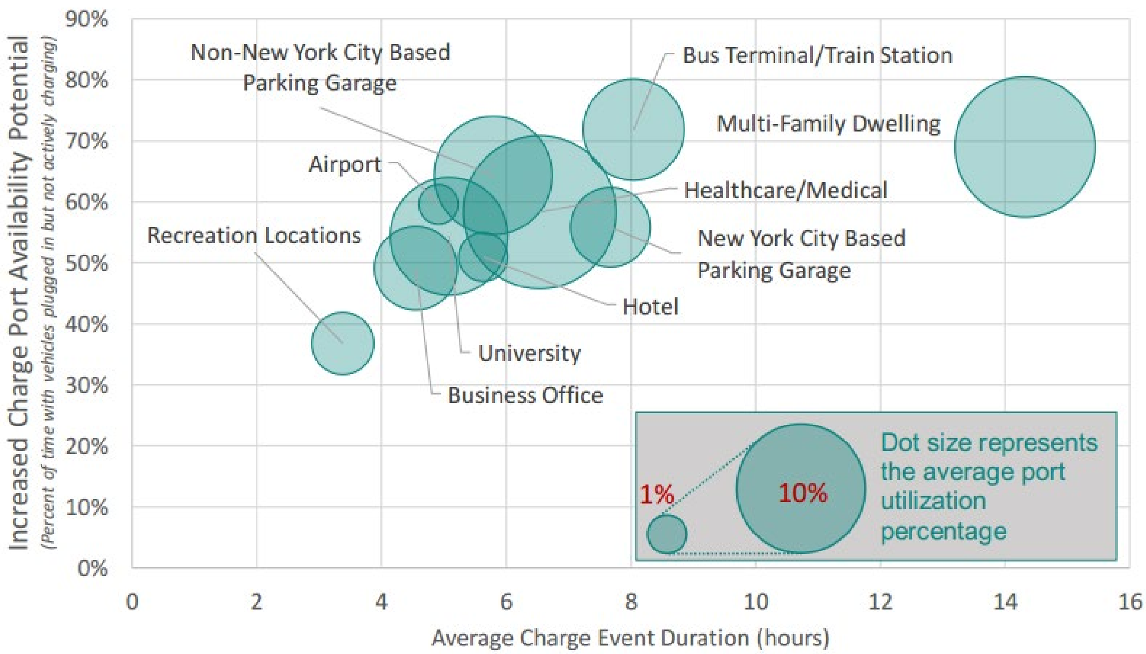
New York State long-dwell parking venue electric vehicle supply infrastructure (EVSE; i.e., a charging station) utilization data were analyzed by Idaho National Laboratory and Energetics to determine the usage characteristics of each type and to identify technology and strategy options to reduce installation and operations costs for new installations and for expanding and upgrading existing installations. Some long-dwell EV parking venues showed better potential to implement hardware or management strategies. All options should be evaluated on a per-site basis to incorporate site-specific details.

Figure S-1 shows several EV charging characteristics for each venue type, including: 1) the average charge event duration (total time connected to a charging station) (x-axis), 2) the potential for increased station utilization from shared station use (related to the percentage of time EVs were connected to charging stations, but not drawing power) (y-axis), and 3) the average charging station utilization (larger dots indicate longer average connection times).

Multifamily dwellings (also referred to as multi-unit dwellings) charging stations have regularly occurring long duration events where charging stations are occupied much longer than necessary for charging the connected vehicles. The results showed that multifamily dwellings have high potential for implementing charging stations management and/or hardware strategies to lower the installation and operations costs for new installations. The results also indicated that options exist to maximize the current charging infrastructure usage to avoid/delay investment in additional stations.

Transit stations also have regularly occurring long duration events where charging stations are occupied much longer than necessary for charging connected vehicles. These two venues typically serve the same group of PEV drivers daily, while the PEVs are parked for a period of eight hours or more for an entire workday (transit) and overnight (multifamily dwellings). Consistent and long charge events were also typical at workplace charging stations (e.g., business offices, healthcare, and universities).

Figure S-1. Long-Dwell EV Charging Station Usage Characterization



Prime candidates for implementing lower cost management or lower power hardware strategies have a long average charge event duration (right), high potential for increased charge port availability (top), and higher utilization (large dots).

Charging station use in multiuse parking garages and lots were analyzed in and around New York City. These locations have varied use, including short- and long-dwell parking and charging event characteristics. The analysis showed potential for some of the low-cost charging technologies and approaches, but their use will be location specific and require additional data analysis to develop an appropriate solution.

Other long-dwell PEV parking venues including airports, hotels, and recreational locations, had very limited charging station usage data. This, and the fact these stations experienced a wide range of charging event durations, meant that strong conclusions could not be made. PEVs at hotels are likely coming from farther away, so a longer, higher power charge event is often needed. The changing PEV population make the developed approaches not an ideal fit for hotels. Unfortunately, the charging station usage data at New York State airports was limited. Some of the airport EVSE that were studied were installed in short-term parking lots (not a long-dwell parking type). These charging stations and the long-dwell charging events could not be separated out. This impacted the accuracy of the airport parking charging data analysis results.

Factors dictating long-dwell, low-cost charging strategies were calculated for each long-dwell PEV parking venue type using usage data from NYSERDA supported EVSE in 2016. Table S-2 presents the results.

Table S-2. Long-Dwell Parking Venue EV Charging Characteristics

	Multi-Family Dwelling	Bus Terminal/ Train Station	Healthcare/ Medical	University	Business Office	Parking Facilities Outside of NYC	NYC Parking Garages and Lots	Airport	Hotel	Recreation Locations
Charging Port Utilization (%)	11.9	6.2	14.0	8.4	4.2	8.4	3.9	1.0	1.5	2.4
Potential for Shared Station Use	69%	72%	58%	54%	49%	64%	55%	59%	51%	36%
Energy Dispensed per Charge Event	17.1	8.7	9.6	7.4	7.5	6.6	17.1	6.7	12.1	8.0
PEV Movability Potential	Low	Low	Med	High	High	Med	Med	Low	Med	Med
Average Charge Event Duration	14.3	8.0	6.5	5.1	4.6	5.8	7.7	4.9	5.6	3.4
Time-of-Day Variability (standard deviation)	3.5	2.5	8.6	19	8.3	12.6	4.4	N/A	N/A	N/A
AC Level 1 Cordset (1.4 kW) Potential	42%	55%	48%	31%	31%	30%	19%	24%	21%	13%
AC Level 1 EVSE (1.9 kW) Potential	58%	64%	62%	47%	49%	45%	29%	65%	30%	24%
AC Level 2 EVSE (3.3 kW) Potential	83%	76%	80%	83%	81%	81%	57%	87%	57%	73%

S.4 Strategies for Installing New Long-Dwell EV Charging Stations

The proposed installation strategies for new charging station installations identified in this project are summarized to outline the equipment required and to describe how each option could be implemented.

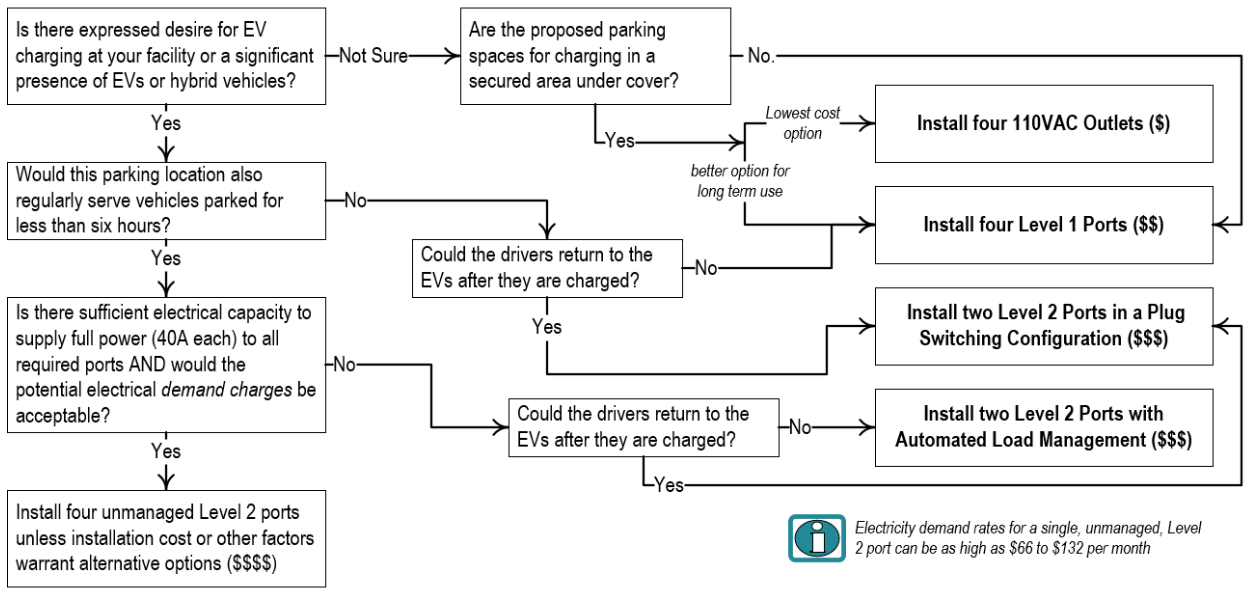
AC Level 1 Charging Stations. Lower power (and cost) EVSE can provide sufficient energy to EVs for most long-dwell charging events. Use of AC Level 1 EVSE limits the peak power and maximum sustained power draw which reduces electrical infrastructure installation. The largest potential savings from using this approach is from avoiding/delaying electrical service upgrades and reducing demand charges.

AC Level 2 Plug Sharing. Configuring EV parking spots to enable a single charging station to serve multiple vehicles throughout the day is a cost-effective solution. The station must be installed so the charging cord is accessible to multiple parking spaces, so it can be moved from one EV to another during the day without moving vehicles. Users must return to the vehicles during the day for this strategy to work, which may not be feasible in every setting.

AC Level 2 Power Management. Installing either power sharing dual-port AC Level 2 charging stations or an automated power management system can be a cost-effective strategy for long-dwell parking situations where the AC Level 2 charging is needed, but there is limited available electrical service capacity and/or minimizing demand charges is critical.

A simple long-dwell parking EV infrastructure decision flowchart tool (Figure S-2) was developed for host sites to use to help identify the appropriate installation strategy. The decision tool assumes the majority of EVs are plugged in for six hours or more, four vehicles will be charged during the same period, and the comparison baseline is 6.6 kW AC Level 2 charging stations. The baseline requires two dual-port EVSE to charge four EVs in the same period.

Figure S-2. Decision Tool Strategies and Techniques for Reducing the Installation and Operating Costs of EVSE for New Installations



S.5 Strategies to Expand Existing Charging Station Installations

Many existing charging station locations have installed dual-port AC Level 2 EV charging stations as they initially deployed EVSE and gauge interest. As EV adoption increases and there is more demand for charging stations, site owners with existing infrastructure will need to explore their options for adding charging stations or optimizing the use of existing charging stations. Installing additional AC Level 2 charging stations can be costly, particularly if upgraded electrical equipment and service is needed to provide sufficient power.

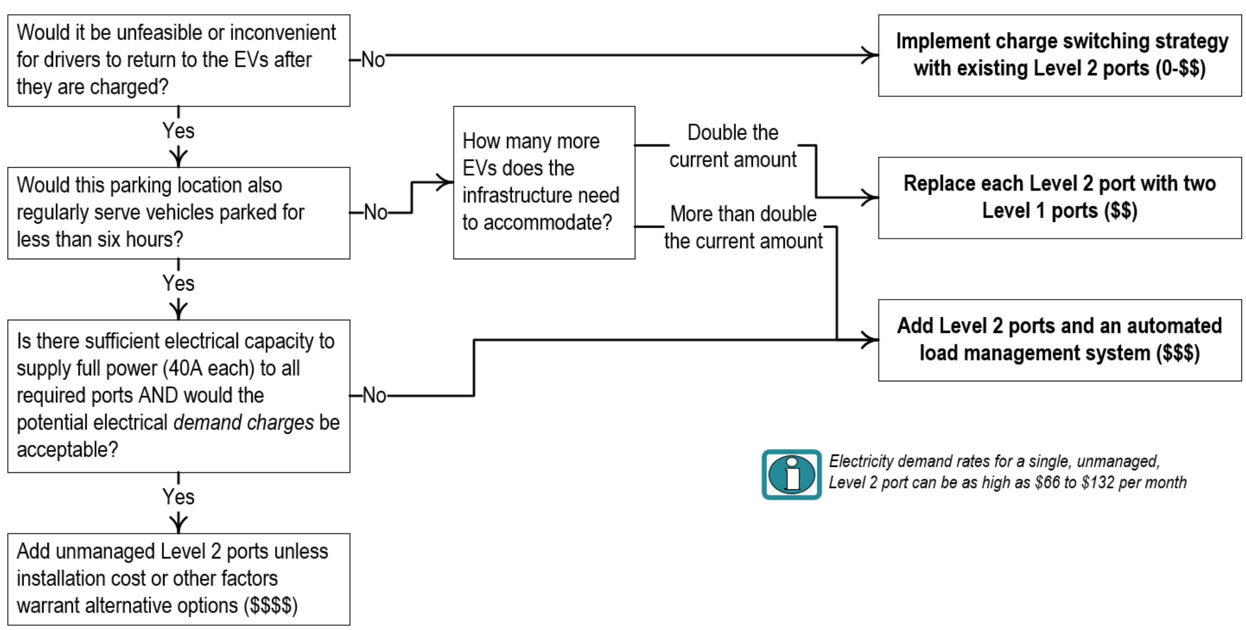
Replace AC Level 2 Charging Station with Multiple AC Level 1 Charging. Use of AC Level 1 EVSE limits the peak power and maximum sustained power draw, which reduces the electrical infrastructure installation cost. Two AC Level 1 charging ports can typically be powered using the same conduit and circuit as one existing AC Level 2 port EVSE with only minor changes. This change would double the number of EVs that can charge at one time. The peak and average charging power will be lower, but still sufficient for long-dwell parking locations. This approach would require replacing the existing AC Level 2 station and purchasing new AC Level 1 EVSE.

Implement AC Level 2 Charging Station Plug Sharing. If the existing station's charging cords can reach additional adjacent parking spaces, the EVSE's use can be shared among multiple vehicles without any charging equipment investment or EV drivers moving vehicles. Users must return to vehicles during the day for this strategy to work, which may not be feasible in every parking application. Charging station use policy solutions (e.g., for workplaces or multifamily dwellings) such as limited charging times, reserved nearby EV charging "staging" spaces to move vehicles to/from, and communications strategies (e.g., calendar applications and social media pages) have been proven to be effective.

Add AC Level 2 Charging Station Power Management – Installing either power sharing dual-port AC Level 2 charging stations or an automated power management system can be a cost-effective strategy for long-dwell parking situations where the AC Level 2 charging is needed, but there is limited available electrical service capacity and/or minimizing demand charges is critical.

A simple long-dwell parking EV infrastructure decision flowchart tool (Figure S-3) was developed for host sites to identify the best strategy to expand the number of charging ports at sites with an existing stations. The decision tool's structure assumes EVs are plugged in for six hours or more and the existing station is a dual-port AC Level 2 charging station.

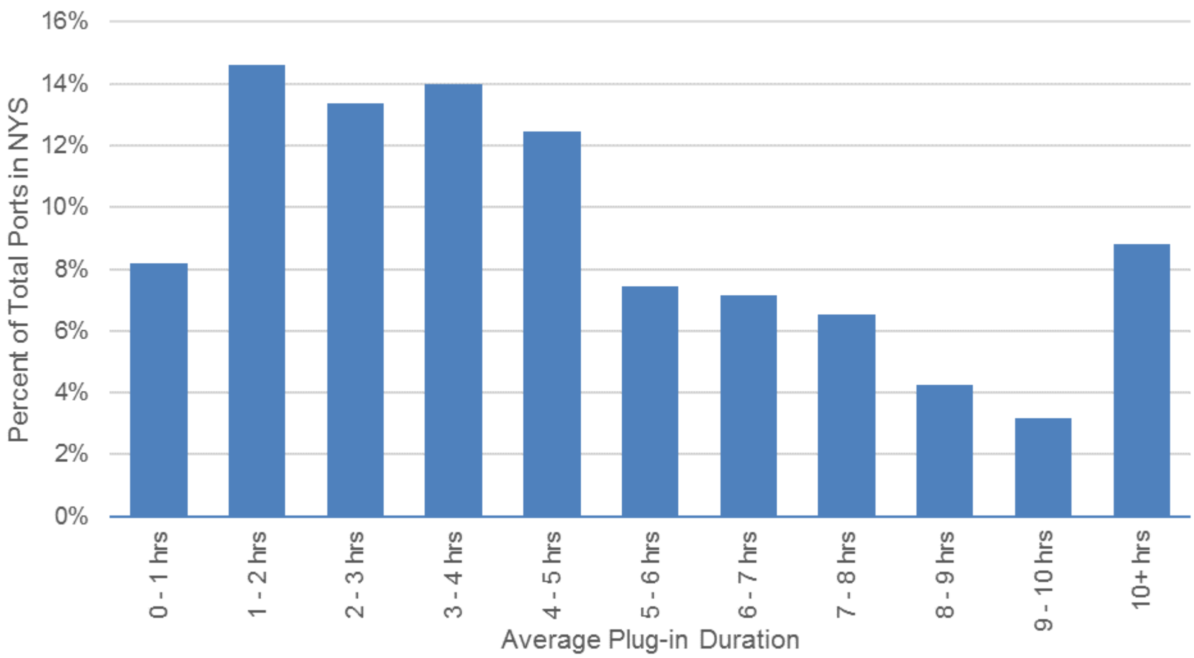
Figure S-3. Decision Tool Strategies and Techniques for Reducing the Installation and Operating Costs of EVSE for Expanding Existing Installations



S.6 Potential Impacts of Low-Cost EVSE Strategies

There are currently more than 1,500 publicly-accessible AC Level 2 EV charging ports available throughout the State. EVSE usage data analysis revealed that approximately 33% of the charging ports have an average connection time duration of six or more hours per charge event (Figure S-4). Therefore, approximately 500 currently installed EVSE (33% of the current EVSE population) could have utilized one of the low-cost charging strategies evaluated in this study when originally installed or could be used to expand charging port availability. Using the strategies described in this project, the amount of EV charging provided at these long-dwell locations could be increased with minimal cost.

Figure S-4. New York State EV Charging Port Average Plug-in Duration



As can be expected, no single low-cost solution is appropriate for all long-dwell situations. Each parking venue must be evaluated to determine a suitable strategy to determine optimized installation with the lowest installation and operational costs. The outlined strategies can fulfill most long-dwell charging requirements at several common long-dwell parking venues where charging stations are typically installed. Parking venues that mostly serve long duration parking/EV charging customers, may also serve short duration parking/EV charging customers. These short-term parking customers may require higher power stations, so EV charging site hosts cannot fully take advantage of the low-cost charging solutions if the site host wants to meet these needs. Costs can still be reduced by following installation best practices and lower cost stations.

1 Long-Dwell Electric Vehicle Charging Technologies and Strategies

1.1 Long-Dwell EV Charging Requirements

The plug-in electric vehicle (EV) charging technologies and strategies discussed in this report are targeted at "long-dwell" or "long-duration" parking venues where vehicles are parked for six or more hours per day. These charging technologies and strategies can meet vehicles' charging needs using less expensive and lower power options. Long-duration parking venues include, but are not limited to, long-term airport parking, multifamily dwelling units (e.g., condominiums and apartments) (also referred to as multi-unit dwellings), park-and-ride commuter parking, transit (e.g., bus and train) commuter parking, workplaces, and hotels. EVs include both battery-electric vehicles (BEV; e.g., Nissan Leaf and Chevrolet Bolt) and plug-in hybrid electric vehicles (PHEV; e.g., Toyota Prius Prime and Ford Fusion Energi).

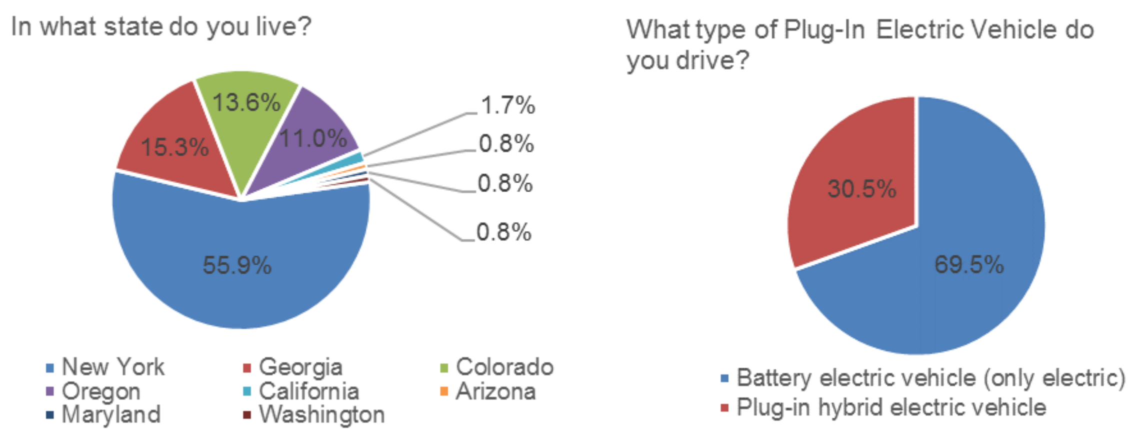
Property owners and site managers with long-dwell parking interested in installing EV charging infrastructure, but are unable to invest in extensive, high-power charging infrastructure, need low-cost solutions. Low-cost, long-dwell EV charging solutions are also applicable for facilities with existing charging infrastructure that needs to be expanded or optimized to serve more EV drivers while minimizing additional installation costs. Many of the low-cost solutions discussed allow for a scalable system that provides a low-cost entry level technology that can be expanded as EV charging demand expands.

A web-based survey was conducted to identify EV driver needs and willingness to modify their charging practices for various long-dwell charging strategies and practices. The survey was distributed in New York State and throughout the U.S. by the organizations listed as follows.

- Plug-In America
- Clean Communities of Central New York
- Electrification Coalition
- Sustainable Hudson Valley
- Forth Mobility
- Massachusetts Clean Cities Coalition
- Electric Drive Transpiration Association
- Center for Sustainable Energy
- Capital District Clean Communities Coalition
- Clean Cities-Georgia
- Central New York Regional Planning and Development Board

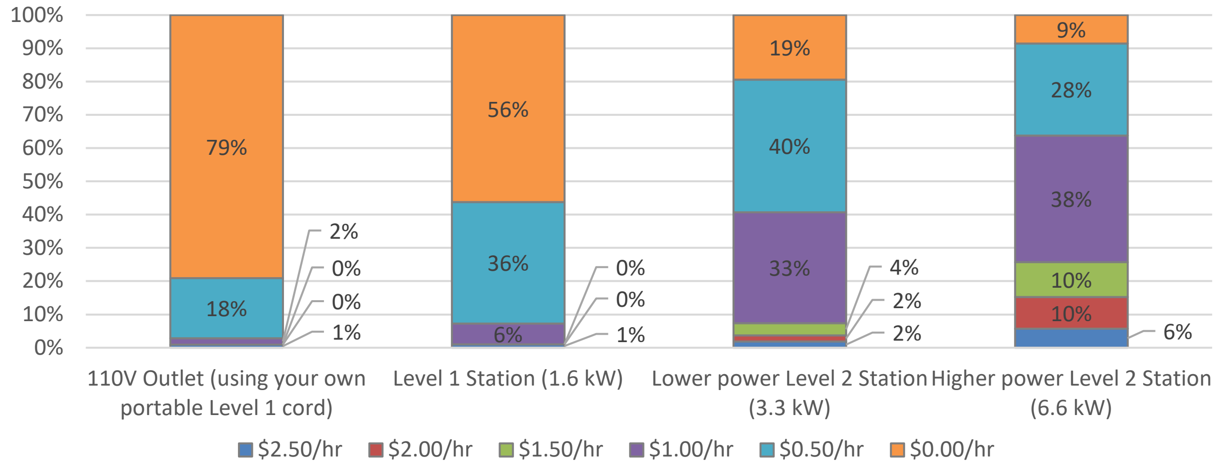
A total of 118 EV drivers responded to the survey; the majority from New York State and driving BEVs as shown in Figure 1. These drivers reported a wide range of EV utilization levels, travel distances, and charging habits.

Figure 1. Survey Respondent's Demographics and EV Ownership



More than 54% of respondents reported using a public charging station for six hours or longer less than once per month. This low usage likely indicates sufficient home charging, the lack of public charging infrastructure availability, paired with limited occurrences of this parking duration when a battery charge was needed. (77% of respondents stated that more public charging stations would enable them to drive more electric miles.) Workplaces were identified as the location that would benefit the most from additional EV charging infrastructure, followed by multifamily dwellings and hotels. However, EV drivers' willingness to pay for any public charging was quite limited, particularly if only low power charging options are offered. Most respondents felt that the fee should be $1.00 per hour or less, even for higher power charging stations (Figure 2).

Figure 2. EV Driver Acceptable Costs for Charging Station Use



1.2 Long-Dwell EV Charging Technology

EV charging stations are classified by the type of power delivered (alternating current [AC] or direct current [DC]) and the maximum charging power. The charge time for each vehicle varies depending on the battery capacity, the battery state-of-charge (i.e., how "full" the battery is at the time of charging), the EVSE's maximum charging rate, and the vehicle's maximum charging rate. The SAE International J1772 standard connector provides important safety and shock-proof design elements and is the established standard for AC Level 1 and AC Level 2 EVSE for all EV manufacturers.

Because this project focused on EV charging for long-dwell venues, the evaluation focused on lower power, "slower" low-cost charging infrastructure options. These options provide long-dwell parking operators with flexible EV charging options. For this reason, only AC Level 1 and AC Level 2 EVSE along with manual and automated power management approaches were applicable. The approach's premise is that identifying low-cost installation and operations options will to address the cost barrier to result in the accelerated adoption of cost-effective EV charging infrastructure installations. Increased public charging accessibility will in turn lead to accelerated EV adoption in the State.

Some surveyed EV drivers felt higher power charging stations are needed to provide a full charge as quickly as possible and 31% wanted a full charge if plugged in for eight hours. However, about 50% of the survey respondents would be satisfied even if they did not receive a full charge within eight hours as shown in Figure 3.

Figure 3. Acceptable Charging Rates for EV Drivers

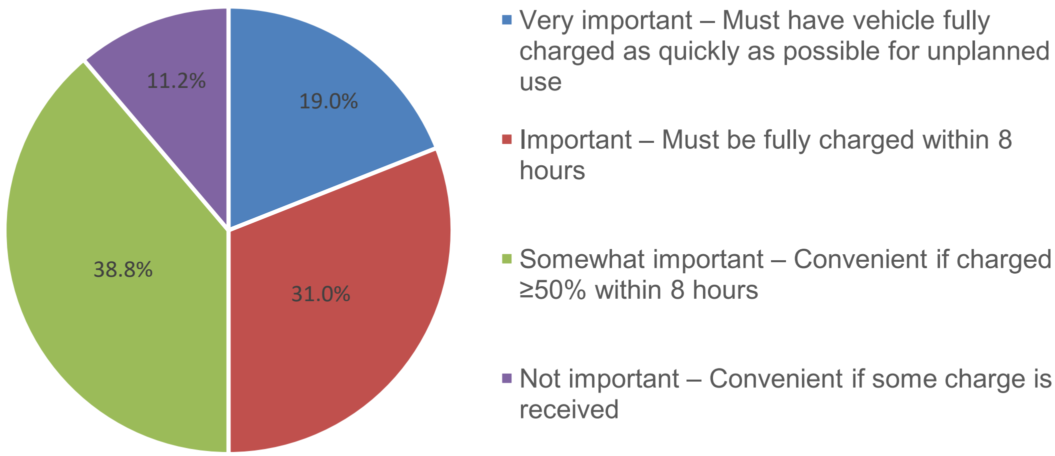


Table 1 summarizes the EV charging technologies that are described in the following sections.

Table 1. EV Charging Infrastructure Specifications and Performance Characteristics

Type	Input Power	Maximum Output Power (kW)	Maximum Driving Miles per Hour Charge	Maximum Driving Miles per Six Hour Charge
AC Level 1 Outlet	120VAC, 15-20 A	1.4	5	30
AC Level 1 EVSE	120VAC, 20 A	1.9	7	42
AC Level 2 EVSE (low power)	240VAC, 20 A	3.3	10-12	60-72
AC Level 2 EVSE	240VAC or 208VAC, 40 A	6.6	20-25	120-150

1.2.1 AC Level 1 Outlets and EVSE Cordsets

The lowest cost EV charging infrastructure option is an AC Level 1 120 volts-alternating current (VAC) ground fault current interrupter (GFCI) outlet on a dedicated 15 amp (A) or 20 A circuit. AC Level 1 outlets should be National Electrical Manufacturers Association commercial grade outlets that meet National Electric Code requirements. Commercial grade outlets, such as hospital grade outlets, are better suited for EV charging because they may be more durable and retain optimal tension longer than lower quality outlets. Outlets must have a cover if they are installed outside, or anywhere they could get wet.[1] These outlets can be installed in parking lots (example shown in Figure 4) for drivers to use the occasional use AC Level 1 EVSE cordset that is included with all EV purchases. Light poles are commonly used to install AC Level 1 outlets because of the low power and convenient locations. Installing the conduit and electrical wiring for the dedicated circuit is the highest portion of the cost for this solution.

Figure 4. AC Level 1 GFCI Outlets for Parking Lot Charging

Source: Pictures taken by Woodruff, Brendan G, in VT, Used by permission

The electrical infrastructure for AC Level 1 outlets is less expensive than AC Level 2 EVSE because of the lower required electrical service capacity infrastructure (lower capacity circuit breakers, less wire, etc.). AC Level 1 EVSE (described below) use the same electrical wiring infrastructure, so the AC Level1 outlets can be upgraded to AC Level 1 EVSE in the future if desired. Alternatively, a low power (3.3 kilowatt [kW]) AC Level 2 charging station could be powered by this circuit (the bare wire would be used as the neutral line) in the future if needed.

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1 Smith, Margaret. Level 1 Electric Vehicle Charging Stations at the Workplace. United States: N. p., 2016. Web. doi:10.2172/1416120.

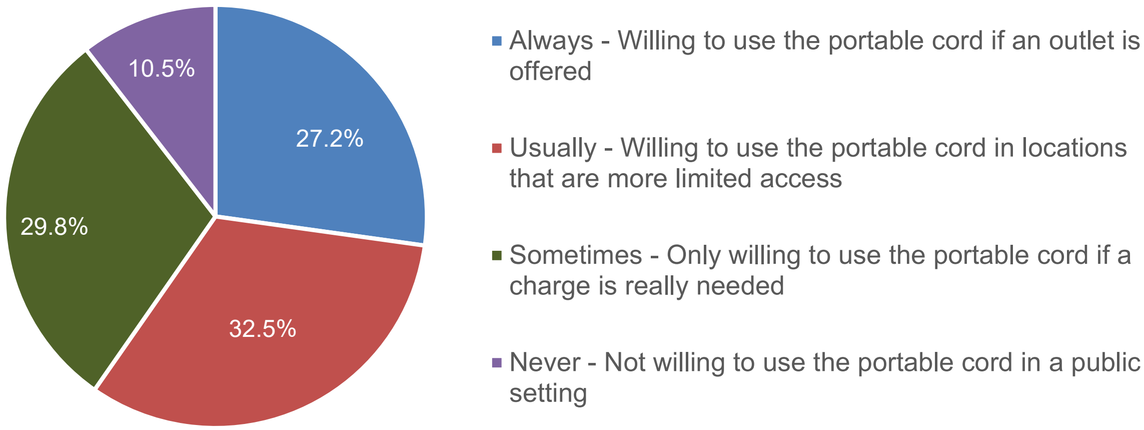
AC Level 1 EVSE cordsets typically provide a maximum of 1.4 kW of charging power. This equates to approximately 5.0 miles of driving range per hour of charging. At this charging rate, a current typical PHEV (8 kilowatt-hour [kWh] battery capacity) would require approximately six hours. A current typical BEV (25 kWh battery capacity) would need 18 hours to be fully-charged from “empty”. However, not all vehicles will arrive at the charging station with a fully discharged battery or require the battery to be completely charged at the end of the charging session, so actual charge times will be the same or shorter.

Providing AC Level 1 outlets is a very low-cost option, but drivers may not prefer this option. EV drivers must use their own charging cordset, so some are concerned about theft or vandalism when using their charging cordset in a public setting. When the weather conditions are not ideal EV drivers also do not like to place a wet, frozen, or muddy cordset in their vehicle after charging. Despite these potential drawbacks, this option could meet the site owners’ and users’ needs. This method may also allow charging infrastructure to be easily installed when more expensive and more capable stations are not cost-effective. The site owner can evaluate the usage to determine if an upgraded and expanded approach is needed.

Several commercially available solutions can improve the AC Level 1 GFCI outlet charging experience. Most solutions focus on deterring and reducing theft and vandalism to provide more secure charging. Many newer EV models lock the J1772 connector into the vehicle’s charging port when in use, which reduces drivers’ concerns of charging cordset theft.

The EV drivers’ survey results indicated that many EV drivers are willing to charge using an AC Level 1 GFCI outlet in well-known areas (e.g., workplace or a restricted parking lot) or when no other options were available (Figure 5).

Figure 5. Willingness of Drivers to Use Their Included Charging Cordset



1.2.2 AC Level 1 EVSE

AC Level 1 EVSE have more functionality and convenience for charging than an AC Level 1 outlet, but costs slightly more. As described in the previous section, the electrical infrastructure for AC Level 1 EVSE is less expensive than AC Level 2 EVSE because of the lower required electrical service capacity infrastructure (lower capacity circuit breakers, less wire, etc.). AC Level 1 charging stations for commercial installations are permanently installed and include the charging cord and connector so drivers do not need to use their charging cordset (example shown in Figure 6). They are more durable than AC Level 1 GFCI outlets for long-term deployments and frequent connection/disconnection that occurs with frequently used EVSE.

AC Level 1 EVSE use 120VAC input power to provide a maximum of 1.9 kW of charging power. This equates to approximately 7.0 miles of driving range per hour of charging. These charging stations can have access-control and cable management functionality (e.g., retractable cords) for added convenience and control. They typically do not include monitoring, payment, or management capabilities, although some manufacturers offer these functionalities.[2] Most AC Level 1 charging station manufacturers offer wall-mounted and stand-alone pedestal-mounted options.

For comparison purposes, a wall-mounted, non-networked dual-port AC Level 1 charging station costs approximately $500 less per charging port than a pedestal-mounted charger ($1,700 compared to $2,700).

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2 U.S. Department of Energy. Level 1 Electric Vehicle Charging Stations at the Workplace. Accessed May 31, 2017 from https://www.energy.gov/sites/prod/files/2016/07/f33/WPCC_L1ChargingAtTheWorkplace_0716.pdf

Figure 6. Example AC Level 1 EVSE Installation

AC Level 1 EVSE are appropriate in long-dwell charging settings to keep costs low while providing the added security and convenience over simple AC Level 1 GFCI outlets. The lower charging rate is less of a concern with extended dwell periods because the EVs are connected long enough to still meet most charging needs.

1.2.3 AC Level 2 EVSE

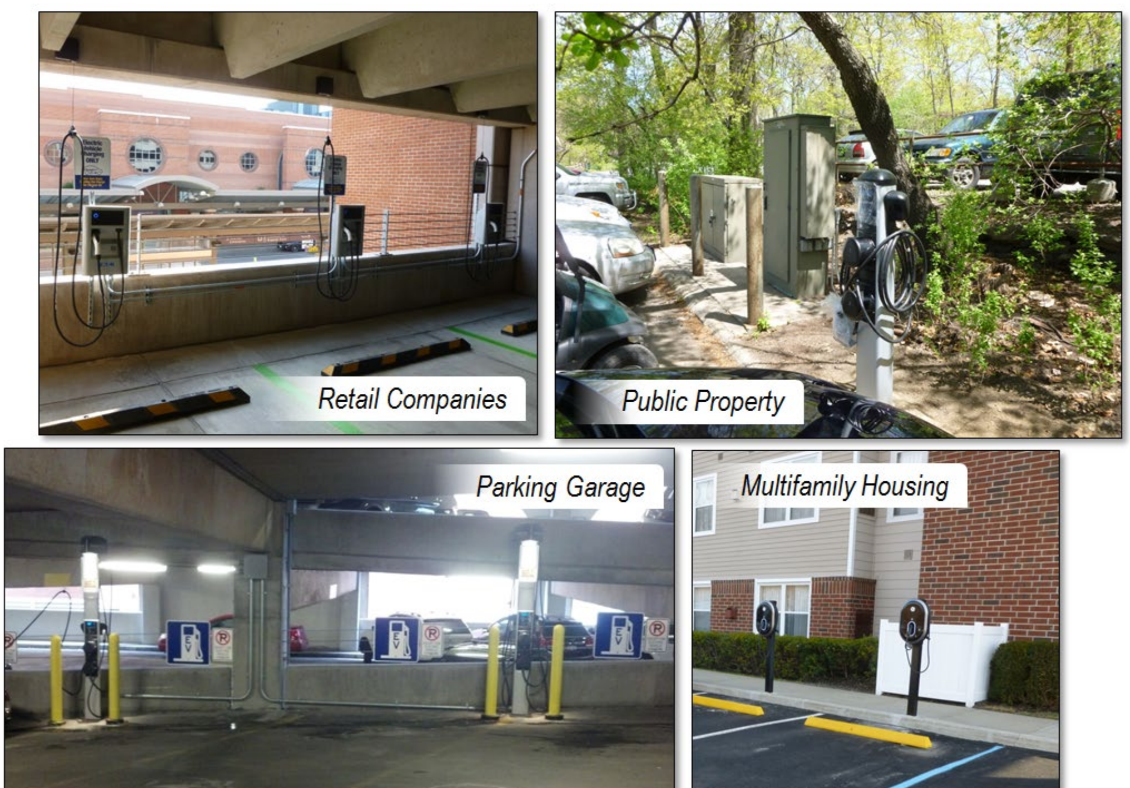
AC Level 2 charging stations use 240VAC or 208VAC (commercial and industrial) input power to provide up to 19.2 kW of charging power. AC Level 2 EVSE are permanently installed units connected to a dedicated electrical circuit. The charging rate depends on the specific station model and EV using it. The most common commercial AC Level 2 (6.6 kW) EVSE provides approximately 20-25 miles of driving range per hour of charging or a full charge for a 25-kWh battery capacity BEV within five hours. Most PHEVs have a maximum charge rate of 3.3 kW, but they have smaller capacity battery packs of around 8 kWh. The result is an AC Level 2 charging station will fully charge the battery within three hours.

AC Level 2 charging stations are a popular choice for commercial public installations because they typically offer a faster charge, better durability, and more features than simpler options. Commercial AC Level 2 charging stations typically have a cord management system that keeps the cord off the ground when not in use.

AC Level 2 charging stations are available for networked (managed) or non-networked (unmanaged) operation. Managed stations operate on a charging management network (e.g., ChargePoint) that secures the plug until properly activated, manages payments, manages charging station reservations, and monitors energy use, and collects and analyzes usage data. Managed AC Level 2 charging stations provide valuable functionality but are more expensive than unmanaged charging stations. They must be activated for a fee, may require a cell signal repeater for reliable network communication, and have a reoccurring subscription fee. Because of the high initial and ongoing costs, networked stations are typically not suitable for low-cost charging infrastructure installation solutions.

Non-networked AC Level 2 charging station models cannot directly collect user payments or monitor and collect charging station usage data. Most managed and unmanaged charging station manufacturers offer wall-mounted and stand-alone pedestal-mounted options. Charging station models are often available with either a single or double charging port. For comparison purposes, a wall-mounted non-networked dual-port AC Level 2 charging station costs approximately $500 less per charging port than a pedestal-mounted charger ($2,200 compared to $3,200). Several charging station installations are shown in Figure 7.

Figure 7. Example AC Level 2 EVSE Installations



Standard AC Level 2 EVSE hardware can be powered by 240VAC on a 20 A circuit (lower than the maximum allowable by the hardware) to provide approximately 3.3 kW. This low-power (3.3 kW) AC Level 2 EVSE option provides an opportunity to provide an increased number of available charging ports compared to standard AC Level 2 EVSE. A low-power AC Level 2 EVSE provides approximately 10-12 miles of driving range per hour of charging. Because standard AC Level 2 hardware is used, if higher rate charging is needed at a later time, the full power capability (6.6 kW) can be used by upgrading the electrical supply to 40 A.

1.2.4 Implementation Cost

Several factors influence charging station installation costs, which can often exceed the cost of the hardware itself. These factors must be considered when determining the viability of a site and the ideal location to install the charging station on the property. The largest factor can be the existing electrical service. All new charging station installations should have an electrical load analysis performed on the facility's electrical service to determine available capacity for EV charging stations. The results will determine whether an electrical panel and/or service upgrade is required. This can be a significant cost.

EVSE costs vary based on the power level, features, and whether the stations are networked. Charging infrastructure installation costs vary widely by location depending on the site configuration. Various factors influence installation costs (wire run length, obstacles to routing wires, trenching length, pavement/concrete repair, etc.), as well as any needed utility infrastructure upgrades. Installation costs often exceed the charging station hardware costs. The simplest installation is a wall-mounted unit. Routing the electrical wiring from the electrical panel to the station requires conduit and (in some cases) penetrating the building's exterior. Typical wall-mounted charging station installation costs are between $1,500 and $3,000. (Longer distances from the electrical panel cost more.) Pedestal-mounted EVSE away from the building will require an excavator to route the conduit and prepare the ground for the concrete pad, which increases costs. Pedestal-mounted station installation costs are typically at least $3,000 even for stations placed close to the building and when digging is solely through dirt. Costs are much higher for installations that require longer distances and conduit routing that must go under pavement (including pavement repair). Thus, low-cost charging station installations should be designed with optimally located stations to minimize installation costs. Because of this, the total installed costs are difficult to accurately estimate, so the costs shown in Table 2 are representative range examples to guide the charging infrastructure design development.

Table 2. Estimated EV Charging Infrastructure Costs

Type	Charging Infrastructure Cost	Installation Cost
AC Level 1 Outlet	$100	$100-$1,000
AC Level 1 EVSE	$300-$1,500	$300-$5,000
AC Level 2 EVSE (low power)	$300-$1,500	$500-$8,000
AC Level 2 EVSE	$400-$6,500	$1,000-$10,000

There may be opportunities to use existing AC Level 1 GFCI outlets for EV charging, but outlets must be on a dedicated circuit. If a candidate AC Level 1 outlet is not on a dedicated circuit, another electrical line must be run, or other electrical loads/outlets on the circuit must be disabled. If upgrades to an existing circuit are required or a new outlet needs to be installed, typical costs range between $200 and $500 per outlet. Upgrades that require significant effort (longer wire runs, trenching, conduit, etc.) have higher costs. The cost for installing a dedicated 120VAC circuit for EV charging can range from $300 to $1,000, or more, per outlet depending on length of run, obstacles to routing wires, and other factors. In general, adding multiple outlets at the same time reduces the cost per outlet due to combined installation efforts and use of the same conduit. Costs can also be reduced by locating the outlets near the electrical panel providing power. The maintenance requirement for AC Level 1 outlets is limited; although the outlet itself may need to be replaced every couple of years if it is heavily used for charging.

Installation cost factors for AC Level 1 EVSE are similar to dedicated AC Level 1 GFCI outlets, with the addition of the station hardware and installation cost. AC Level 1 EVSE hardware costs typically range from $300 to $1,500 depending on manufacturer, cord length, cord management, and other options. Wall-mounted units are typically less expensive and easier to install because mounting does not require a separate robust foundation.

AC Level 2 EVSE require a dedicated 240VAC circuit with 20-80 A current capacity, depending on the EVSE output. If needed, upgrading electrical service will likely add a significant cost to the installation. Longer distances between the electrical panel and the charging stations results in higher installation costs because of more trenching, repair, conduit, and wire costs. Examples of indoor and outdoor wire runs are shown in Figure 8.

Site owners may want to recover the costs for the network subscription, the electricity, to use for station maintenance. Charging stations must be networked and have an active subscription to allow for collecting a usage fee. The resulting cost may be higher than many EV drivers are willing to pay (except for in emergency situations). Parking site hosts should not view the purpose of operating networked stations as an opportunity to generate revenue. Rather, parking site hosts should view the purpose of operating networked stations to be for tracking charging station usage, receiving real-time notification of issues, online availability, and other available benefits.

Some networked charging station systems leverage local WiFi and Bluetooth networks for data transfer to eliminate the cost of cellular subscriptions. To keep initial purchase costs low, non-networked stations can be used, but some parking site hosts have found they wanted to add this functionality later to help manage station use (e.g., fee collection, maintenance monitoring, in-use status for online availability) or expenses. There are some aftermarket solutions to add monitoring capabilities to a non-networked station, such as the eMotorWerks JuicePlug (less than $100) that adds smart, remote monitoring and control of any SAE International J1772 standard connector (AC Level 1 EVSE and AC Level 2 EVSE) using WiFi communication.

Figure 8. Example EVSE Installation Factors

1.3 Long-Dwell EV Charging Installation Strategies

The lower power 120VAC charging solutions described earlier may be viable for several long-dwell parking venues. However, several factors for each type must be considered before installation, including:

- ***Cost*** – Simple AC Level 1 GFCI outlets have extremely low hardware costs, but similar installation costs (including trenching, conduit, wiring, sub panels, etc.) as AC Level 1 EVSE as both require a similar electrical supply. Installing AC Level 1 GFCI outlets to gauge EV charging demand and replacing with an AC Level 1 EVSE at a later date, when demand is confirmed, can provide a low risk strategy for incorporating charging infrastructure.
- ***Security*** – If only AC Level 1 GFCI outlets are installed, EV drivers must use their personal charging cordset. Drivers may be concerned that unattended equipment can be stolen or vandalized. This is particularly a concern for locations that are not well patrolled or monitored. AC Level 1 EVSE can provide more security for only a slightly increased upfront cost at these locations.
- ***Convenience*** – Because an AC Level 1 GFCI outlet requires the use of the driver's charging cordset, additional effort is required to connect and then the cordset must be coiled up and placed in the vehicle after charging is complete. Some users are less willing to place a wet or dirty cordset back in their vehicle after charging in inclement weather.

The installation of lower power charging solutions can often leverage existing infrastructure to reduce installation costs and impacts. Parking lot light poles could be used for installing an AC Level 1 outlet or for mounting an EVSE. The electrical conduit may have sufficient space to run additional dedicated circuits to power EV charging infrastructure. Many facilities are converting parking lot lights to LED bulbs to decrease electricity use and increase bulb replacement intervals. Lower power charging solutions may be able to leverage the electrical service capacity freed up from LED conversions and power EV charging infrastructure without costly electrical upgrades. Several organizations are also working on solutions to allow the existing light circuits to provide power for EV charging (discussed in a later section). Monitoring and controls would be included to manage the electrical load from the source.

Low-power, low-cost 120VAC charging solutions have a potential upgrade path if needed. AC Level 1 GFCI outlets and AC Level 1 EVSE have similar electrical requirements using a dedicated circuit with 12-2 wire (or 10-2 for extremely long runs due to increased resistance). So, AC Level 1 EVSE could replace AC Level 1 outlets. Similarly, low power (3.3 kW) AC Level 2 EVSE can use the same wiring as AC Level 1 EVSE. The only needed change is to instead use a double throw 20A, 240VAC breaker (using white and black wires for load, and the bare wire for both ground and neutral). This upgrade provides a power capacity increasing the maximum power output from 1.9 kW to 3.3 kW.

The largest potential savings from using lower power charging stations is from reduced hardware and electrical service installation costs, avoiding/delaying electrical service upgrades, and reducing demand charges.

1.4 Long-Dwell EV Charging Operational Strategies

An alternative cost saving strategy to installing lower power (AC Level 1) charging technologies, is using AC Level 2 EVSE to serve multiple EVs throughout a long-dwell charging event. This solution requires plug sharing using either manual (sharing one charging cord by moving it from one EV to another by the vehicle owners, a lot attendant, or a valet service) or automated power management methods. Strategies can be implemented during initial installation or post-installation to increase the vehicle charging potential when there are a limited number of AC Level 2 EVSE or the use of limited available electrical service capacity must be optimized.

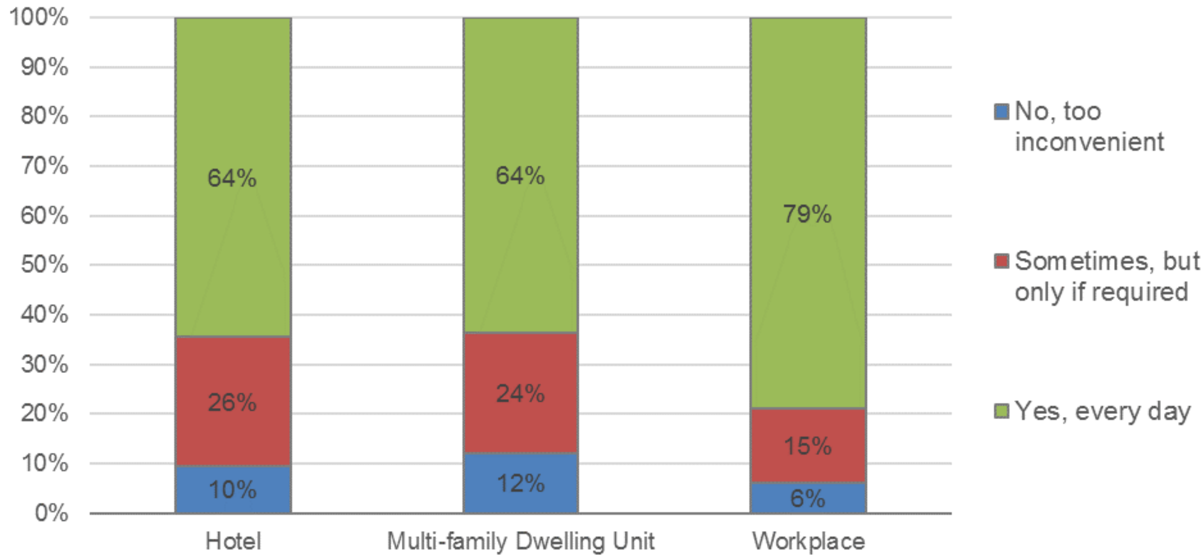
1.4.1 Manual Charge Management Strategies

AC Level 2 charging stations provide more power than is typically required for long-dwell charging events. Host sites may still want to provide faster charging for EV drivers that park for shorter periods. Plug sharing is a low-cost option that maximizes the use of charging stations. Configuring the EV parking spots to enable a single station to serve multiple vehicles throughout the day is a more cost-effective solution because it requires purchasing fewer charging stations. To share charge ports, the charging station must be placed so the charging cord is accessible to multiple parking spaces and can be moved from one EV to another after it is charged. This allows the EVSE's use to be shared among multiple vehicles without any charging equipment investment or (in many cases) EV drivers moving vehicles. This simple plug sharing method involves EV drivers disconnecting a charged vehicle and moving the connector to an adjacent vehicle that requires charging. At least one driver must return to the vehicles during the day to do the plug switching (with the other driver's prearranged approval to do so). Alternatively, the driver could move the EV to another parking spot to allow another EV driver to use the station. This may not be feasible in every long-dwell parking application (e.g., long-term airport parking).

The required level of communication is typically easiest when EV drivers know each other (e.g., workplace or multifamily dwellings). Charging station use policy solutions such as limited charging times, reserved nearby EV charging "staging" spaces to move vehicles to/from, and communications strategies (e.g., calendar applications and social media, such as a Facebook group, workplace schedules, and even cards that identify when it is acceptable to unplug a vehicle[3]) have been proven to be effective. Most EV surveyed drivers were willing to self-manage plug sharing in a variety of long-dwell parking venue settings as shown in Figure 9.

3 Introducing the Take Charge and Go EV Charging Indicator Hanger. Retrieved June 5, 2017 from www.takechargeandgo.com/2015/02/14/hangers/

Figure 9. EV Driver Willingness to Switch Plugs



A similar, but somewhat more advanced strategy is ChargePoint's Waitlist. Waitlist lets "drivers use their mobile phone or ChargePoint card to get in line at charging stations when all of the ports are full. Drivers get a friendly message when their EV is charged, asking them to move it. Once they unplug, ChargePoint notifies the next driver in line and holds the station until that driver plugs in. Drivers can also take advantage of automatic scheduling to place them on a particular waitlist every day, which is especially useful for busy workplaces."[4] Similar applications that use mobile device or internet notifications are offered or are being developed by other charging networks.

Manual plug sharing also works well in valet parking operations as valet personnel are tasked with managing charging vehicles and parking. Plug sharing can be integrated into the required duties of valet attendants. This would be a value-added service in addition to the convenience factor with valet parking. This solution is particularly attractive for long-dwell situations where a single EVSE can support many EVs throughout the parking period with minimal additional effort by the attendant. The largest potential savings from using this approach that maximizes the EVSE utility is from avoiding additional equipment and lower electrical service capacity costs.

4 Waitlist, retrieved June 14, 2017 from http://www.chargepoint.com/products/waitlist/

1.4.2 Automated Power Management System Strategies

Automated power management systems manage charging for multiple EVs without user and site manager intervention. These management solutions can provide time-of-use charging to take advantage of the lowest cost electricity available and minimize costly demand charges in commercial settings. Automated EVSE management may increase the installed hardware costs, but it may provide operational cost savings by affecting how and when stations are used to optimize overall electricity demand dynamics. EVSE management solutions are available, either integrated into the EVSE itself or as an “upstream” electric control system. The largest potential savings from these approaches is from reducing demand charges and electrical service upgrade costs.

1.4.2.1 Power Sharing Dual-Port AC Level 2 Charging Stations

Power sharing dual-port AC Level 2 charging stations are powered by the same input power as a standard single charger. These charging stations share the power between the two connected vehicles based on need. When one vehicle is connected, the charging station functions as a standard charging station. When two vehicles are connected, internal hardware shares the available power between the two vehicles based on need. The hardware costs are somewhat (~25-30%) higher than two standalone EVSE, but the system demand charges and the electrical infrastructure cost will be lower because only half the power is required. Example systems are described as follows.

ChargePoint’s CPF25 model EVSE includes intelligent charge management that dynamically distributes power to all EVs plugged into a station. By splitting power between two vehicles, this solution can double the number of vehicles charged per day per dedicated electrical circuit at long-dwell locations (Figure 10).[5]

[5] Chargepoint. CPF25 Family. Accessed June 5, 2017 from https://www.chargepoint.com/files/brochures/br-cpf25.pdf

Figure 10. ChargePoint CPF25 Charge Sharing AC Level 2 EVSE

Source: https://www.chargepoint.com/products/commercial/, reprinted with permission

Clipper Creek AC Level 2 EVSE models equipped with the Share2™ technology (Figure 11) allows two 32 A AC Level 2 EVSEs to share a single 40 A circuit. These EVSE include 25-foot cords to allow access to multiple parking spaces.[6]

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6 Clipper Creek. Share2™ Enabled HCS-40 EVSE Bundle, 32 Amp Level 2, 240V, with 25 ft cable. Accessed June 5, 2017 from https://store.clippercreek.com/featured/Share2-HCS-40-Bundle

Figure 11. Clipper Creek Share2 EVSE

Source: https://www.clippercreek.com/new-power-sharing-electric-vehicle-charging-stations/,reprinted with permission

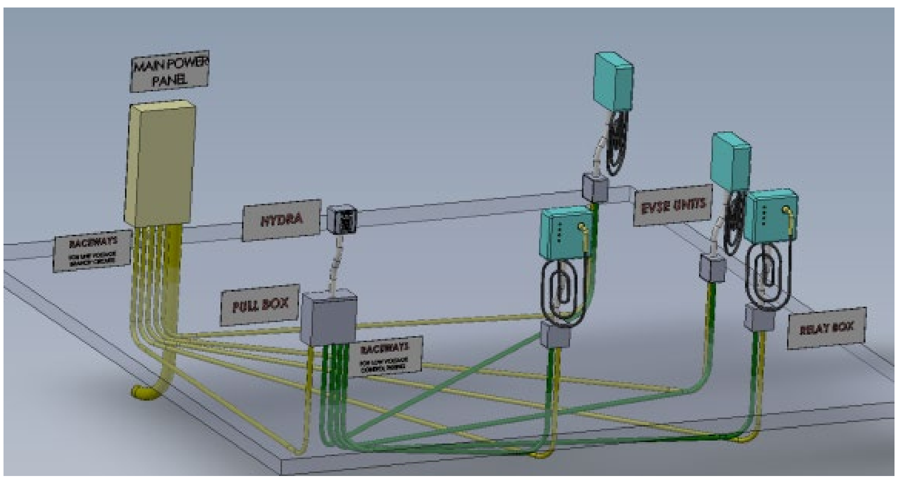
1.4.2.2 Automated Power Management Systems

Automated power management systems actively control/manage the power among multiple charging stations at a facility to minimize the system-level electrical demand and cost impacts by optimizing charging times and rates. Some systems communicate with the grid and incorporate pricing signals in the management algorithms. System costs (initial and monthly) can be high, but it can also be a cost-effective solution for long-dwell parking situations where the AC Level 2 charging is needed; however, there is limited available electrical service capacity and/or minimizing demand charges is critical. Example systems are described as follows.

The Liberty Plugins Hydra R EVSE management solution (Figure 12) provides time-of-use management, access control, monitoring, data recording, data reporting, and demand response functionality. Each module controls up to 10 EVSE and is compatible with AC Level 1 outlets, AC Level 1 EVSE, and AC Level 2 EVSE. This approach leverages and manages a single electrical circuit to power multiple charging points. The system provides smart vehicle switching without driver or facility owner intervention. The system costs were estimated at $6,000 for a primary control module plus $500 for each EVSE or outlet being controlled. Monthly service fees include $29 per Hydra system and $5 per for each connected EVSE.[7] The system can be submetered to allow for billing individual customers' usage.

Figure 12. Liberty Plugins Hydra R Charge Management System Electrical and Control Wiring

Source: http://www.libertyaccesstechnologies.com/solutions/hydra-r.php, reprinted with permission



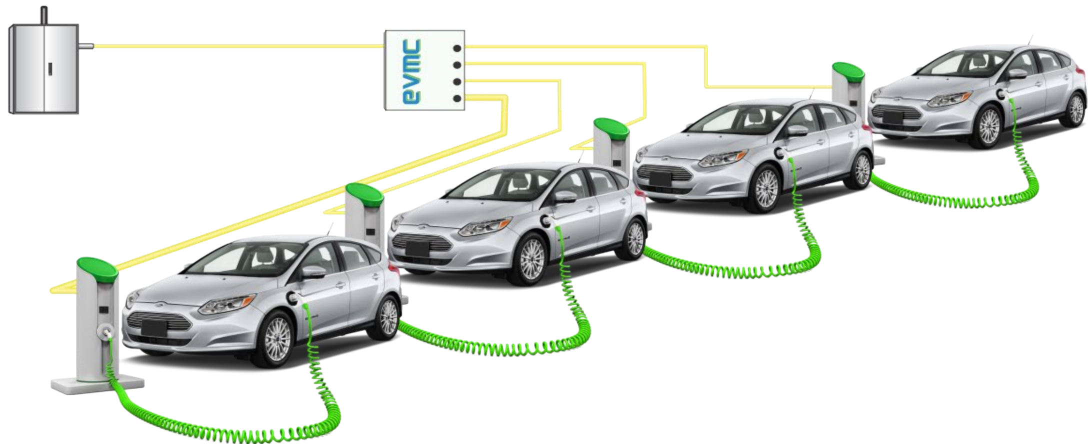
Cyber Switching Solutions, Inc. provides a similar solution called the EV Master Controller that allows several EVSE to be intelligently powered from a single electrical circuit (Figure 13). [8] Multiple EVSE are charged using a controlled "round-robin" schedule to optimize vehicle charging and electrical service capacity use. The system polls vehicles' charging status and bypasses already charged EVs. The system can be submetered to allow for billing individual customers' usage.

7 Telephone interview with Chris Outwater with Liberty Plugins, http://www.libertyaccesstechnologies.com/solutions/hydra-R.php and http://libertyplugins.com/products/hydra-r-multi-charger-control-system/

8 Cyber Switching Solutions, Inc. Electric Vehicle Charging. Accessed June 5, 2017 from https://www.cyberswitching.com/evcharging.php

Figure 13. Example Cyber Switching Solutions, Inc. EV Master Controller System Layout

Source: https://www.cyberswitching.com/evcharging.php, reprinted with permission



EVSE with integrated power splitting capabilities (allowing a single EVSE to charge several EVs) was identified by several site owners as a potentially viable option. Commercially available solutions are not widely available. MOEV Inc. is in medium-scale pilot demonstrations of its intelligently controlled EVSE charge port multiplexing system that splits a single AC Level 2 EVSE's power into 2, 3, or 4 outputs. The system targets long-dwell parking situations and is applicable to new installations and upgrading existing installations. The system maximizes the infrastructure's use to minimize infrastructure costs (e.g., trenching and electrical service capacity installation), manages energy use timing and peak load to minimize operational and utility demand costs. Users interact with the system via a smart phone app. Multiple units can be used on the same circuit and at the same facility. When this is done, the group of EVSE are managed as a whole to minimize the facility-level energy costs and grid impact.

Each charge management strategy discussed in this section has factors that make each solution a better fit for specific applications. Table 3 provides a general comparison of these factors including costs, value added, and required effort.

Table 3. Charging Operational Strategies Matrix

	Installation Costs	Operational Costs	Value Added Potential	Human Involvement
Driver Plug sharing	1	1	5	5
Valet Plug sharing	3	5	1	3
Automated Charge Switching	5	3	3	1

2 Long-Dwell EVSE Utilization Summary

2.1 Data Analysis and Methodology

Idaho National Laboratory, Energy Storage, and Advanced Vehicles group and Energetics Sustainable Transportation Solutions staff analyzed historic EV charging event data (including location, date/time, total time connected, time actually charging, and total energy consumed) from more than 500 charging ports throughout the State to evaluate how long-dwell EV charging locations are used and estimate potential strategies to reduce costs and/or enable more charging points to be installed. Additionally, data for more than 200 charging ports from other areas around the U.S. were also evaluated for comparison (included similar data as New York data, but less was known about each specific location). Peak power demand within charging events and data from non-networked stations were not available for evaluation. Charge events shorter than one minute were eliminated since these were most likely a test or some error occurred and do not represent an actual charging event.

Parking locations where EV drivers remain for long duration charging events were categorized into long-dwell parking venue types to identify important key attributes for each. The long-dwell parking categories are listed in Table 4 with the metrics that describe their usage. It is important to note that the parking venue types are rarely homogeneous. They are typically a combination of long-dwell and some short-dwell parking. However, locations where most EV drivers park for short durations (defined as less than two hours) such as supermarkets, restaurants, and rest stops were not included in this evaluation since only a small percentage of the parking events were long-dwell.

Table 4. EVSE Long-Dwell Parking Venue Usage Summary

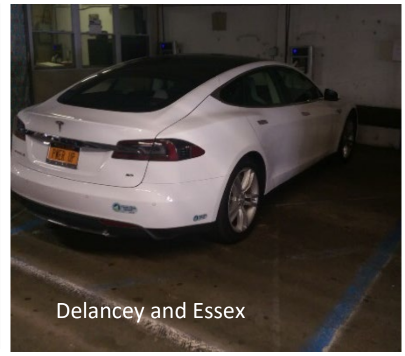
Long-Dwell Parking Venue Type	Charging Ports Analyzed	Average Percentage of Time an EV is Connected to EVSE	Percentage of Connection Time that an EV is Charging	Average Event Duration (hours)	Average Energy per Charging Event (kWh)
Multi-Family Dwelling	21	11.9%	31%	14.3	17.1
Hotel	37	1.5%	47%	5.6	12.1
Recreation Location	15	2.4%	63%	3.4	8.0
NYC Parking Lots and Garage	88	3.9%	44%	7.7	17.1
Upstate Lots and Garage	95	8.4%	36%	5.8	6.6
Bus Terminal/Train Station	31	6.2%	27%	8.0	8.7
Airport	13	1.0%	40%	4.9	6.7
University	96	8.4%	45%	5.1	7.4
Healthcare/Medical	25	14.0%	42%	6.5	9.6
Business Office	88	4.2%	52%	4.6	7.5

Most of the EV charging infrastructure included in State data were funded by the NYSERDA EVSE Deployment Support program and are installed at primarily long-dwell parking venues. The long-dwell parking venue charging station data analyzed for the project showed that EVs were only actively being charged between 30-38% of the time they were connected. This clearly shows the opportunity and potential for strategies to better manage the EVSE infrastructure shown in Table 4. Similar behaviors were seen in New York and the rest of the U.S.

2.2 Multifamily Dwellings

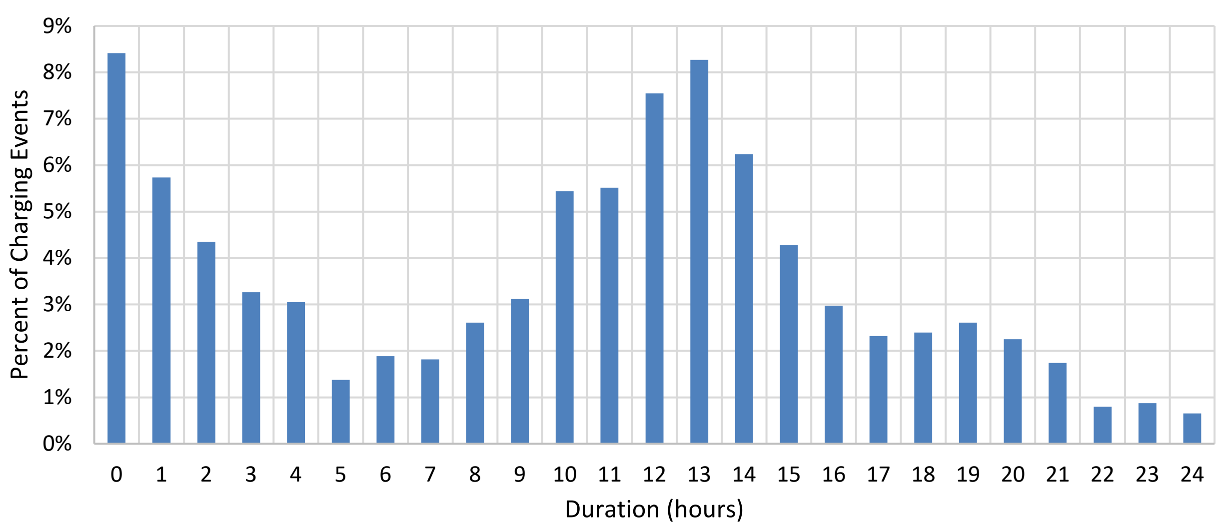
Multifamily dwelling locations in New York include a mix of large (vertical) apartment and condominium buildings and more spread out (horizontal) townhouse, apartment, and condominium housing. Current EV charging stations are typically installed in a common parking area (examples shown in Figure 14) and enable tenants to drive EVs since they can charge overnight. At some locations, such as large apartment buildings in New York City, residents who rely heavily on public transportation often leave their EVs parked and connected to the EVSE for many days. This results in very long charging events (longer than 24 hours), but with power being supplied for only a short percentage of the connected time. Parking locations managed by a valet service could move charged EVs to a standard parking spot when charged to allow other EVs to be charged.

Figure 14. Multifamily Dwelling Charging Station Installation Examples



Multifamily dwellings had the second highest EVSE connection percentage (11.9% from Figure 14). However, a relatively low percentage of time (3.7%) is spent charging. The time vehicles are plugged in, but are not actually charging, provides opportunities for applying charging station management strategies and/or different hardware configurations to increase the EVSE utilization and decrease capital/operating costs. The charging event duration distribution (Figure 15) shows there are many charge event durations nine hours or longer, which is longer than required to fully charge most current EVs using an AC Level 2 charging station. Twenty-one charging ports at multifamily dwelling locations were evaluated under this effort, with a total of 4,400 charge events.

Figure 15. Multifamily Dwelling Plug-in Event Duration Distribution



Daily utilization profiles for multifamily dwelling locations are shown in Figure 16. The percentage of charging stations with an EV plugged in and total electricity demand from all EVs charging is shown. The data show heavier use during evening and nighttime hours as would be expected for residential charging. More level charging station use throughout the day is seen on weekends because drivers are more often at home. Overall, the weekday data show EVs being plugged in when residents return each evening with the actual battery charging ending midway through the night when the vehicles are fully charged.

Figure 16. Multifamily Dwelling Charging Station Use Profiles

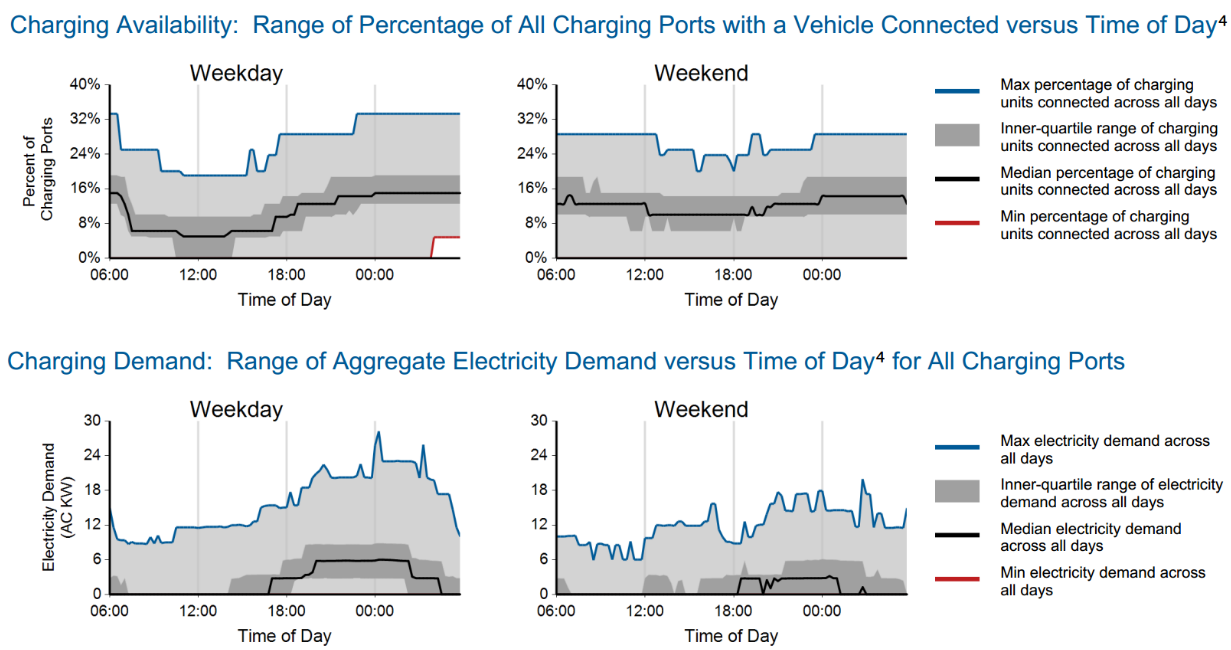
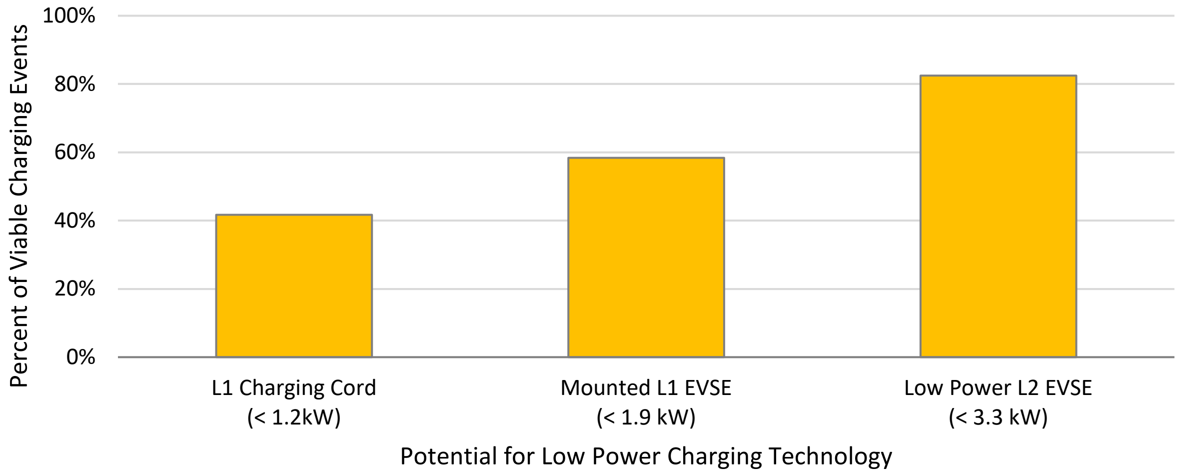


Figure 17 shows the potential for how lower-power/lower-cost charging solutions could have been used to meet EV charging needs at multifamily dwellings compared to the baseline 32 A AC Level 2 station. The percentage of charging events that could have been met with these alternatives was calculated based on the power level and number of hours the EV was plugged in. Of the charging events, 40% could have been met with an AC Level 1 charging cordset. Nearly 60% of the charge events could have been met by an AC Level 1 EVSE. More than 82% of the charge events could have been completed with a low power (3.3 kW) AC Level 2 station.

Figure 17. Multifamily Dwelling Alternative Charging Power Level Analysis Results



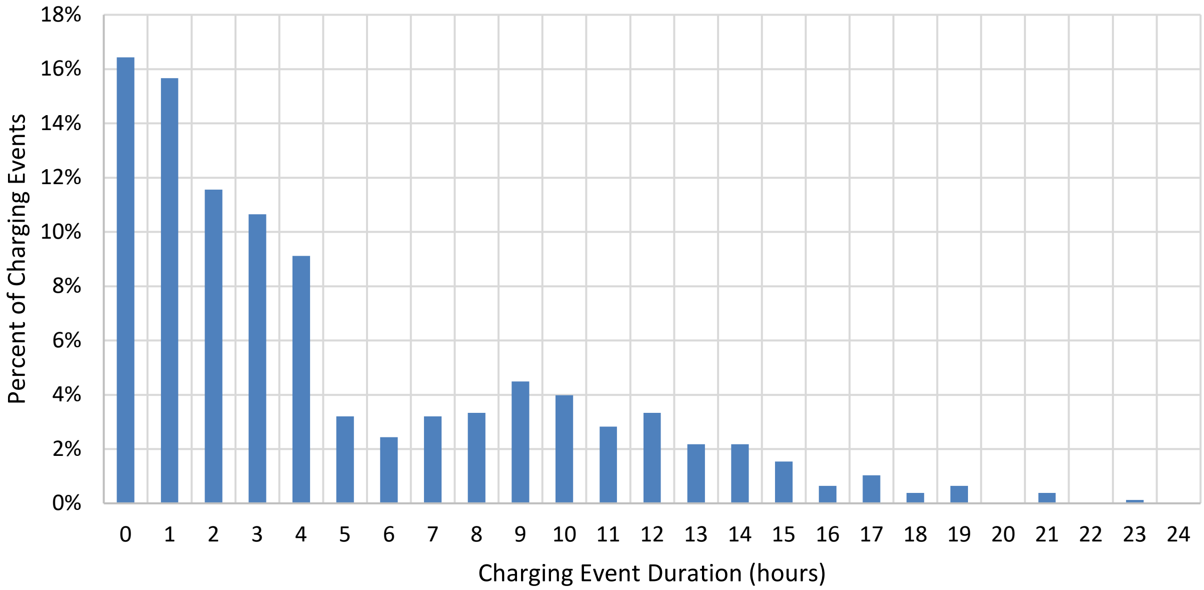
2.3 Hotels

EV charging stations are installed at a range of hotels, including large chain hotels as well as small bed and breakfast establishments around the State. Most of these charging stations were installed to attract and serve hotel guests, but many hotels also allow public charging. Thirty-seven hotel location charging ports with a total of 781 charge events were evaluated. The low number of charge ports and low charger usage calls into question the representative nature of the usage profiles, limiting the ability to draw strong conclusions from the data. Example hotel EVSE installations are shown in Figure 18.

Figure 18. Example EV Charging Station at Hotels

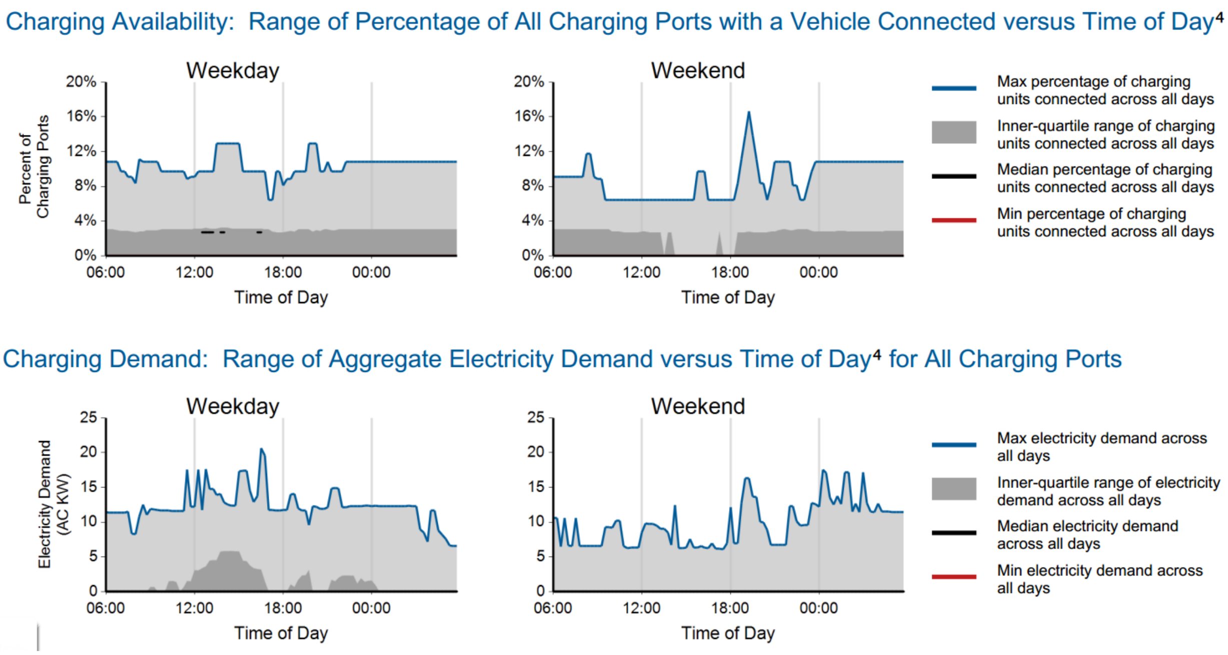
EVSE located at hotels had low utilization with EVs being plugged in only 1.5% of the time on average. EVs at these locations were actually charging the battery approximately half of the time they were connected (i.e., 0.75% of the total time). The charging event duration distribution data in Figure 19 show that most charging events were between one and five hours. This is much shorter than an overnight stay, which may indicate these charge events were not guests' EVs. These shorter charging events could also have occurred when the EV driver needed to charge the battery when they first arrived and then left the hotel for dining or entertainment. The smaller usage peak in the 9- to 12-hour charge session duration likely represents hotel guests' overnight charges.

Figure 19. Hotel Plug-in Event Duration Distribution



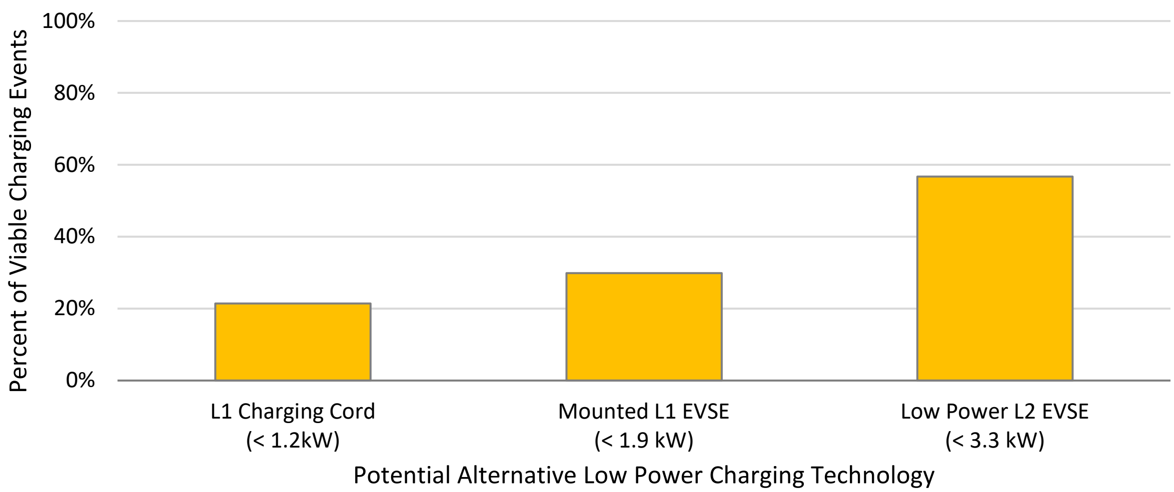
The limited station use was not enough to create robust statistics to characterize the usage (Figure 20). Stations with use limited to hotel clients would be expected to see more nighttime use.

Figure 20. Hotel Charging Station Use Profiles



With a high number of short duration charging events (which might be by the public rather than hotel guests), the potential to use low-power charging technologies using the analysis approach described earlier is more limited (Figure 21).

Figure 21. Hotel Alternative Charging Power Level Analysis Results



2.4 Recreation Locations

A number of public attractions and recreational locations throughout the State have the potential to provide long duration charging for visitors. These locations, including parks and ski mountains, were grouped together in this analysis because of the expected similar visitor behavior. (Common New York State site examples are shown in Figure 22.) These locations attract EV drivers for visits of several hours to a whole day. The EVs may also come from longer distances which would require a longer charge. Some recreational location charging stations also regularly accommodate EV drivers for shorter times during weekday evenings.

Figure 22. Example EV Charging Station Installations at Recreational Locations

Many recreation locations experience visitor count variations based on the time of year and time of day. Because of this, the overall charging port utilization levels are low (2.4%). Average charge event charging port connection times are also short (2.1 hours). As shown in Figure 23, a larger percentage of charging events are less than four hours. The slight usage increase at 12 hours indicates some long-term parking/charging for guests and/or perhaps a facility based vehicle. This usage indicates these stations are being used mainly for short duration parking. Fifteen charging ports at recreational locations were evaluated under this effort, with a total of 931 charge events

Figure 23. Recreational Location Charge Event Duration Distribution

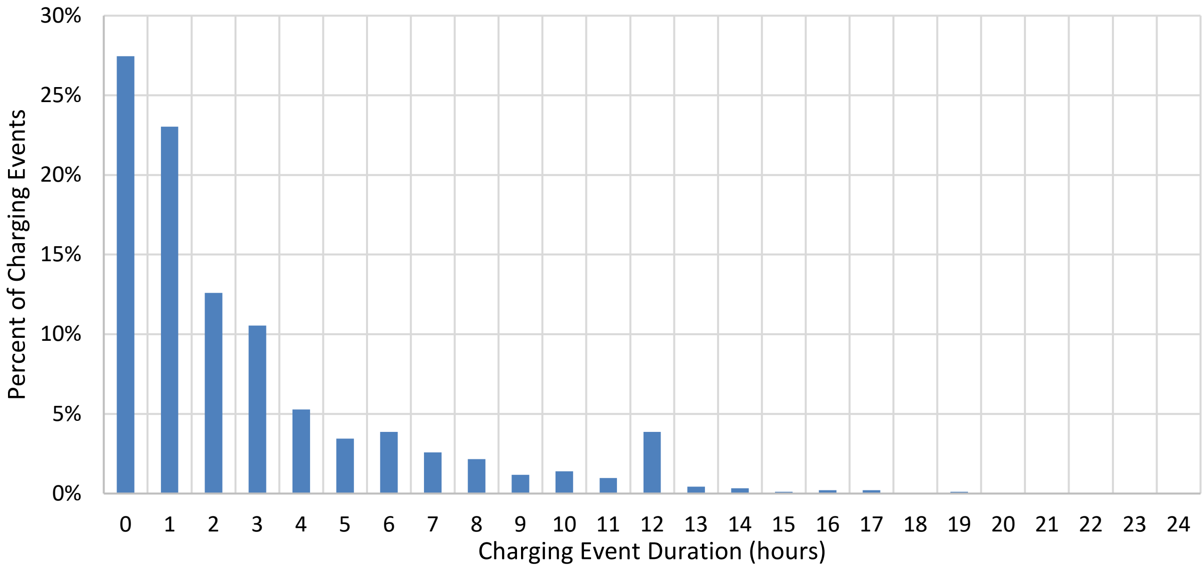
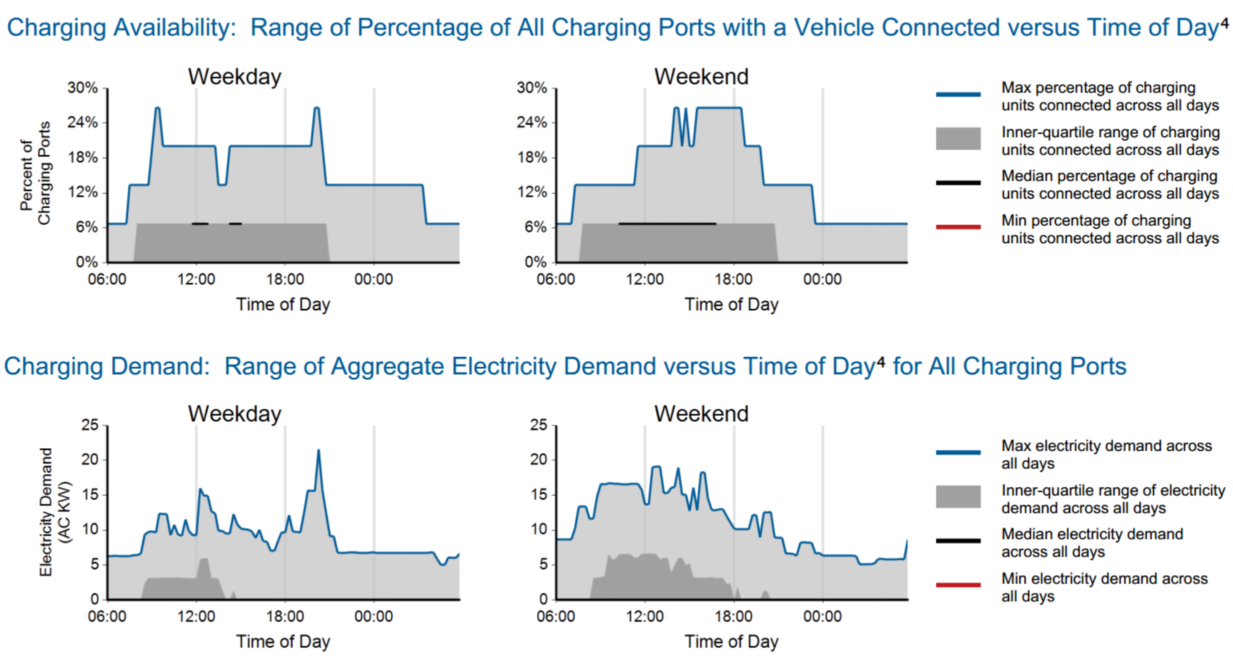


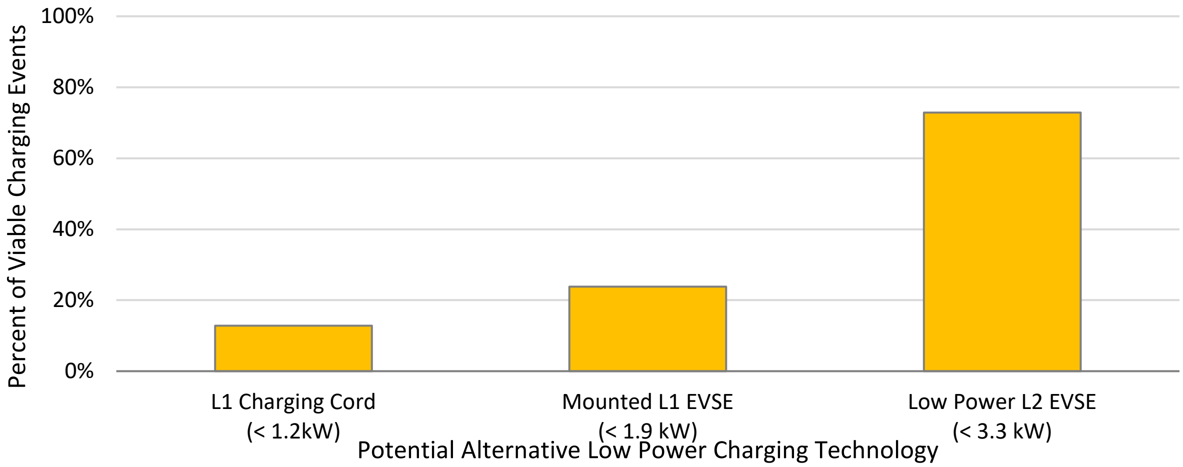
Figure 24 summarizes the EVSE daily usage profile. Overall charging station use at these locations is minimal. The maximum percentage of charging does indicate that more charging events occur during daytime hours. This is logical since these locations primarily draw visitors for daytime activities.

Figure 24. Recreational Location Charging Station Use Profiles



Because of the short charging sessions and high percentage of time the EVSE were providing power, these recreation destination locations have a low percentage of charging events that could been met with AC Level 1 charging options (Figure 25). Even so, 74% of charging events could have been met with a low power (3.3 kW) AC Level 2 charging station. This is half of the power rating of the EVSE located at these installations.

Figure 25. Recreational Location Alternative Charging Power Level Analysis Results



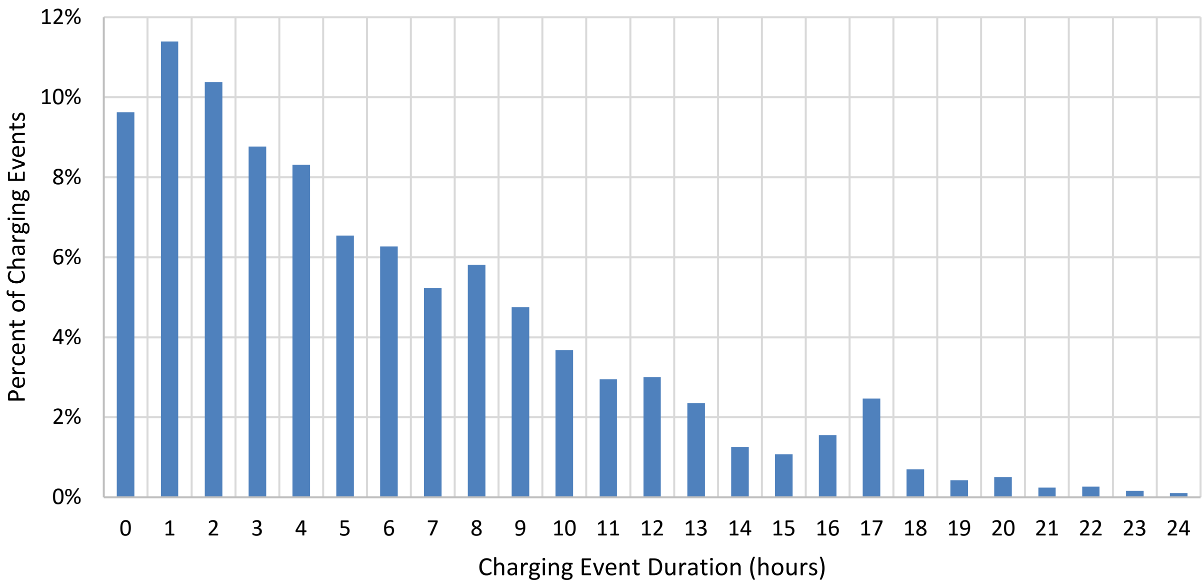
2.5 New York City Multiuse Parking Lots and Garages

New York City's size and population density create unique parking and charging station situations for EVs. This necessitates New York City parking lots and garages being analyzed separately from others in the State. Multiuse parking garages are used for local residents, daily mass transit commuters, daily business customers, and visitors. Because of the variety of user types at each garage, defining a typical charging use case for the entire garage or EV population is challenging, if not impossible. Local employee and mass transit riders park their vehicles for eight or more hours per stay on workdays. Residents will park for eight or more hours per stay overnight most days. Visitor parking includes short stays (e.g., patronizing local businesses) and all-day stays. The strategies developed in this study were designed to be applicable to use in these mixed-use garages with long- and short-dwell parking. Some example EV charging installation at multiuse parking lots and garages in New York City (NYC) are shown in Figure 26.

Figure 26. EV Charging in NYC Multiuse Parking Lots and Garages

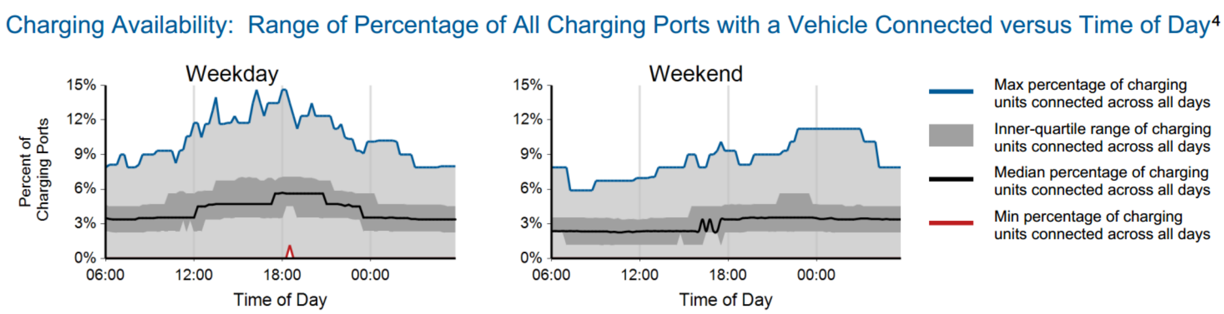
The charging stations in NYC parking facilities have an EV plugged in only 3.9% of the time. This is less than most other venues. NYC residents typically use one garage to park their vehicle. Because of this, some NYC garage charging stations have very high use when an EV driver has a permit for that garage. Other charging stations, however, are rarely used. The average connection time for EVs at NYC garages is 7.7 hours. This is sufficiently long enough to implement the improved charging strategies developed in this study. The charging station connection times are widely varied (Figure 27). The average NYC parking venue charging time was 3.4 hours along with the 7.7-hour average connection time indicate that there is the potential to implement the developed long-dwell charging strategies, but they will be on a case-by-case basis. Under this effort, 88 charging ports at NYC parking locations were evaluated, with a total of 3,799 charge events.

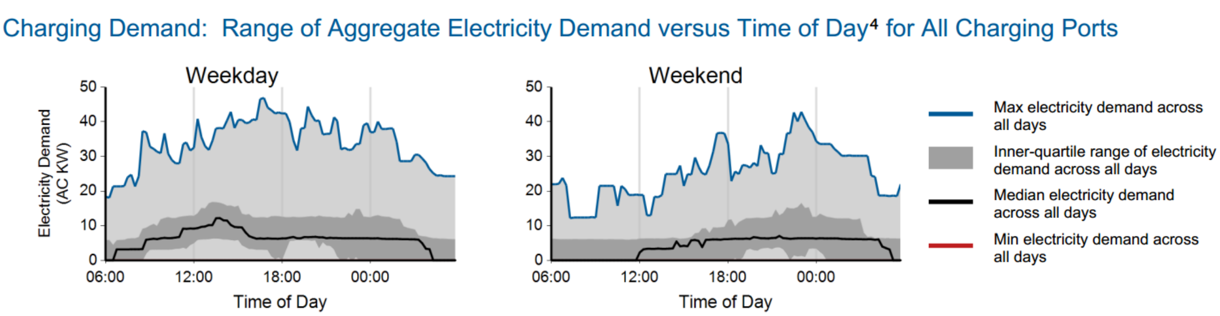
Figure 27. NYC Lots and Garages Charge Event Duration Distribution



The NYC parking venue charging station utilization profiles (Figure 28) indicate a relatively consistent median connection and charging levels throughout both weekdays and weekends. The EVs that remain connected to EVSE continuously throughout the day are likely local residents.

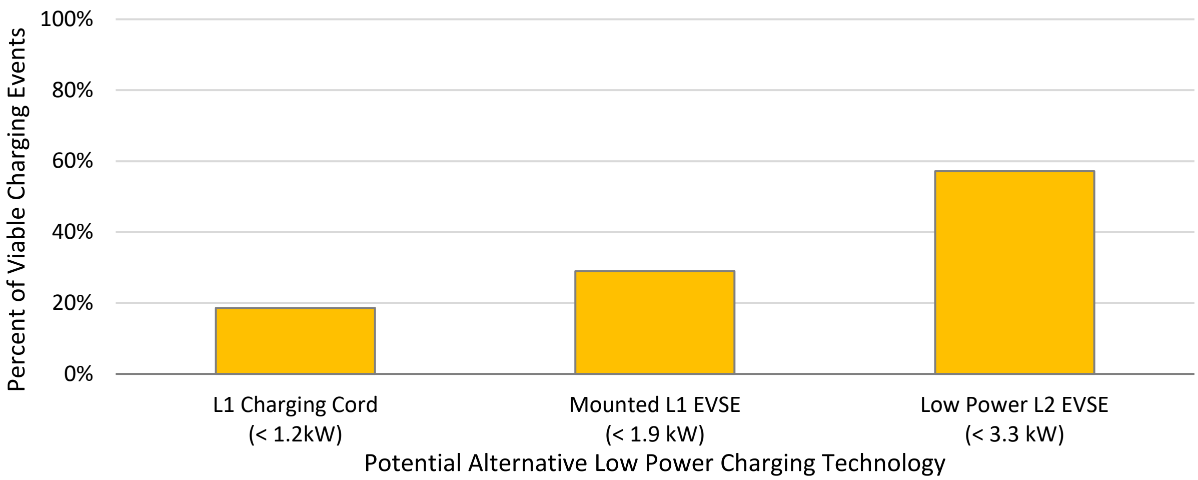
Figure 28. NYC Parking Lots and Garages Charging Station Use Profiles





The analysis indicated that between 19% and 29% of charging events could have been met with low power AC Level 1 charging options (Figure 29). Some of the overnight charging and extremely long charging events could use AC Level 1 charging stations. Low power (3.3 kW) AC Level 2 EVSE were estimated to meet 57% of the long-dwell EV charge events.

Figure 29. NYC Parking Venues Alternative Charging Power Level Analysis Results



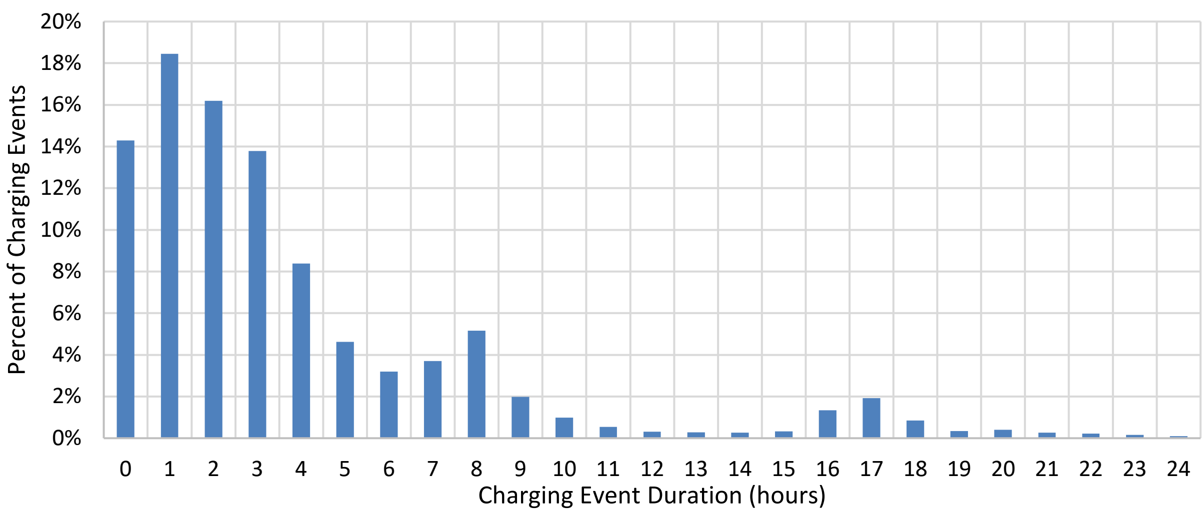
2.6 Multiuse Parking Lots and Garages Outside NYC

Most parking locations in NYC are large underground or multi-story garage structures. Multiuse parking facilities in the rest of the State vary in size and include both garages and lots. These parking locations vary significantly in size and purpose, and many are operated by municipalities (Figure 30).

Figure 30. EV Charging in Multiuse Parking Lots and Garages Outside of NYC

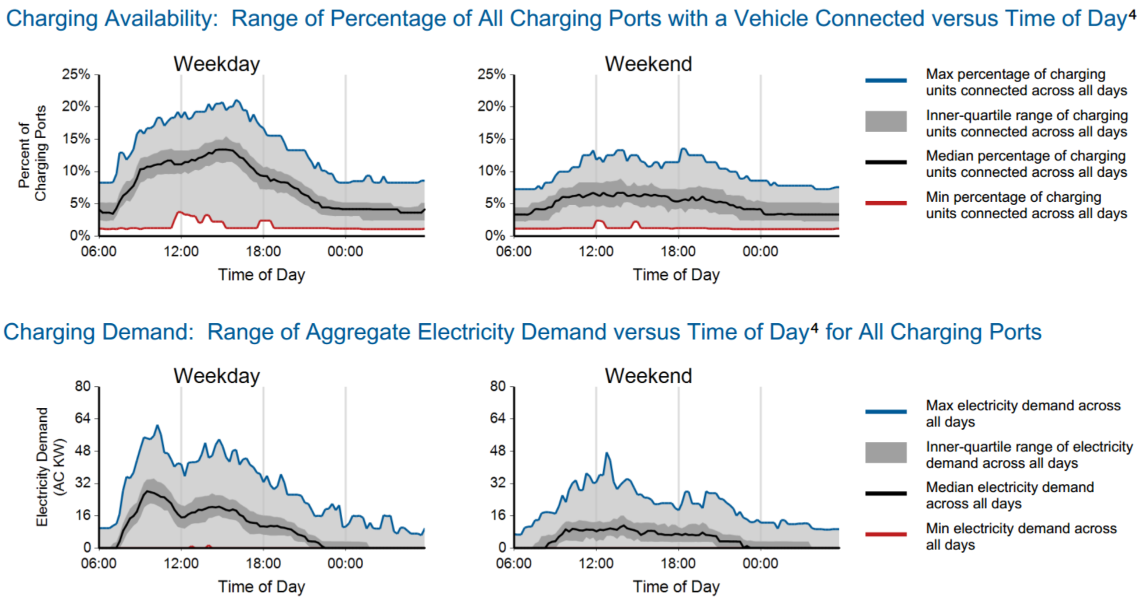
The charging infrastructure in these multiuse parking garages and lots had an average vehicle connection time of 8.4%. This makes these locations one of the more heavily utilized venues. However, the EVs at these locations only drew power 36% of the time they were plugged in. The charge event duration distribution (Figure 31) shows the average event duration is 5.8 hours. This indicates there is an opportunity for the developed strategies to be applied to improve the station use. Under this effort, 95 charging ports at parking facilities outside of NYC were evaluated, with a total of 11,323 charge events.

Figure 31. Multiuse Parking Lots and Garages Outside of NYC Charge Event Duration Distribution



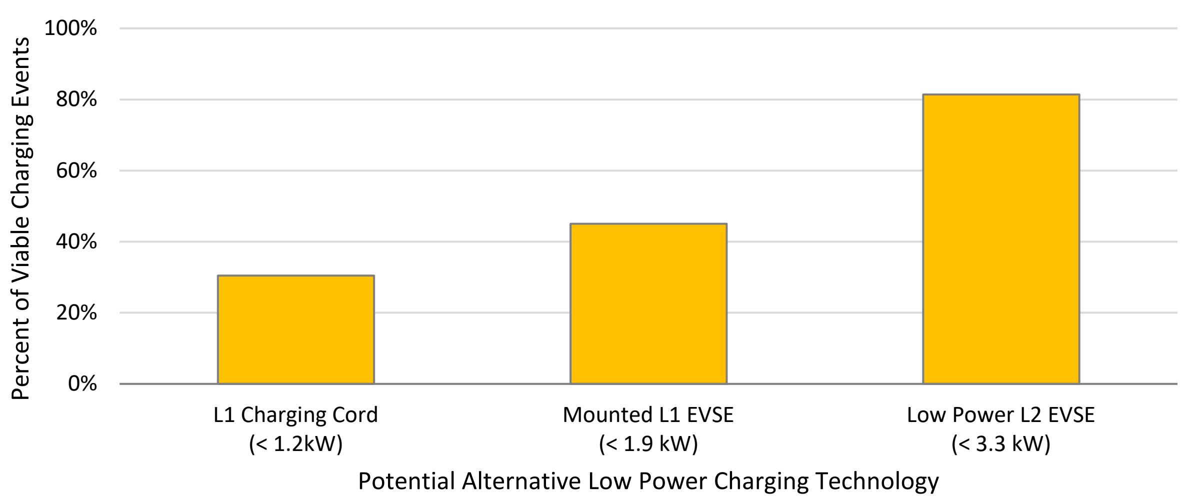
Charging stations located at parking facilities outside of NYC see heavier use during daytime hours on weekdays (Figure 32). There are some EVs that continue to be plugged in throughout the nights at facilities that are likely near downtown residential apartments, but virtually no charging is needed during this time.

Figure 32. Multiuse Parking Lots and Garages Outside of NYC Charging Station Use Profiles



The average energy dispensed per charging event for this parking venue (6.6 kWh) was the lowest of any long-dwell parking venue. This means that even though there are many shorter duration charging events, more than 81% of the events could have been met using a low power (3.3 kW) AC Level 2 charging station (Figure 33).

Figure 33. Non-NYC Multiuse Parking Locations Alternative Charging Power Level Analysis Results



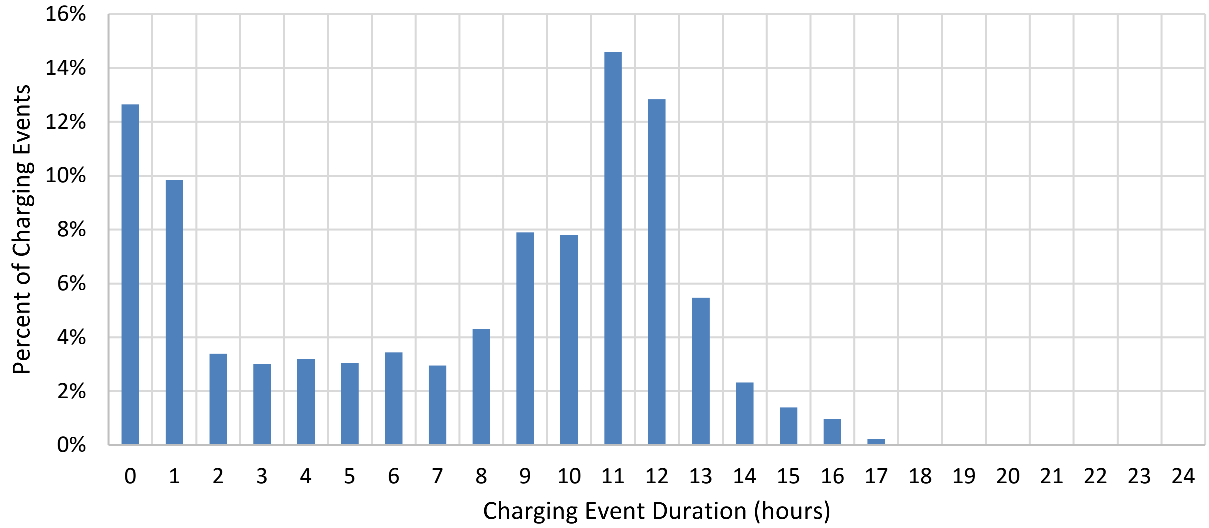
2.7 Bus Terminals and Train Stations

The mass transit facility charging stations analyzed for this study included bus terminals and train stations. Many of these are located in the lower Hudson Valley and Long Island. These parking locations are mainly used for drivers that use public transportation to commute into NYC to work (Figure 34).

Figure 34. Example EV Charging Stations at Transit Locations

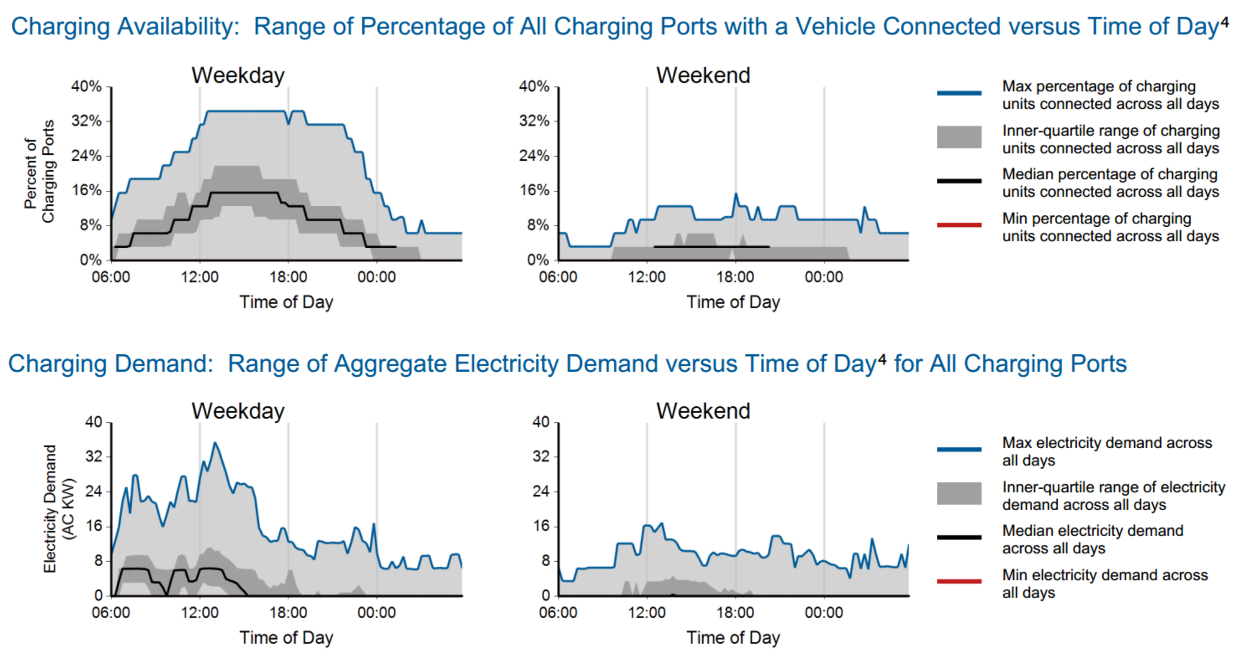
EVSE utilization at transit locations was 6.2%. This was the average for all State long-dwell EV parking venues. The average charging event duration was eight hours (second highest after multifamily dwellings) with about half of the charge events lasting between 9 and 13 hours (Figure 35). The vehicles are being charged less than 30% of the time they are plugged in. Under this effort, 31 charging ports at transit locations were evaluated, with a total of 2,097 charge events.

Figure 35. Transit Locations Charge Event Duration Distribution



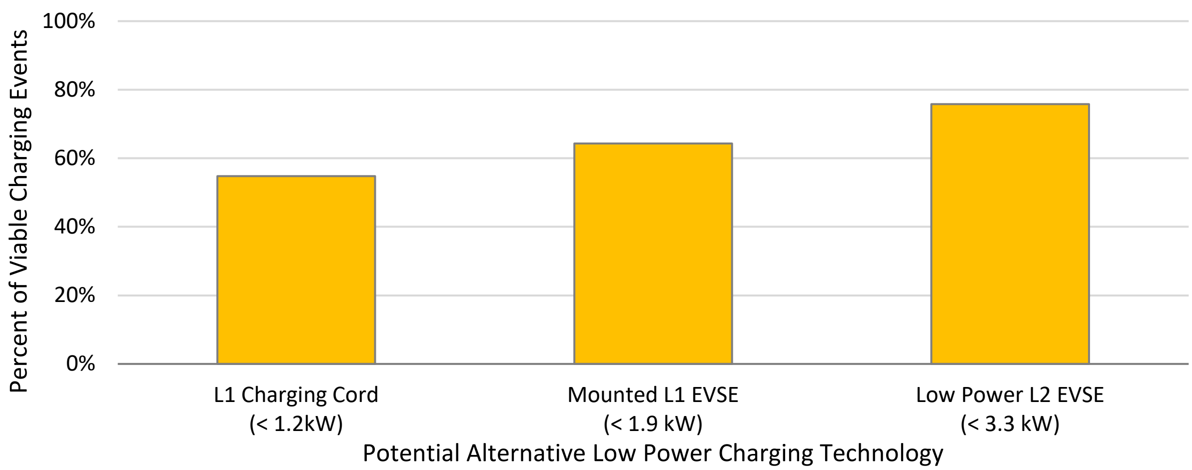
Charging stations at transit locations are used much more heavily by commuters during weekdays between 7 a.m. and 10 p.m. (Figure 36). Electricity demand from charging occurs primarily during weekday mornings after EVs are plugged in when the driver parks to use public transit for the remainder of their commute. There is almost no EVSE use during weekends.

Figure 36. Transit Location Charging Station Use Profiles



For the entire charge event, 25% of charging events required the full 6.6 kW EVSE output power for the entire charge event. The analysis showed that the battery charging demands of most other charging events could have been achieved with lower power level EVSE (Figure 37) because of the extended parking durations. This shows that AC Level 1 charging options are viable charging solutions for a large portion EV charging needs at transit locations.

Figure 37. Transit Location Alternative Charging Power Level Analysis Results



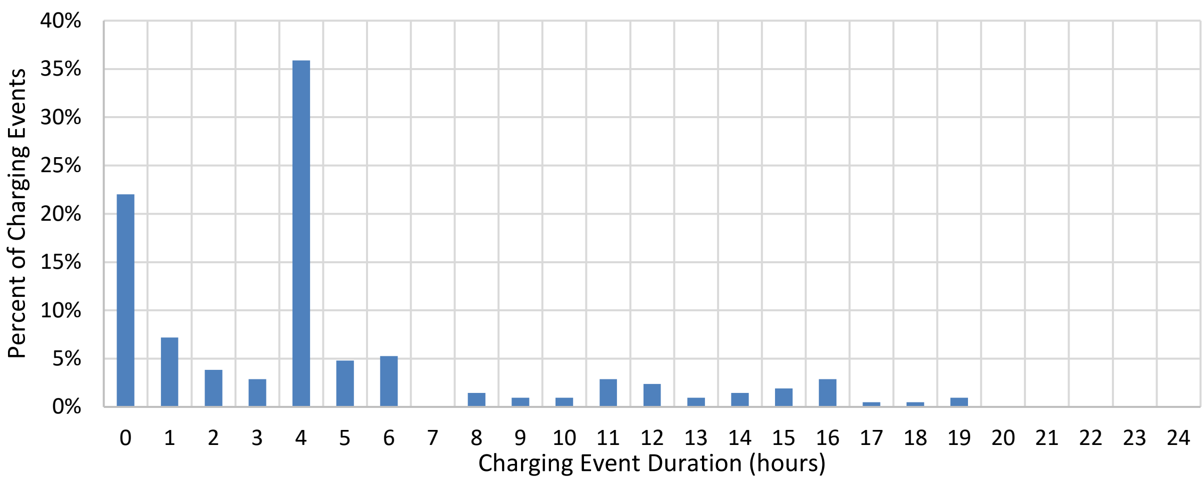
2.8 Airports

EV charging stations have been installed at several State airports including Albany International Airport, Buffalo Niagara International Airport, Niagara Falls International Airport (Figure 38), and East Hampton Airport. These stations were installed in a combination of short- and long-term parking areas. The charging port utilization data available to the project did not designate which type of parking lot they were installed in. Since short- and long-term parking behavior is different, this affects the charging event characteristics when airport parking is considered as a single group.

Figure 38. Example EV Charging Stations at Airports

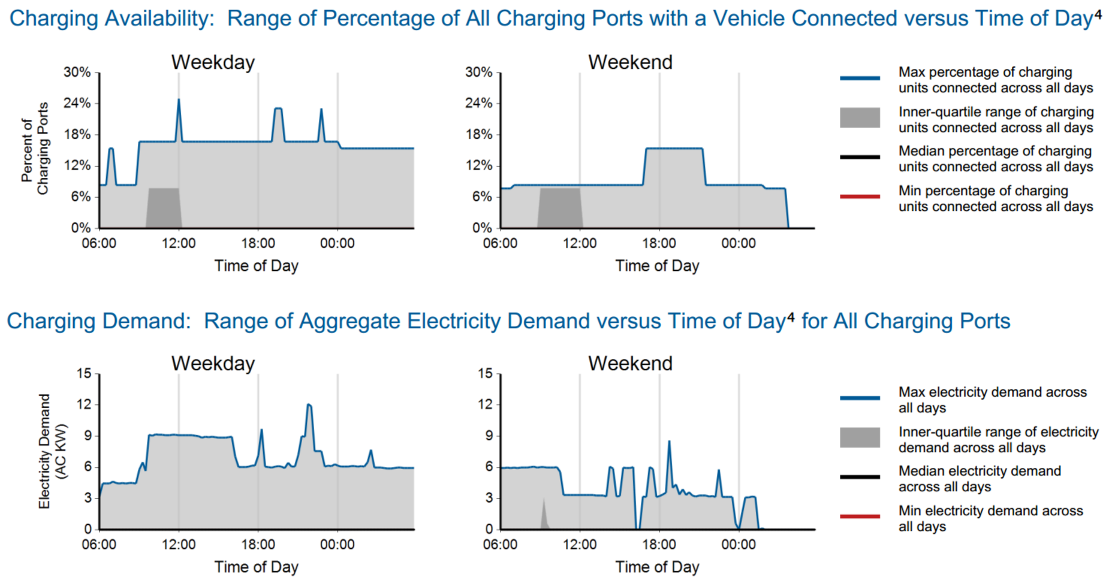
The analysis included data from 13 airport charging stations. Figure 39 shows the charge duration distribution. Several EVSE were used only a few times. EVs were connected to these stations less than 1% of the time and 40% of that time was spent charging on average. The average connection time per charging event was approximate 4.9 hours, but many events lasted 4-5 hours. Charge events lasting less than one hour are likely when the driver was picking up someone from the airport. Parking at an airport for 4-5 hours is not typical, unless these are employees using the charging stations for half of their workday.

Figure 39. Airport Charge Event Duration Distribution



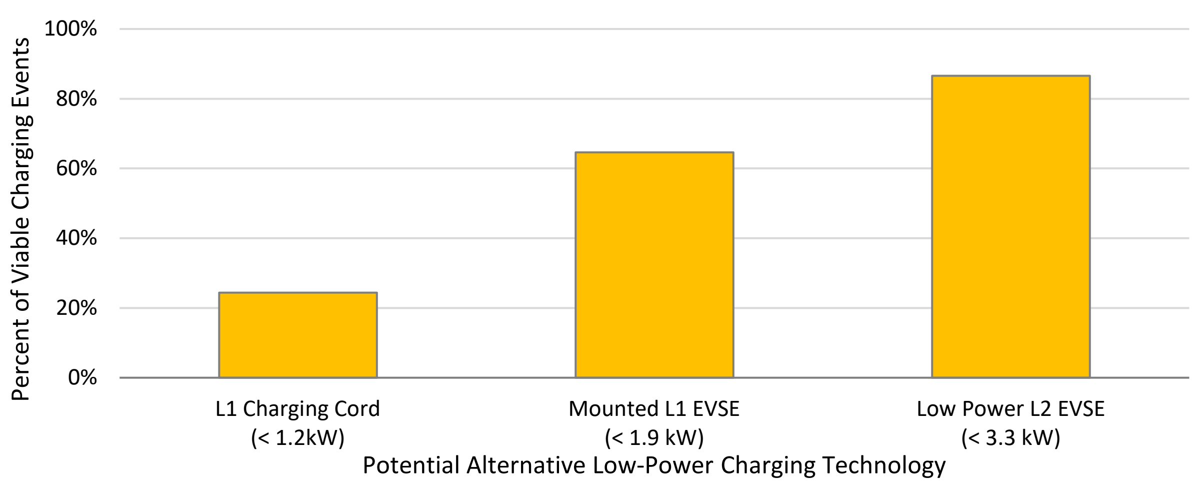
Due to limited charging station utilization, the daily profiles for airport charging stations shown in Figure 40 could not accurately demonstrate typical charging behavior.

Figure 40. Airport Location Charging Station Use Profiles



The airport charging stations provided an average of 6.7 kWh per event, the second lowest amount for all long-dwell EV parking venues in NYS. With the average event duration of 4.9 hours (and many around 4.0 hours), a low power (3.3 kW) AC Level 2 EVSE or an AC Level 1 EVSE could have met most charging events requirements (Figure 41). However, the low station usage and inability to separate the short/long-dwell parking limits these conclusions. It could be assumed that the AC Level 1 charging options would be sufficient for long-term parking since vehicles are likely parked for a day or longer. AC Level 2 charging stations could also be used if a valet service was used to swap EVs once they were charged.

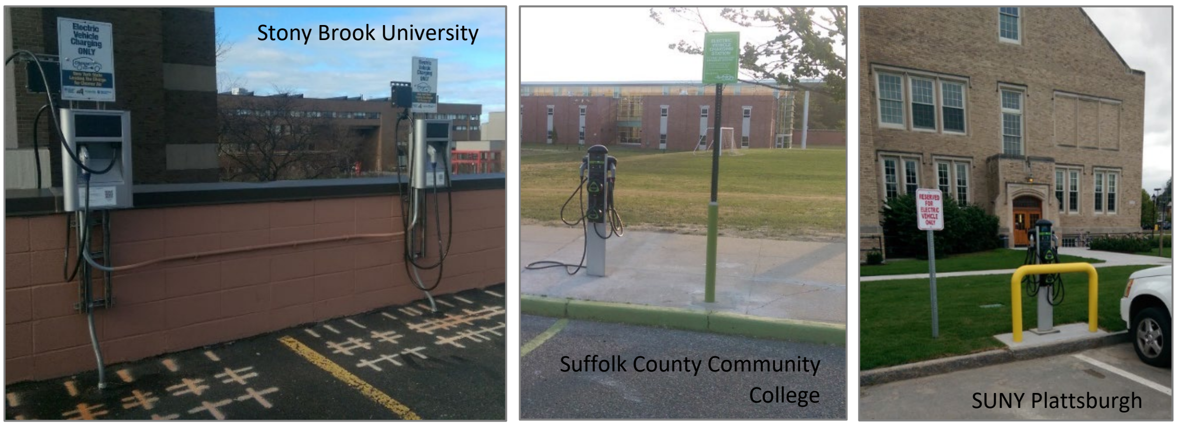
Figure 41. Airport Location Alternative Charging Power Level Analysis Results



2.9 Universities

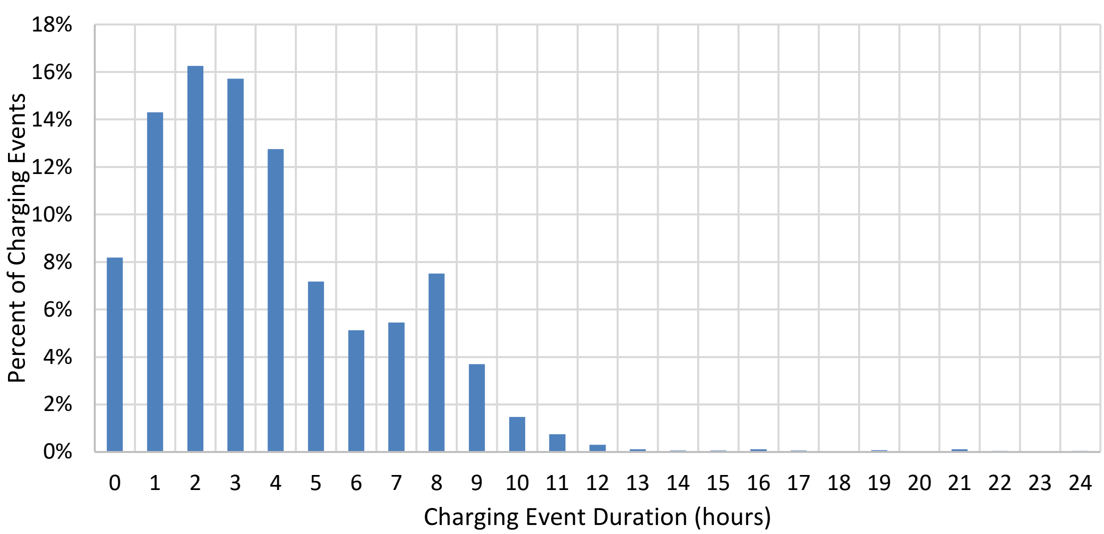
Data from 96 charging ports installed at 55 universities located throughout the State were evaluated to characterize typical charging behavior. These stations are typically available for students, staff, and visitors. (Examples are shown Figure 42). The portion of time the EVSE are used by staff should be classified as workplace charging.

Figure 42. Example EV Charging Stations at Universities



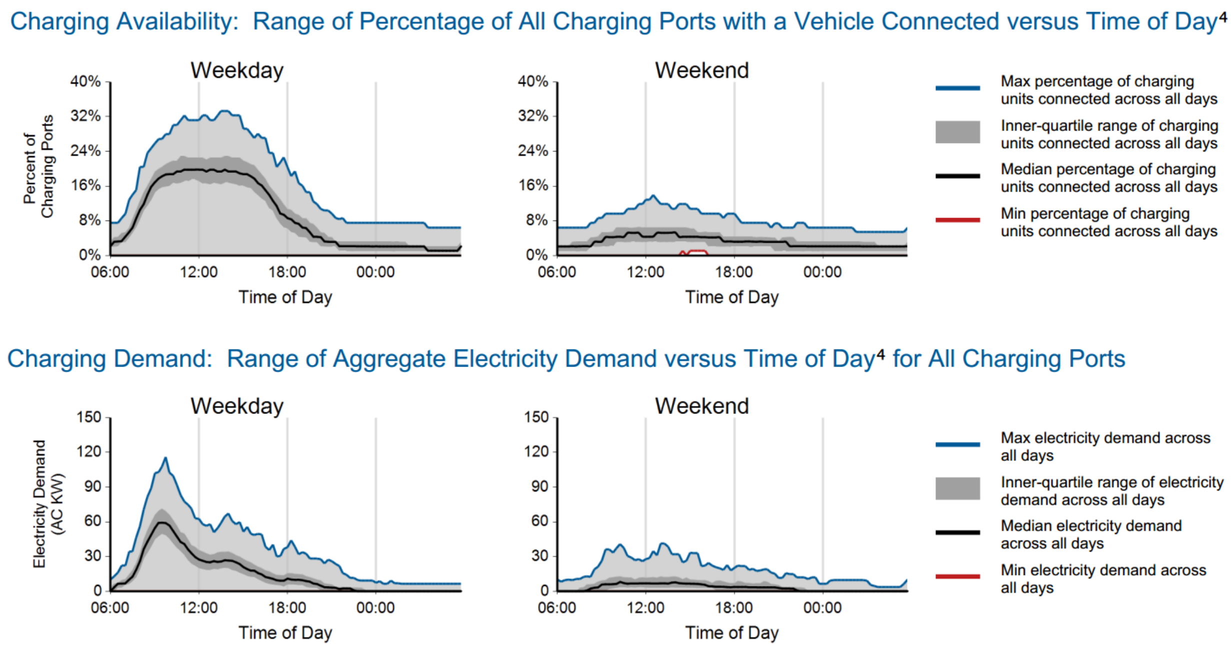
University charging stations had a vehicle connected 8.4% of the time on average. This provided ample data to analyze. From the charging duration distribution data shown in Figure 43, only a few EVs connect for longer than 10 hours. However, there are charge events of various durations under 10 hours, which indicates a mix of station users.

Figure 43. University Charge Event Duration Distribution



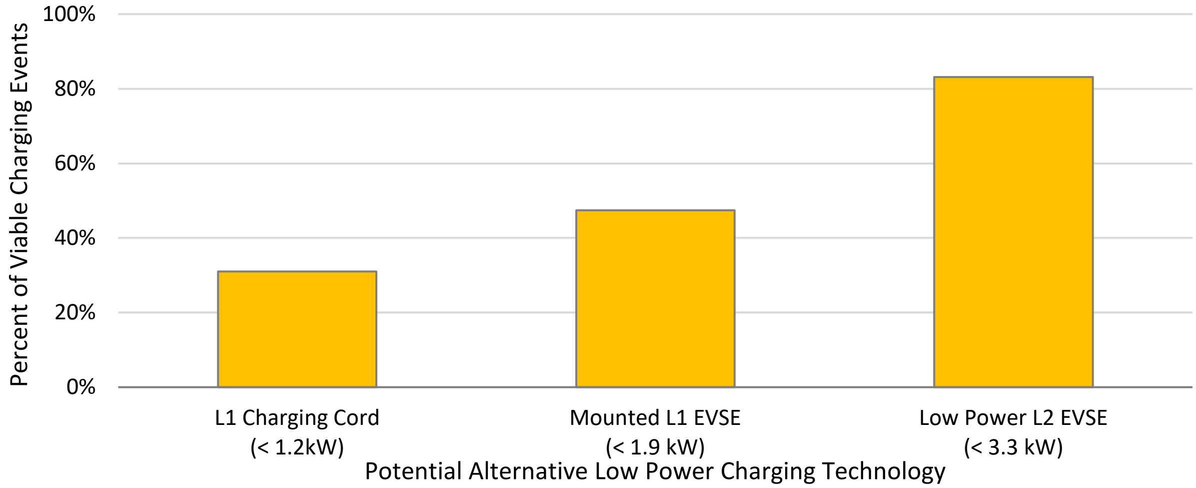
University charging station use is heavily weighted towards weekdays between 8 a.m. and 8 p.m. (Figure 44). Charging demand spikes in the morning when university staff and students likely arrive for work and class, with some additional charging in the early afternoon (perhaps with staff that swap vehicles).

Figure 44. University Location Charging Station Use Profiles



More than 83% of university charging events could have been met using a low power (3.3 kW) AC Level 2 charging station (Figure 45). This would be a viable option if the electric supply power is limited or if the university wanted to increase the number of charging ports without increasing electrical demand. Alternatively, AC Level 1 EVSE could meet 47% and AC Level 1 cordsets could meet 31% of the charging needs.

Figure 45. University Location Alternative Charging Power Level Analysis Results



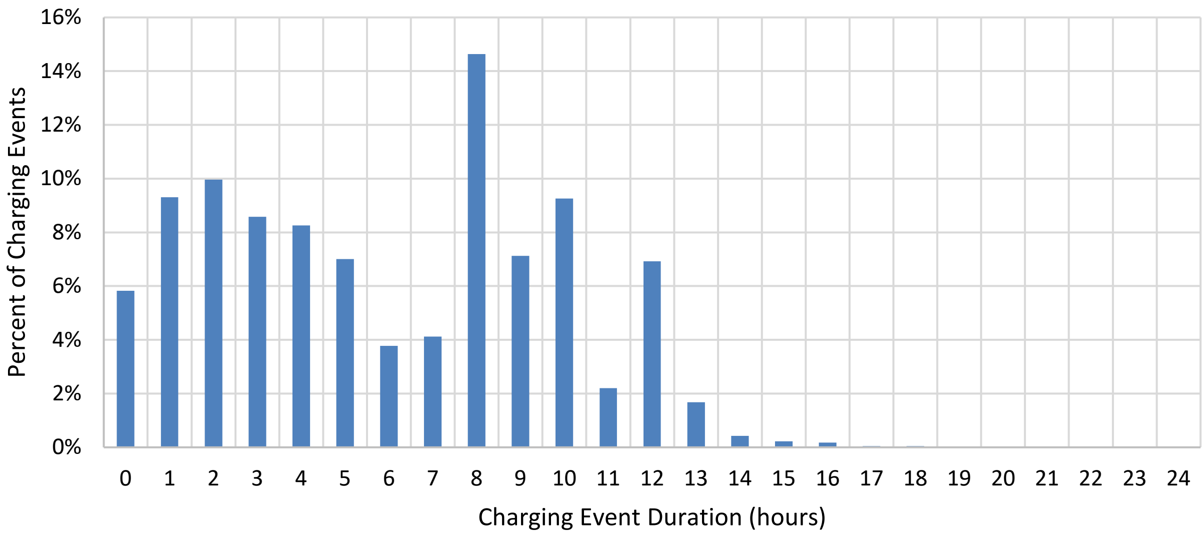
2.10 Healthcare and Medical Facilities

Data from 13 EV charging stations with 25 charge ports located at healthcare and medical facilities throughout the State were evaluated (Figure 46). These stations are installed primarily for staff to use during work hours, but several are also available for visitors or any EV driver to use. Because of this, the healthcare and medical facilities' EVSE can mostly be classified as workplace charging.

Figure 46. Example EV Charging Stations at Healthcare and Medical Facilities

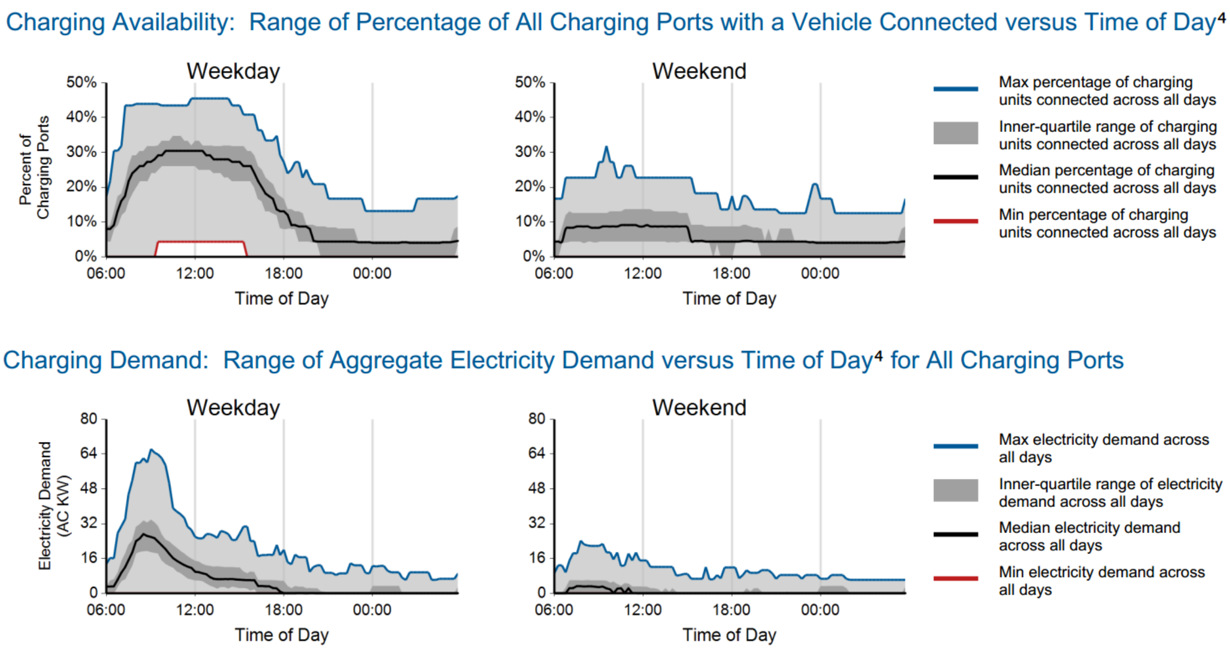
EV charging stations at medical facilities have the highest average utilization levels. Vehicles were connected 14% of the time and the average charge event duration was 6.5 hours. Figure 47 shows the charge event duration distribution. Many are between 8 and 11 hours (correlating to a the typical staff workday). However, approximately half of the events are less than six hours long, which may indicate visitor use.

Figure 47. Healthcare and Medical Facility Charge Event Duration Distribution



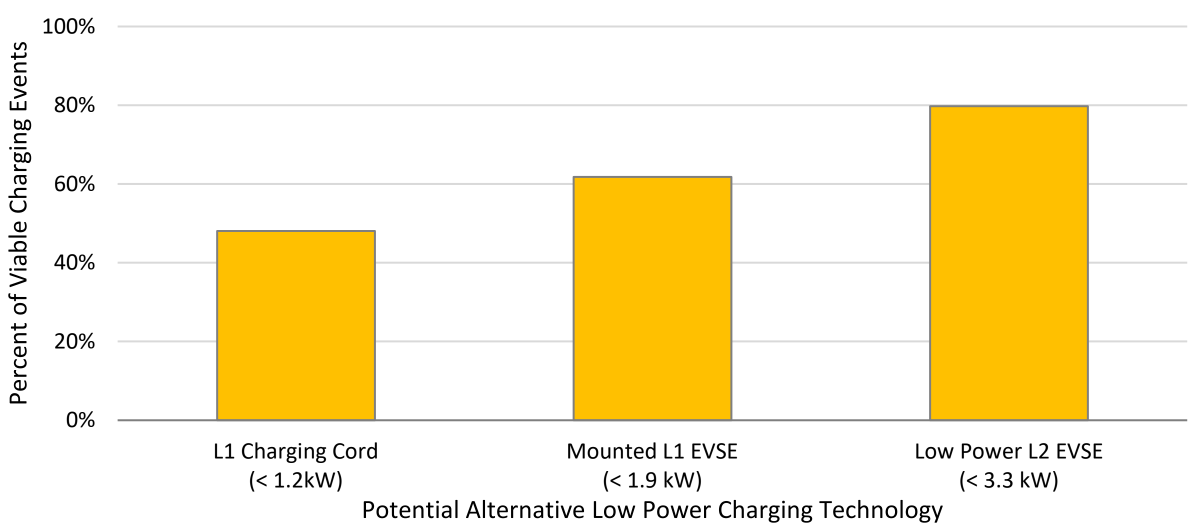
The charging profiles in Figure 48 show the majority of EV charging events occur on weekdays from early morning to evening. Power was delivered mostly in the morning hours of weekdays, which closely aligns with when employees arrive for work.

Figure 48. Healthcare and Medical Facilities Charging Station Use Profiles



Some of the shorter duration charging events would benefit from a 6.6 kW AC Level 2 EVSE to accomplish the desired charge. Low power AC Level 2 charging stations could have met the charging needs of 79.7% of the charge events (Figure 49) A large portion of charging events could have been accomplished with lower power options; AC Level 1 charging station (over 61.8%) and AC Level 1 cordset (48.1%).

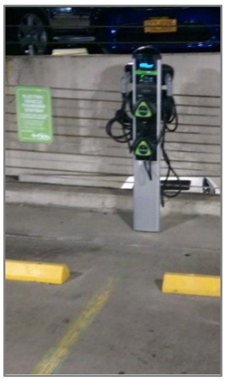
Figure 49. Healthcare and Medical Facilities Alternative Charging Power Level Analysis Results

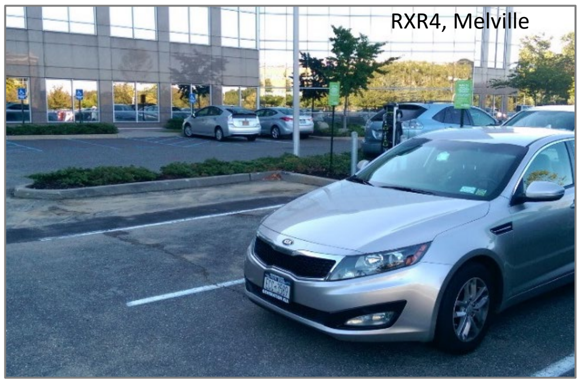


2.11 Business Offices

Charging stations at business offices throughout the State (examples shown in Figure 50), are installed primarily for employees, but can also be used by visitors or other EV drivers. Like with healthcare and medical facilities, business office' EVSE can mostly be classified as workplace charging.

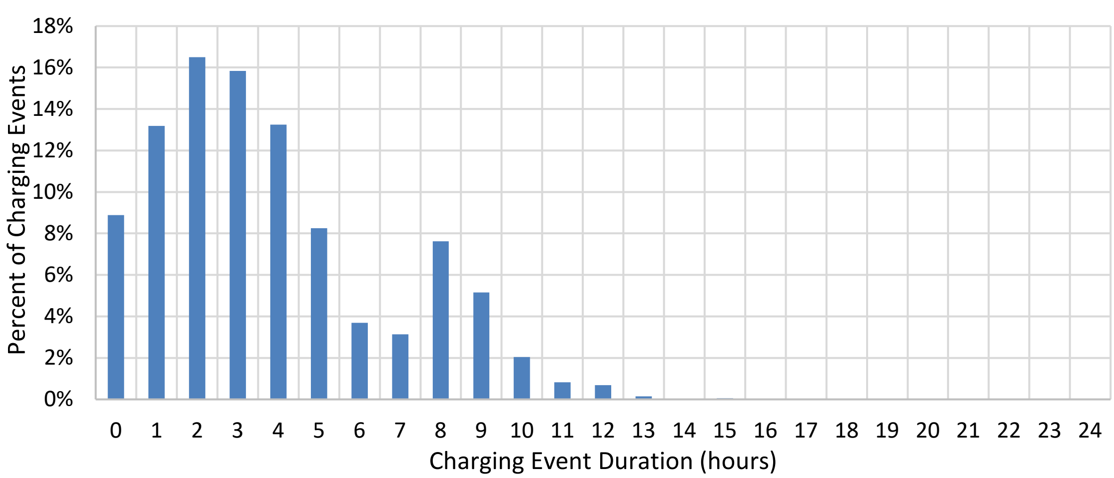
Figure 50. Example EV Charging Stations at Business Offices





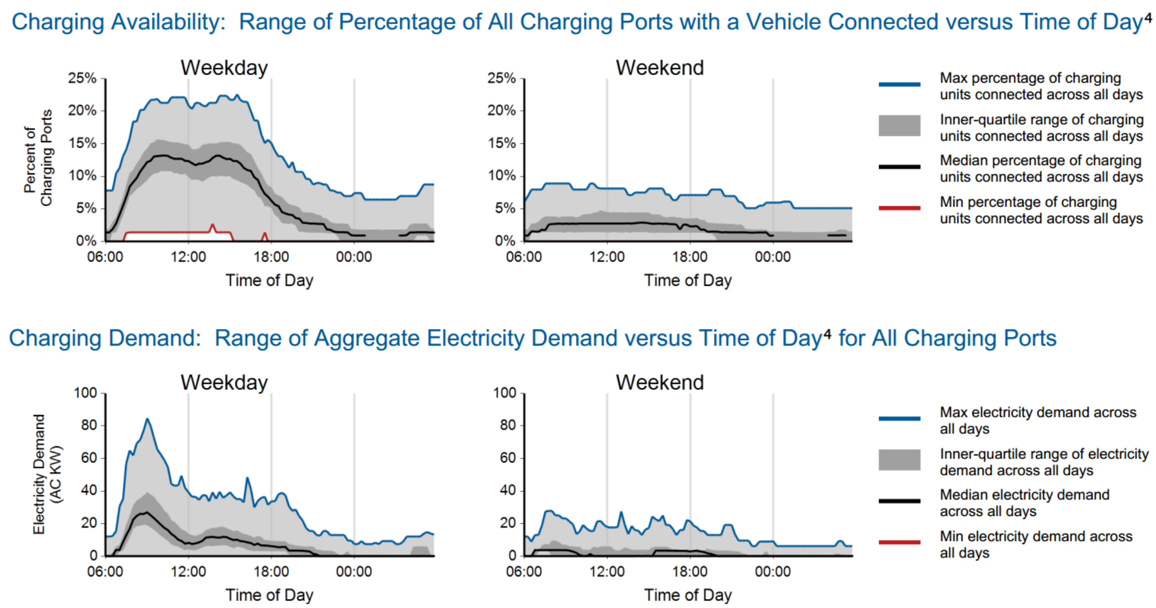
The 88 charging ports at business offices only had an EV connected 4.2% of the time on average. This is lower than average for long-dwell EV parking venues in the State. Some charging events lasted all workday (8-10 hours), but the duration for most of the charging events was between 1 and 5 hours (Figure 51). This may indicate that employees move their EV after it is charged to free up the EVSE for others. The average event duration at business office charging stations is 4.6 hours, the second shortest of all long-dwell EV parking venues in the State. Under this effort, 88 charging ports at business office locations were evaluated under this effort, with a total of 6,290 charge events.

Figure 51. Business Office Charge Event Duration Distribution



Since they are used for employee charging, business office stations are occupied almost exclusively during daytime hours on weekdays, with limited charging events on the weekends (Figure 52). The number of vehicles connected and charging demand has peaks in both the morning and early afternoon with a low around midday when EV drivers go out to lunch or potentially move the vehicle to a standard parking space so another EV driver can use the charger.

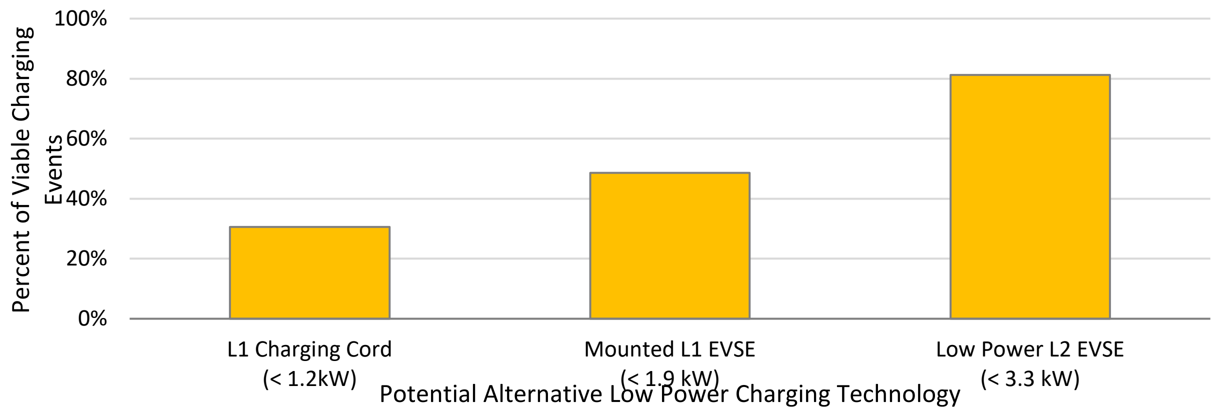
Figure 52. Business Office Charging Station Use Profiles



With shorter average event durations and the likelihood that EV driving coworkers are sharing charging stations, EVs drew power approximately 50% of the time they were plugged in. This is the second highest of all long-dwell EV parking venues in the State. This limits the need for lower power charging solutions. This is particularly true for the AC Level 1 options which were estimated to meet between 30.5% and 48.6% of all charging events (Figure 53). However, low power (3.3 kW) AC Level 2 stations were estimated to have been a viable option that would meet the needs of most charging events (81.3%).

If employees regularly move their EV once charged to accommodate others, having more AC Level 1 EVSE instead of sharing AC Level 2 EVSE could be a more convenient option for employees. This option, however, would not satisfy the EV charging needs of visitors that park for a shorter time and need a quicker charge.

Figure 53. Business Office Alternative Charging Power Level Analysis Results

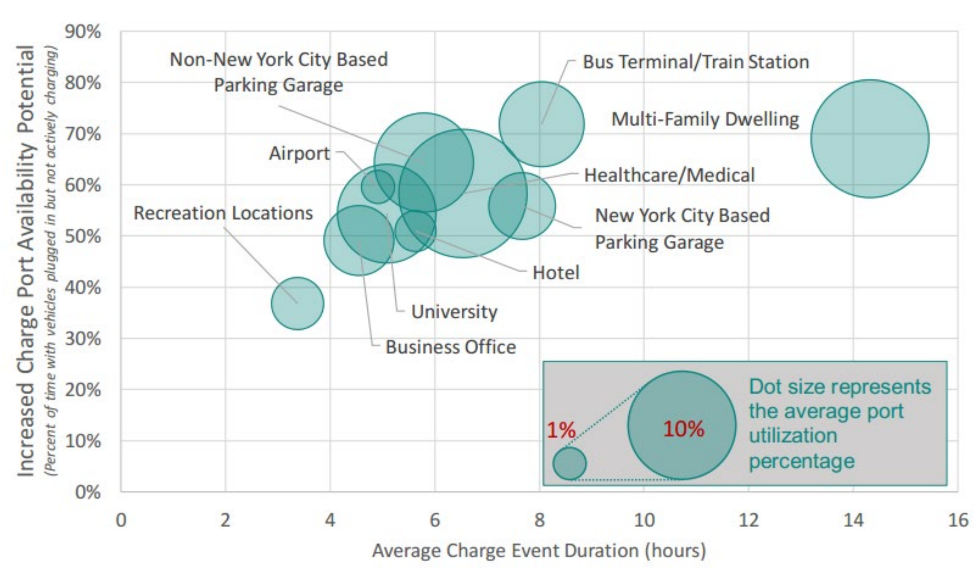


2.12 Use Case Analysis

There are unique situations and EV clients at individual charging station locations as demonstrated by the variation in charge event durations and different percentage of charge events that could have been met by lower power charging stations. Therefore, lower cost charging solutions should be evaluated on a per-site basis, but certain types of long-dwell EV parking venues showed better potential to implement different management or hardware strategies. Figure 54 shows several EV charging characteristics for each venue type, including: 1) the average charge event duration (total time connected to a charging station) (x-axis), 2) the potential for increased station utilization from shared station use (related to the percentage of time EVs were connected to charging stations, but not drawing power) (y-axis), and 3) the average charging station utilization (larger dots indicate longer average connection times). Prime candidates for implementing lower cost management or lower power hardware strategies have a long average charge event duration (right), high potential for increased charge port availability (top), and higher utilization (large dots).

The data analysis results show that the average energy provided per long-dwell charging event at most State long-dwell parking venues is less than 10 kWh (approximately 28 miles of driving range). A few venues averaged higher per charge event energy demands: multifamily dwellings, multiuse parking facilities, and hotels.

Figure 54. Long-Dwell EV Charging Station Usage Characterization



Multifamily dwellings had an average energy provided per long-dwell charging event of 17 kWh (approximately 49 miles of driving range). This and the usage characteristics indicate high potential for implementing charging stations management and/or hardware strategies to lower the installation and operations costs or to maximize the usage so additional stations are not needed. These stations typically experience regular use and have EVs connected for long durations after charging has been completed. Charging stations at transit facilities are also occupied much longer than necessary for charging and have regular long duration events. These two venues typically serve the same EV drivers daily while the EVs are parked for a period of eight hours or more for an entire workday (transit) or overnight (multifamily dwellings).

Consistent and long charge events are also typical at several venues that serve as workplace charging (healthcare, university, and business offices). Workplace charging would likely have the same EVs charging on a regular basis. Charging event activity at healthcare and medical facilities lasted longer and were more frequent, which makes them the best workplace candidates. Charging stations at universities and business offices had shorter average event durations and less utilization; however, this could be partially due to employees managing station use by moving vehicles during the day. Locations that move vehicles midday are often smaller workplace settings where EV drivers can easily coordinate with each other for charging schedules. While this strategy is effective, implementing automated technology-based management strategies and/or installing more low power charging stations might be more convenient for EV owners.

Multiuse parking facilities, both in NYC and statewide, have a much higher variety of EV charging use. Multiuse parking facilities in NYC averaged 17 kWh (approximately 49 miles of driving range) per charge event. Some facilities, particularly the NYC garages, serve EV drivers that park for extended periods including use as their primary residence parking. These garages and lots are also used frequently by other visitors that park for a much shorter duration. Each of these charging station locations needs to be evaluated on an individual basis to determine the value of the management or hardware strategies to lower installation costs or maximize use. Long-term parking at airports should be an ideal application for such strategies when EV drivers leave their vehicles for days during travel. Unfortunately, the analyzed charging station use at State airports was too limited to show this, and some of those EVSE were placed in short-term parking lots where they may be used by employees or EV drivers picking up travelers from the airport.

Two other types of long-dwell EV parking venues, hotels and recreational locations, also had very limited operation data available, so definitive conclusions cannot be made. There was a wide range of charging event durations at these venues. There were some longer, likely overnight, charging events at hotels. There were also many shorter charging events that may have occurred when the EV driver first arrived and needed to charge the battery before going out for food or entertainment. EVs arriving at hotels are also likely coming from farther away, so a longer charge event is needed. A higher powered EVSE may be desired for these instances. Parks/ski mountain recreation locations also had very limited charge event data, so may not be an ideal application for management or hardware strategies to lower installation costs or maximize use due to widely varying arrival times, parking durations, seasonal use, and range of EV drivers that visit there.

The most viable potential type of management or hardware strategy for each long-dwell EV parking venue is influenced by a number of factors, including the following:

- **Charging Port Utilization**: average percentage of time a vehicle is connected to the charging station
- **Potential for Shared Station Use**: average percentage of charge events that an EV was connected to a charging station but not drawing power
- **Energy Dispensed per Charge Event**: average kWh supplied by the charger
- **EV Movability Potential**: the estimated availability of an EV driver to move the vehicle after it is fully-charged
- **Average Charge Event Duration**: average number of hours a vehicle remains connected per charge event

- **Time-of-Day Variability**: standard deviation of the connection percentage throughout a 24-hour period
- **1.4 kW AC Level 1 Cordset Potential**: percentage of charging events that could have been completed using the portable charging cordset and a dedicated AC Level 1 GFCI outlet
- **1.9 kW AC Level 1 EVSE Potential**: percentage of charging events that could have been completed using a 1.9 kW AC Level 1 EVSE
- **3.3 kW AC Level 2 EVSE Potential**: percentage of charging events that could have been completed using a 3.3 kW AC Level 2 EVSE

These factors were calculated for each long-dwell EV parking venue type using usage data from NYSERDA supported EVSE from 2016 (the most recent data available). Table 5 presents the results. These values are overall averages for the venues and will vary for individual sites throughout the State.

Table 5. Long-Dwell Parking Venue EV Charging Characteristics

	Multi-Family Dwelling	Bus Terminal/Train Station	Healthcare/Medical	University	Business Office	Parking Facilities Outside of NYC	NYC Parking Garages and Lots	Airport	Hotel	Recreation Locations
Charging Port Utilization (%)	11.9	6.2	14.0	8.4	4.2	8.4	3.9	1.0	1.5	2.4
Potential for Shared Station Use	69%	72%	58%	54%	49%	64%	55%	59%	51%	36%
Energy Dispensed per Charge Event (kWh)	17.1	8.7	9.6	7.4	7.5	6.6	17.1	6.7	12.1	8.0
EV Movability Potential	Low	Low	Med	High	High	Med	Med	Low	Med	Med
Average Charge Event Duration (hr)	14.3	8.0	6.5	5.1	4.6	5.8	7.7	4.9	5.6	3.4
Time-of-Day Variability (standard deviation)	3.5	2.5	8.6	19	8.3	12.6	4.4	N/A	N/A	N/A
AC Level 1 Cordset (1.4 kW) Potential	42%	55%	48%	31%	31%	30%	19%	24%	21%	13%
AC Level 1 EVSE (1.9 kW) Potential	58%	64%	62%	47%	49%	45%	29%	65%	30%	24%
AC Level 2 EVSE (3.3 kW) Potential	83%	76%	80%	83%	81%	81%	57%	87%	57%	73%

3 Low-Cost Strategies for Installing New Long-Dwell EV Charging Stations

As described earlier, several key factors influence the equipment and installation costs when installing EV charging infrastructure. Table 6 compiles the infrastructure costs, electric power requirements, maximum power output, and the estimated maximum electric miles of range can be provided by each charging infrastructure option using information provided earlier in this document.

Table 6. EV Charging Infrastructure Specifications, Performance, and Cost Characteristics

Type	Charging Infrastructure Cost	Installation Cost	Input Power	Maximum Output Power (kW)	Driving Miles per Hour Charge	Maximum Driving Miles per Six Hour Charge	Maximum Driving Miles per Nine Hour Charge
AC Level 1 Outlet	$100	$100-$1,000	120VAC, 15-20 A	1.4	5	30	45
AC Level 1 EVSE	$300-$1,500	$300-$5,000	120VAC, 20 A	1.9	7	42	63
AC Level 2 EVSE (low power)	$300-$1,500	$500-$8,000	240VAC, 20 A	3.3	10-12	60-72	90-108
AC Level 2 EVSE	$400-$6,500	$1,000-$10,000	240VAC or 208VAC, 40 A	6.6	20-25	120-150	180-225

Charging station installation planning should always consider the potential future demand for additional charging points and develop a flexible approach to minimize future installation work. For example, use a larger diameter conduit than needed, or install additional conduit to simplify future station installations. If additional electrical service is installed or a subpanel is added, sufficient additional capacity to add more charging stations should be included if feasible.

3.1 Potential Installation Strategies

The installation strategies for new charging station installations identified in this project are summarized to outline the equipment required and describe how each option would be implemented. The technologies and commercial product examples were presented in earlier sections of this report.

3.1.1 AC Level 1 GFCI Outlets

Providing AC Level 1 GFCI outlets for EV drivers to use their AC Level 1 EVSE Cordsets is the lowest cost EV charging infrastructure option. It is recommended this solution be for limited use only since the outlets are not designed to handle frequent connections at maximum power. This option, however, can be a good initial step for parking facilities who are interested in providing charging for a low cost, but are uncertain about making an investment in the type of charging infrastructure, or who are uncertain about the EV parking customer's charging demand. Installing the conduit and electrical wiring for the dedicated circuit is the highest portion of the cost for this solution. AC Level 1 charging stations use the same electrical wiring infrastructure, so the charging infrastructure could be upgraded in the future if needed once EV charging demand increases and the system's costs are quantified for the parking facility operator. The largest potential savings of this approach are from low hardware costs, low installation costs, lower electrical service cost, and minimizing demand charges.

3.1.2 AC Level 1 EVSE

AC Level 1 EVSE provide sufficient energy for many long-dwell charging events. These charging stations limit the total peak power and maximum sustained power draw compared to AC Level 2 EVSE. This reduces electrical infrastructure installation (new installations) and modifications (expanded and upgraded installations). These factors are more critical when several charging stations are installed. Two AC Level 1 EVSE can be installed in place of a standard AC Level 2 EVSE to provide double the number of charging ports and still serve the customers' charging needs. AC Level 1 EVSE hardware and installation costs are only slightly lower than for AC Level 2 EVSE. The largest potential savings from using this approach is from lower electrical service cost and minimizing demand charges.

3.1.3 Low Power AC Level 2 EVSE

Low power (3.3 kW) AC Level 2 EVSE provide sufficient energy to EVs for most long-dwell charging events. This can be an option to increase the number of available charging ports, compared to AC Level 2 EVSE, while providing higher charging power than AC Level 1 infrastructure and limiting the required electrical service capacity. The higher power compared to AC Level 1 will satisfy parking customers that park for somewhat shorter durations and/or require more charge. Because standard AC Level 2 hardware is used, if needed at a later time the full power capability (e.g., 6.6 kW) can be achieved with an electrical service capacity upgrade. The largest potential savings from using this approach is from lower electrical service costs and reducing demand charges.

3.1.4 AC Level 2 EVSE Plug Sharing

AC Level 2 charging station plug sharing, either by vehicle owners or by a valet service, can be an option for long-dwell parking situations where AC Level 2 charging is needed but there is limited available electrical service capacity, limited charging infrastructure, and/or minimizing demand charges is critical. As a convenience, additional designated EV parking (without a charging station) spaces could be designated near the charging stations to provide drivers with a convenient nearby spot to move their vehicle once charged. This approach that maximizes the EVSE utility but requires action by the EV drivers or valet service which is not feasible in every setting. The largest potential savings from using this approach is from reducing equipment costs, decreasing demand charges, and avoiding/delaying electrical service upgrades.

3.1.5 AC Level 2 EVSE Power Management

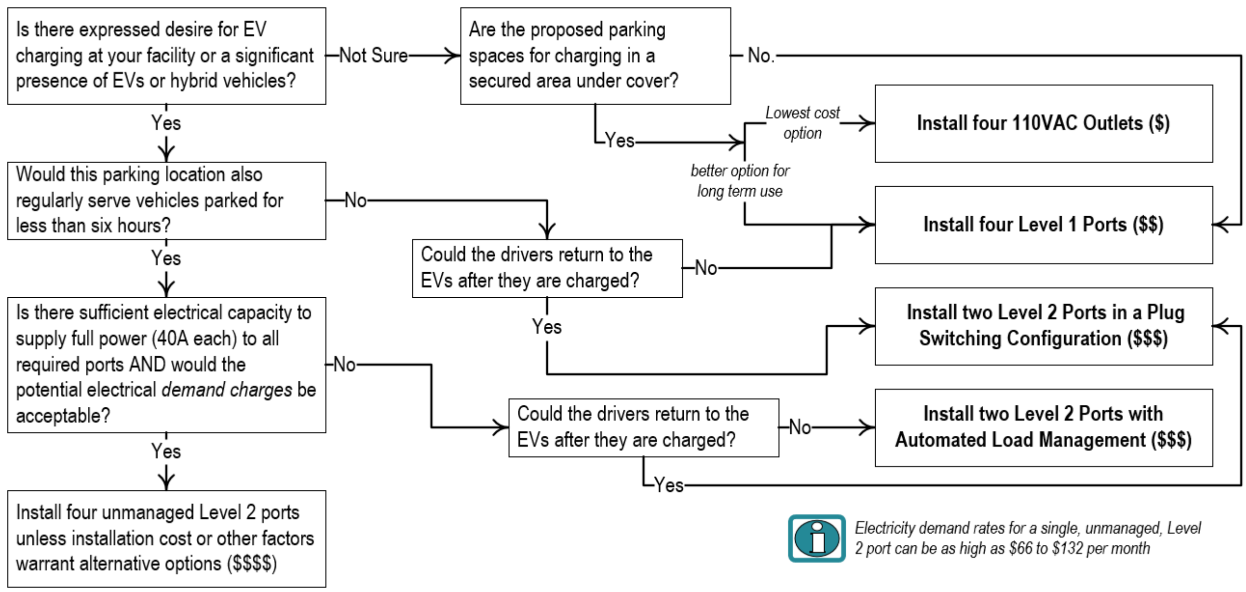
Installing either power sharing dual-port AC Level 2 EVSE or an automated power management system can be a cost-effective strategy for long-dwell parking situations where the AC Level 2 charging is needed, but there is limited available electrical service capacity and/or minimizing demand charges is critical. The largest potential savings from using this approach is from reducing demand charges and electrical service costs.

3.2 Long-Dwell EV Parking Charging Strategy Selection

Several site-specific factors are used to determine the best low-cost installation strategy for each host site. The simple decision flowchart (Figure 55) was developed using these factors for host sites to use to identify the appropriate installation strategy. The decision tree structure assumes:

- The majority of EVs are plugged in for six hours or more (long-dwell parking).
- The decision tree addresses locations that have some shorter duration EV parking. The decision tree should not be used for locations with mostly short duration EV parking.
- Four vehicles will be charged during the same long-dwell period. (Note: Most strategies can be scaled for either more or less vehicles. The electrical service capacity requirements become a more critical factor in the decision process for larger installations.)
- The comparison baseline is the most common commercial charging station hardware; a dual-port high-power (6.6 kW) AC Level 2 charging stations. Two dual-port EVSE are needed to charge four EVs in the same period.
- The questions are designed so most site host owners, or facility managers will be able to answer them, but additional input from facility personnel or an electrician may be needed.

Figure 55. Decision Tool Strategies and Techniques for Reducing the Installation and Operating Costs of EVSE for New Installations



There are several potential options sets for each long-dwell parking venue based on the site-specific conditions. Because of this, it was not practical to attempt to describe every possible permutation and decision path through the flowchart. Instead, three test cases were developed for the installing new charging infrastructure situation to serve as a guide/example for end users' use of the tool.

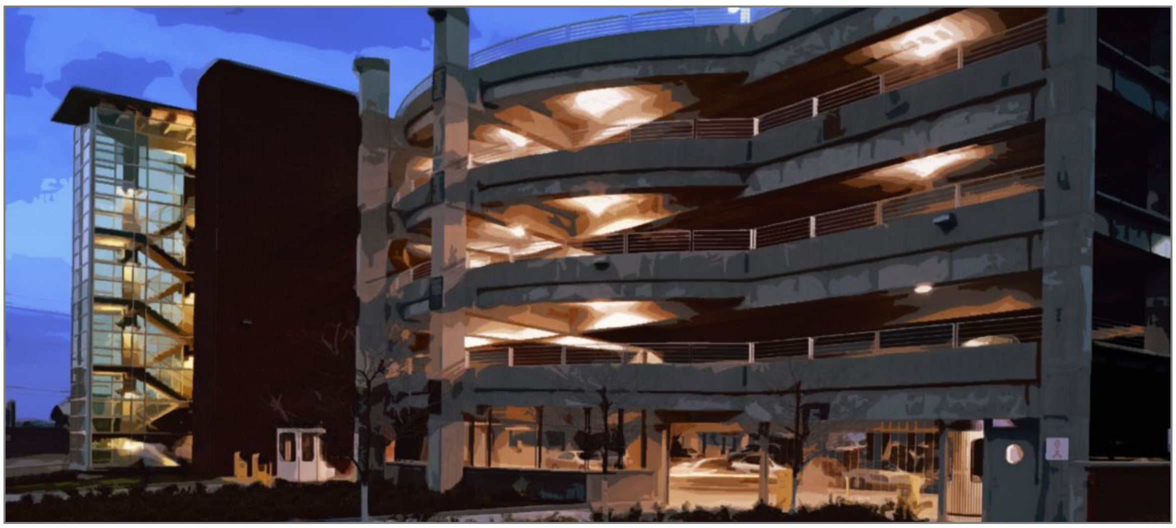
3.3 Example Test Cases – New Installations

There are several potential options sets for each long-dwell parking venue based on the site-specific conditions. Because of this, it was not practical to attempt to describe every possible permutation and decision path through the flowchart. Instead, three test cases were developed for installing new charging infrastructure to serve as a guide/example for end users' use of the tool. An example of the process' use and results for each is shown as follows.

3.3.1 Airport Test Case

Parking events at airports are typically quite long since users are away for one or more days. Airports typically have many parking lots and garages around the terminal (example shown in Figure 56) for long-term parking. It is assumed that no charging stations have been installed at the airport in this example. Locating the charging stations within the parking garage simplifies installation, protects them from the weather, and increases the confidence of plugging in during travel times. Potential charging station utilization rates are not fully known, but interest has been shown from airport commuters.

Figure 56. Example Airport Test Site Layout



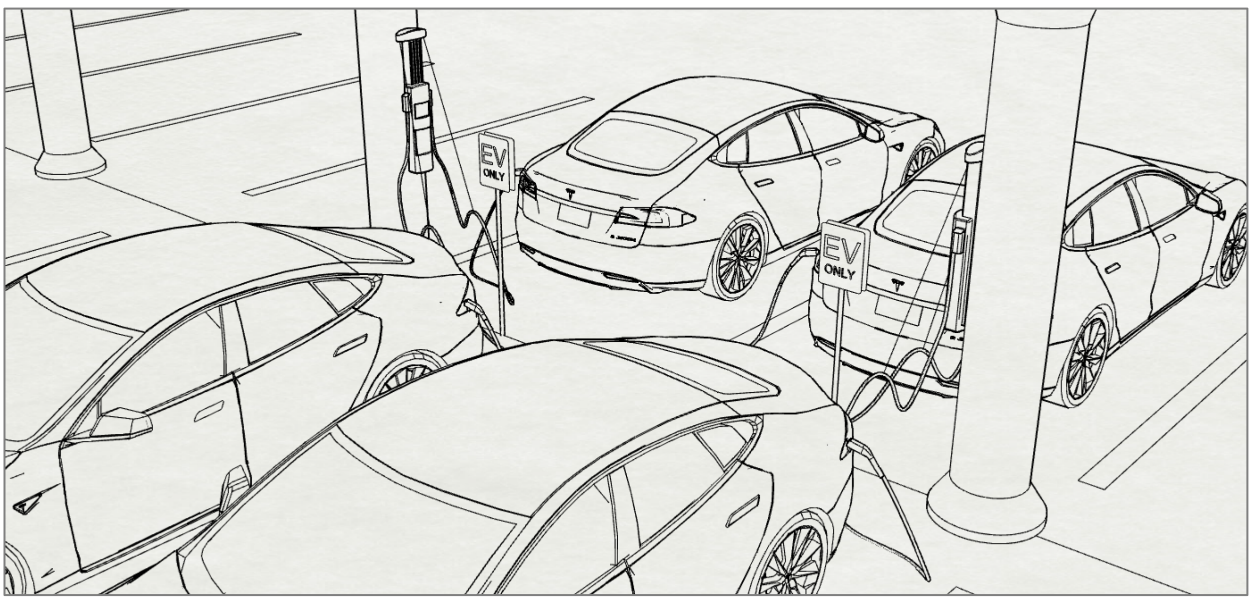
Using the strategies for new stations charging infrastructure decision tree flow chart to determine a strategy for increasing charging capacity at this site, could result in the following:

- Is there expressed desire for EV charging at your facility, or a significant presence of EVs or hybrid vehicles?
    - YES. There has been some interest from commuters using the airport. PHEV owners looking for ways to offset more gasoline use are also typical first users of new stations at these locations.
- Does this parking location also regularly serve vehicles parked for less than six hours?
    - NO. Customers travel long distances and rarely return within the same day. Dwell times at these locations will likely range from 10 hours to many days.
- Could the drivers easily return to the EVs after they are charged?
    - NO. Drivers do not have access to the vehicles during charging periods (and there are no valet services at this location). Manual plug sharing is not feasible.

- Recommendation
  - Two dual-port AC Level 1 stations positioned to allow four EVs to simultaneously charge would be the most cost-effective option at this location. This option would likely top off the battery charge before the EV owners return.

Two dual-port AC Level 1 stations could be positioned (as shown in Figure 57) to charge four vehicles simultaneously. Because of the low charging power level of these stations vehicles would remain plugged into the same charging port for the duration of their stay, so additional spaces for plug sharing are not necessary.

Figure 57. Proposed EVSE and EV Parking Layout at Airport Locations



By installing two dual-port AC Level 1 charging stations, the facility would save an estimated $2,600 compared to installing two dual-port AC Level 2 stations (shown in Table 7). Because of the extremely long-dwell charging and inability to switch plugs between vehicles during the day, this low power option would charge the highest number of vehicles at the lowest cost. Maximum annual demand charges are estimated assuming $10 per kW charge and that all charging load would be in addition to the current facilities maximum demand. Demand cost estimates are the worst-case scenario for each option, but are possible if the stations are heavily used.

Table 7. Estimated Charging System Costs for Airport Locations

Hardware	Hardware Cost	Installation Cost	Total Installed Cost	Maximum Annual Demand Charges	5-Year Costs
Install Four AC Level 2 Charging Ports (baseline)	$4,400	$5,000	$9,400	$3,168	$25,240
Install Four AC Level 1 Charging Ports (proposed)	$3,400	$4,000	$7,400	$912	$11,960
Potential Savings	**$1,000**	**$1,000**	**$2,000**	**$2,256**	**$13,280**

3.3.2 Multiuse Parking Garage Test Case

Parking garages near residential areas (example shown in Figure 58) in heavily urban areas typically serve a mix of local residents and short-term visitors. Local residents' vehicles are parked for extended periods overnight. During daytime hours, the garage may serve drivers parking all day for work or retail customers parking for shorter periods. Charging infrastructure must support a variable number of EVs throughout the day with sufficient power levels to accommodate the shorter-term visitors.

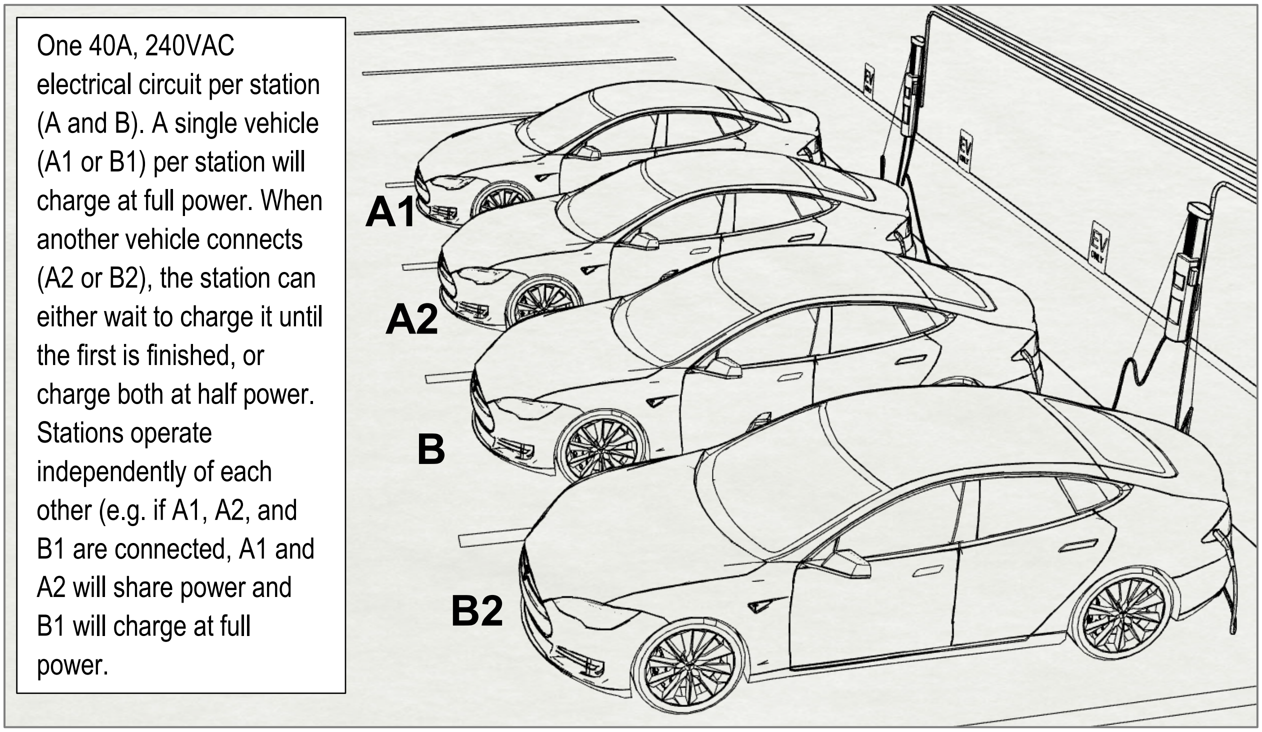
Figure 58. Example Parking Garage in Urban Residential Area

Using the strategies for new installations flow chart to determine an effective strategy for increasing charging capacity at this site, could result in the following:

- Is there expressed desire for EV charging at your facility or a significant presence of EVs or hybrid vehicles?
  - YES. EV ownership is higher in urban areas and garages have found that EV charging infrastructure is desired by their customers. Garages may also view this as an opportunity to bolster their "green image."
- Would this parking location also regularly serve vehicles parked for less than six hours?
  - Potentially YES. Garages in urban areas that accommodate resident parking at night likely also have nearby retail or entertainment venues that draw visitors throughout the day for shorter durations.
- Is there sufficient electrical service capacity to supply full power to all required ports AND would the potential electrical demand charges be acceptable?
  - NO. Typically the installed electrical infrastructure in garages is designed to accommodate lighting and not large electrical demand. The costs incurred by demand charges could also be significant if all EVSE are used at the same time.
- Could the drivers return to the EVs after they are charged?
  - NO. It would be very inconvenient for residents living nearby to return to their vehicles at night, and others who park for long durations for work might not be close enough to easily return to the garage during their workday.
- Recommendation
  - AC Level 2 charging stations with automated load management abilities could accommodate the various requirements while minimizing potentially high electrical installation upgrades and demand charges.

As shown in Figure 59, automated load management systems include arrangements where one controlling unit manages many individual charging stations (best for larger installations where electrical service capacity is severely limited and must be shared among several charging stations) and dual-port charging stations that can operate from a single power source (appropriate for smaller installations and the facility can provide half of the power normally needed by the charging stations). The simpler management systems will share the available power among the number of EVs connected that need to charge. If only a few EVs are connected or many of the EVs connected are already fully charged, the EVs needing a charge can do so at full power (which likely occurs during the daytime when shorter-term charging might be needed more). In the evening, when many residents with EVs plug in and need to charge, the EVs will charge slower until some are finished, but in this situation, most EVs will be parked long enough to eventually get a full charge. Automated load management systems may have the capability to regulate charge based on user needs that are captured through a mobile phone app or local interface, the type of EV connected (could prioritize all-electric vehicles over plug-in hybrids), or current state of charge (prioritize those with the lowest current charge levels).

Figure 59. Proposed Charging Station and EV Parking Layout for a Multiuse Garage



Automated load management systems increase equipment costs for charging station installations. For installations involving only a few charging ports, there may be some potential savings due to lower electrical demand charges. However, this strategy is more commonly used when there are several charging ports being installed, or a new electrical service and panel is needed to provide the power required by charging stations without an automated load management system. Therefore, the estimated costs in Table 8 are for an installation of 10 charging ports and accounts for an electrical panel upgrade shown with the higher baseline installation costs. Using an automated load management system reduced the high installation costs for the proposed solution, but it requires the high initial equipment costs to have that capability.

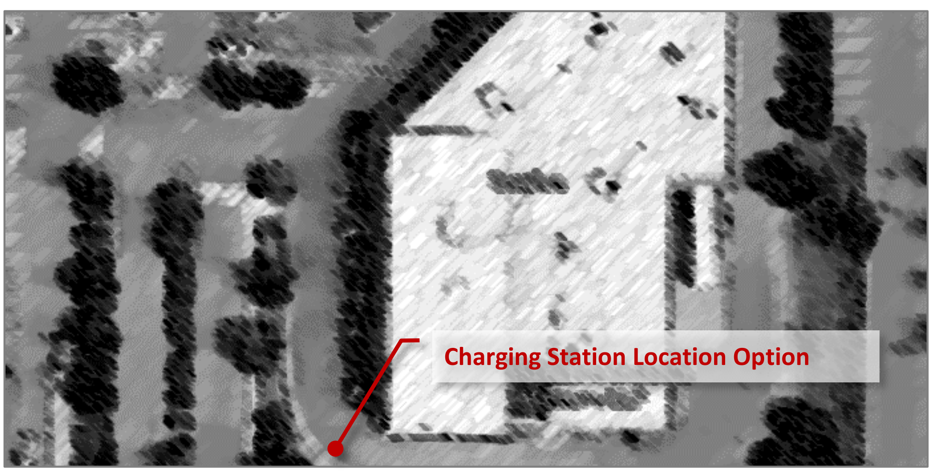
Table 8. Estimated Charging System Costs for Multiuse Garage Example

Hardware	Hardware Cost	Installation Cost	Total Installed Cost	Maximum Annual Demand Charges	5-Year Costs
Install Four AC Level 2 EVSE Ports (baseline)	$4,400	$5,000	$9,400	$3,168	$25,240
Install Four AC Level 2 Ports with Automated Load Management (proposed)	$4,400	$3,000	$7,400	$1,584	$15,320
Potential Savings	**$0**	**$2,000**	**$2,000**	**$1,584**	**$9,920**

3.3.3 Workplace Test Case

A small workplace location—a 30 employee lawyer's office (shown in Figure 60)—wants to install an EV charging station to provide employees with an option to plug-in while at work and to bolster the company's green image. No one currently drives an EV, but at least one employee may purchase one soon. The charging station will be primarily for employee use. The office is in a building with a larger retail store, so if the lawyer's office and building owner agree to share the station usage, there may be some occasional use by the retail store's customers.

Figure 60. Example Small Workplace Interested in Charging Stations

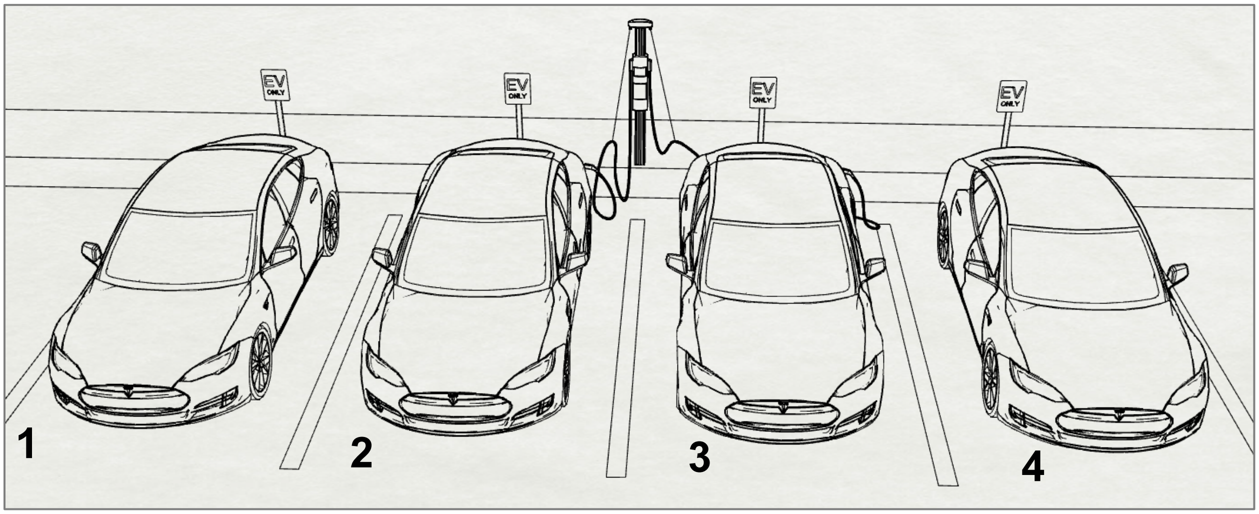


Using the strategies for new stations flow chart to determine an effective strategy for increasing charging capacity at this site, could result in the following:

- Is there expressed desire for EV charging at your facility or a significant presence of EVs or hybrid vehicles?
    - YES. At least one employee is likely purchasing an EV soon and the demographics of employees at this lawyer's office align with likely EV owners.
- Would this parking location also regularly serve vehicles parked for less than six hours?
    - NO. This installation is for employees who regularly park for the entire eight-hour workday. If an employee is meeting a client, they could be parked for a shorter time, or customers of the retail store could potentially use these during non-working hours, but neither situation is critical for planning these charging stations.
- Could the drivers return to the EVs after they are charged?
    - YES. The parking is right outside the office.
- Recommendation
    - One dual-port AC Level 2 charging station can serve more than two EVs by implementing a policy to share charging and incorporating additional dedicated EV parking spaces to facilitate plug switching.

With a new installation, the dual-port AC Level 2 station could be installed with longer charging cords to reach up to four vehicles without moving the vehicles. More EVs could be charged if the EVs are moved once charged. As shown in Figure 61, Vehicles #1 and #2 could share a charging cord from a properly located charging station and Vehicles #3 and #4 could use the other cord. The outer vehicles may need to be selective about which space they park in and orient their EV based on where the vehicle charging port is located. The office should set up an interoffice calendar or communication chain for EV drivers to coordinate charging times.

Figure 61. Proposed EV Charging Layout Workplace to Facilitate Plug Sharing



Installing one dual-port AC Level 2 charging station with longer cords could save $3,200 in hardware costs plus an additional $3,000 in installation costs compared to the baseline approach of two dual-port AC Level 2 stations to charge four vehicles (Table 9). For this situation, most EVs will likely be fully-charged after four hours, plug sharing could enable serving four vehicles with half the number of installed ports. Potential annual demand charges are based on $10 per kW with maximum charging station power draw aligning with the facility's peak demand. By having EVs share charging cords, only a maximum of two EVs would simultaneously draw power instead of four EVs if four EVSE were installed. The resulting decreased annual demand charges could be as high as roughly $1,500. The five-year savings from this approach could be a significant $14,120. The savings could be used to fund expanding the charging infrastructure to satisfy increased demand.

Table 9. Estimated Charging System Costs for Workplace Example

Hardware	Hardware Cost	Installation Cost	Total Installed Cost	Maximum Annual Demand Charges	5-Year Costs
Install Four AC Level 2 EVSE Charging Ports (baseline)	$6,400	$8,000	$14,400	$3,168	$30,240
Install Two AC Level 2 Charging Ports in a Plug Switching Configuration (proposed)	$3,200	$5,000	$8,200	$1,584	$16,120
Potential Savings	**$3,200**	**$3,000**	**$6,200**	**$1,584**	**$14,120**

4 Low-Cost Strategies to Expand Existing Long-Dwell EV Charging Station Installations

As described earlier, several key factors influence the equipment and installation costs when installing EV charging infrastructure. Table 6 compiles the infrastructure costs, electric power requirements, maximum power output, and the estimated maximum electric miles of range can be provided by each charging infrastructure option using information provided earlier in this document.

Many EV charging locations have installed one dual-port AC Level 2 EV charging station as they initially deployed the technology and gauged interest. As EV adoption increases and there is more demand for these charging stations, site owners with existing EV charging infrastructure will need to explore their options for adding charging stations or try to better optimize the existing ones. Unless an additional or larger conduit was installed with the first charging station, there will be no cost savings when installing additional charging stations.

As with new installations, planning when upgrading existing installations should always consider the potential future demand for additional charging points and develop a flexible approach to minimize future installation work. For example, use a larger diameter conduit than needed, or install an additional conduit to simplify future station installations. If additional electrical service is installed or a subpanel is added, sufficient additional capacity to add more charging stations should be included if feasible.

4.1 Potential Installation Strategies

Potential strategies for expanding existing charging station installations are summarized to outline the equipment required and explain how each would be implemented. The technologies and examples of some commercial products were presented in earlier sections of this report.

4.1.1 Replace AC Level 2 Charging Station with Multiple AC Level 1 Charging Stations

For many applications, EVs in the existing configuration are not being actively charged during the entire time the EV was connected to the charging station. As a result, a slower Level 1 charge can provide the sufficient charge. Two AC Level 1 charging ports can typically be powered using the same conduit and circuit as one existing standard 6.6 kW AC Level 2 EVSE with only minor changes. Removing one existing AC Level 2 station and replacing it with two AC Level 1 stations doubles the number of EVs that could charge at one time. If the existing AC Level 2 circuit used four wires (two loads, a neutral, and a ground), the same wires (although larger gage than needed), could be used to power the two AC Level 1 circuits. Alternatively, new wires for the AC Level 1 ports could be pulled through the existing conduit. With a small additional investment, a subpanel could be installed at the existing AC Level 2 station to enable four AC Level 1 circuits to be powered from each existing AC Level 2 circuit. The "lost" AC Level 2 charging station cost for the removed unit will be made up for by lower demand charges and servicing twice the number of EVs. The peak and average charging power will be lower than the baseline AC Level 2 station, but it would still be sufficient for many long-dwell parking locations. The largest potential savings from using this approach is from avoiding/delaying electrical service upgrades and reducing demand charges.

4.1.2 Implement AC Level 2 Charging Station Plug Sharing

If the existing station is in a location where the charging cord can reach additional parking spaces, those spaces can be designated for charging and EV drivers can share the charging cord among multiple vehicles without any new investment in charging equipment. In some locations, implementing a policy that limits parking in the charging spaces to a certain period or to move their car when charged would open up the station for other EV drivers. As a convenience, additional designated EV parking (without a charging station) spaces could be designated near the charging stations to provide drivers with a convenient nearby spot to move their vehicle once charged. Alternatively, EV charging and parking could be managed by a valet service to move charged EVs to a standard parking spot when charged to allow other EVs to be charged. This approach requires action by the EV drivers or valet service, which is not feasible in every setting. The largest potential savings from using this approach that maximizes the EVSE utility is from avoiding additional equipment, avoided/delayed electrical service capacity upgrade costs, and managing demand charges.

4.1.3 Add AC Level 2 Charging Station Power Management

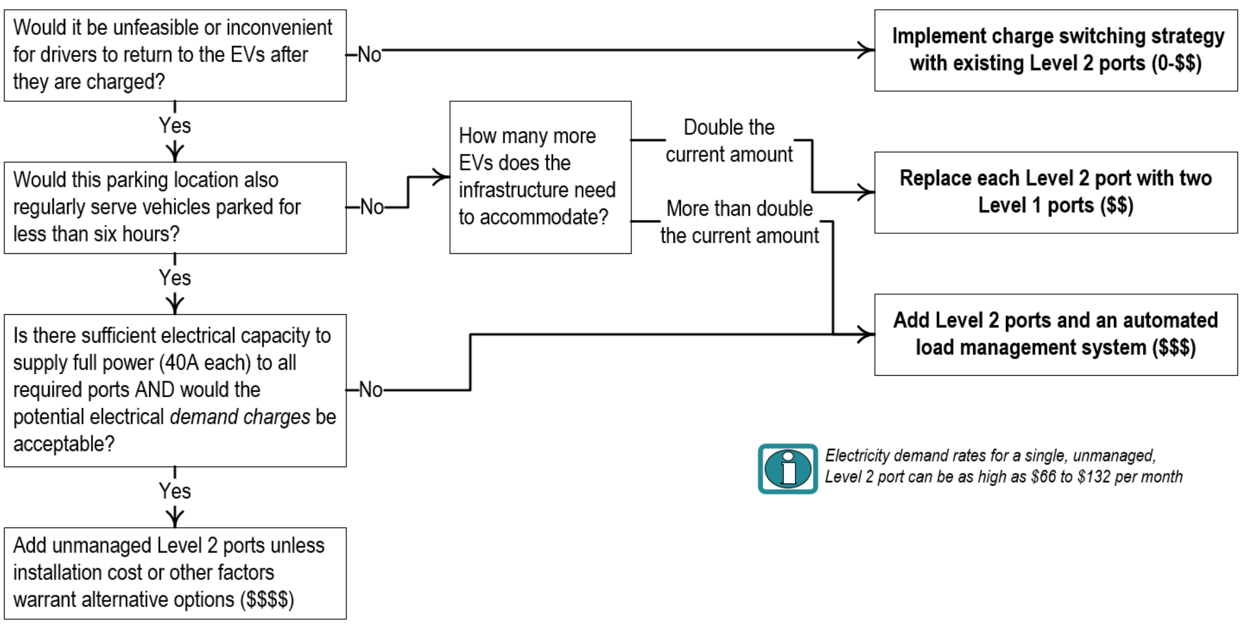
As with new installations, installing either power sharing dual-port AC Level 2 charging stations, or an automated power management system can be a cost-effective strategy for long-dwell parking situations where the AC Level 2 charging is needed, but there is limited available electrical service capacity and/or minimizing demand charges is critical. The largest potential savings from using this approach is from reducing demand charges and electrical service upgrade costs.

4.2 Selecting an Expansion Strategy

Several site-specific factors are used to determine the best low-cost installation strategy. A simple decision flowchart (Figure 62) was developed for host sites to identify the best strategy to expand the number of charging ports at sites with an existing station. The decision tree structure assumes:

- The majority of EVs are plugged in for six hours or more ("long-dwell" parking).
- The decision tree addresses locations that have some shorter duration EV parking. The decision tree should not be used for locations with mostly short duration EV parking.
- The existing station is the most common commercial charging station hardware; a dual-port high-power (6.6 kW) AC Level 2 charging station. Two dual-port EVSE are needed to charge four EVs in the same period.
- The questions are designed so most site host owners or facility managers will be able to answer them, however, additional input from facility personnel or an electrician may be needed.

Figure 62. Decision Tool Strategies and Techniques for Reducing the Installation and Operating Costs of EVSE for Expanding Existing Installations



There are several potential options sets for each long-dwell parking venue based on the site-specific conditions. Because of this, it was not practical to attempt to describe every possible permutation and decision path through the flowchart. Instead, three test cases were developed for installing upgrading existing charging infrastructure situation to serve as a guide/example for tool users.

4.3 Example Test Cases—Expanding Existing Installations

There are several potential option sets for each long-dwell parking venue based on the site-specific conditions. Because of this, it was not practical to attempt to describe every possible permutation and decision path through the flowchart. Instead, three test cases were developed for expanding and upgrading existing charging infrastructure situations to serve as a guide/example for tool users. An example for each is shown as follows.

4.3.1 Transit Station Test Case

Three AC Level 2 charging stations were installed in this train depot parking lot for customers with EVs to use as shown in Figure 63. These stations primarily serve commuters who will take the train into the city for work each morning and not return until evening. The EVs using these stations in the State remain plugged in for an average of eight hours and only receive an average of 8.7 kWh. Thus, the AC Level 2 charging stations are only providing electricity for a small portion of the day. After that, the EVSE are blocked from being used by other users. This situation significantly underutilizes this charging infrastructure.

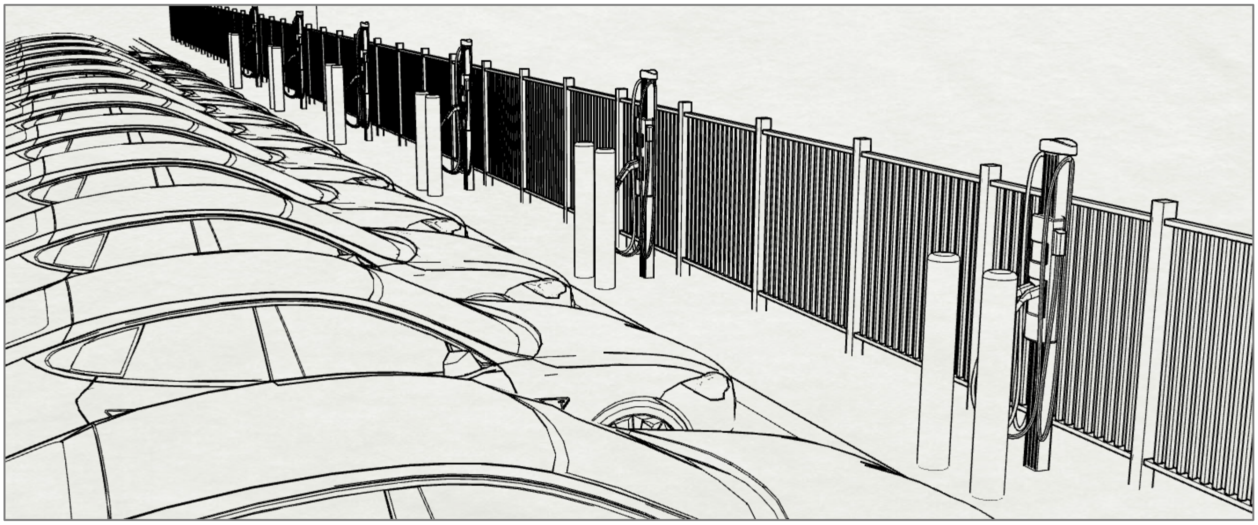
Figure 63. Existing Transit Station Charging Scenario

Using the strategies for existing stations charging infrastructure decision tree flow chart to determine a strategy for increasing charging capacity at this site, could result in the following:

- Would it be unfeasible or inconvenient for drivers to return to the EVs after they are charged?
    - YES. EV drivers take the train and generally do not return for at least eight hours, so they are unable to move the vehicle soon after it is charged.
- Would this parking location also regularly serve vehicles parked for less than six hours?
    - NO. Almost all drivers use of this parking lot is for commuting into NYC, so vehicles are parked for at least eight hours. The parking lot is accessible to other drivers, but it would not be convenient for any other purpose than to use the train.
- How many more EVs does the infrastructure need to accommodate?
    - Doubling the current number of charging stations would be a sufficient estimate.
- Recommendation
    - Commuters typically use a station near their residence, so the amount of charge required to top off the battery is frequently not high. Six AC Level 1 charging stations can use the existing electrical infrastructure of the three AC Level 2 charging stations. This option would likely top off the battery charge before the EV owners return.

Removing existing charging stations for replacement is not ideal. Replacing an AC Level 2 EVSE for two AC Level 1 EVSE uses the existing wiring, so the electrical installation upgrade costs are minimal. Some additional conduit and wiring will be necessary to move some of the power to new pedestals, but this is minimal compared to the work to install all new electrical circuits to this location. The new bank of six AC Level 1 charging stations (rendering shown in Figure 64), would double the number of vehicles that can currently be simultaneously charged at the current three AC Level 2 EVSE. The upgraded infrastructure would provide more electricity and all-electric miles, because of the increased EVSE availability and utilization. The maximum power demand would be less than for the original three AC Level 2 stations. This could allow for further charging infrastructure expansion.

Figure 64. Proposed Strategy for the Transit Location to Expand Existing Charging Infrastructure



In this hypothetical situation, a transit station has three EV parking sports, each with an AC Level 2 EVSE. The transit station wants to double the EV parking spots to six. The conventional solution is to add three new AC Level 2 EVSE to the existing three for a total of six AC Level 2 EVSE. The proposed low-cost solution removes the existing three AC Level 2 charging stations and replaces them with six AC Level 1 stations. AC Level 1 charging stations use the existing wiring, so the installation costs are lower. Even including higher EVSE costs, the approach has a slightly lower installed cost compared to the baseline (Table 10). Additional and significant cost savings come from the lower electrical demand charges (assumes $10 per kW) that occur when all of the EVs plug in each morning. Power sharing and management solutions could accomplish a similar result, but would require more expensive hardware.

Table 10. Estimated Charging System Costs for the Transit Location Example

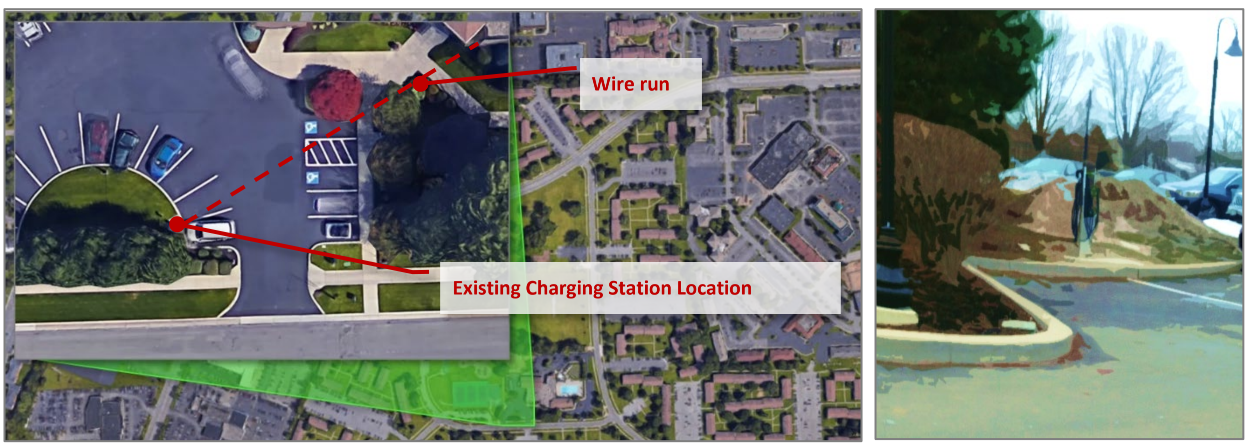
Hardware	Hardware Cost	Installation Cost	Total Installed Cost	Maximum Annual Demand Charges	5-Year Costs
Add Six AC Level 2 EVSE Charging Ports* (baseline)	$9,600	$10,000	$19,600	$9,504	$67,120
Replace each AC Level 2 Charging port with Two AC Level 1 Charging Ports** (proposed)	$16,200	$3,000	$19,200	$2,736	$32,880
Potential Savings	**-$6,600**	**$7,000**	**$400**	**$6,768**	**$34,240**

* Six dual-port charging stations,

4.3.2 Multifamily Dwelling Test Case

A common parking area for the shared-use facility, such as a clubhouse (shown in Figure 65), currently has one dual-port AC Level 2 charging station. Charging is provided for free to residents. As more tenants drive EVs, additional charging capacity will be needed because residents do not have a dedicated parking spot to install their own charging stations. Residents with nearby units can conveniently park and charge at this location overnight. Other tenants may prefer to charge their vehicle while using the clubhouse facility for a few hours in the evening or morning. These tenants will need the higher rate AC Level 2 EVSE. Power routing for the original station would require boring under the pavement, which would be costly. The same process would be necessary to add another AC Level 2 station.

Figure 65. Existing Multifamily Dwelling Charging Scenario



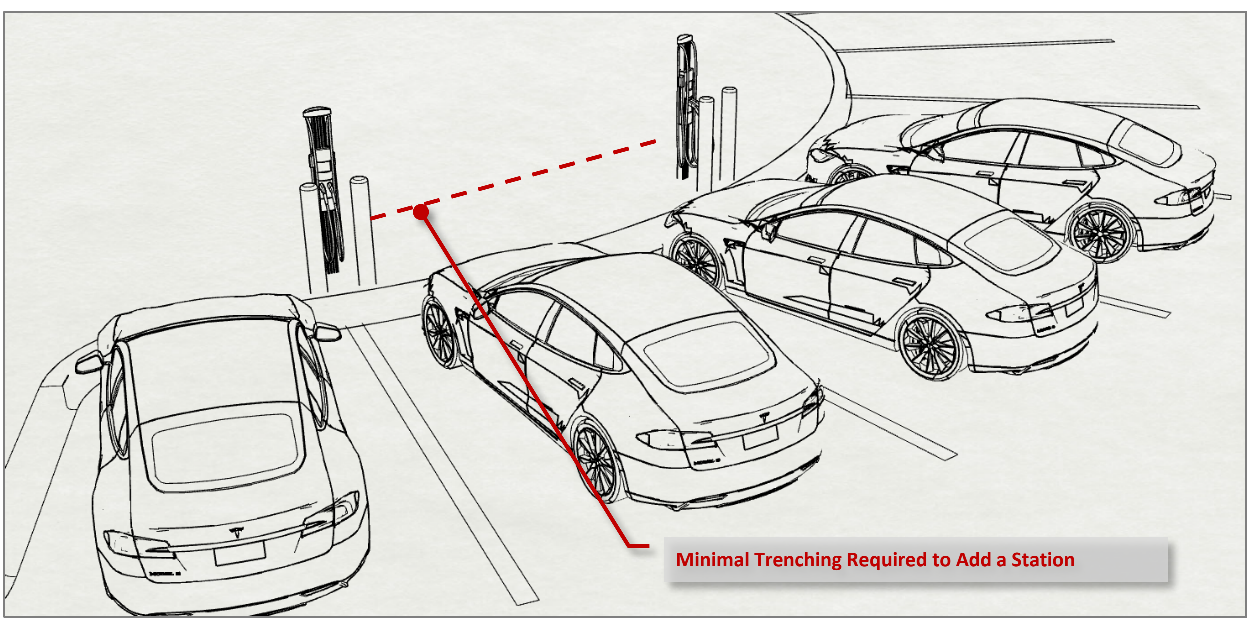
Using the strategies for existing stations flow chart to determine an effective strategy for increasing charging capacity at this site could result in the following:

- Would it be feasible or convenient for drivers to return to the EVs after they are charged?
    - NO. EV are commonly parked to charge overnight. Residents are not willing to get up through the night to move their vehicle.
- Would this parking location also regularly serve vehicles parked for less than six hours?
    - YES. Some residents, particularly those that have a unit farther from this location, may require and prefer to charge during a shorter period of time while they are using the facilities. AC Level 2 charging is needed to meet their requirements.

- Is there sufficient electrical service capacity to supply full power (40A each) to all required ports AND are the potential electrical demand charges acceptable?
    - NO. The power source is on the other side of the parking lot, so it would be costly to bring another circuit to this location. The clubhouse is also close to maxing out the current electrical service. To continue offering charging for free, the property manager must minimize the ongoing costs which is not possible with additional electrical demand costs.
- Recommendation
    - Installing one additional dual-port AC Level 2 EVSE would allow four EVs to connect and provide higher power levels for shorter-term charging. Integrating an automated charge management solution with the stations could leverage the current electrical power run to the existing station to reduce installation costs and maintaining current (or lower) peak electrical demand.

Adding one dual-port AC Level 2 station would only require new trenching between the stations (through soft soil) as shown in Figure 66, and not need a new power run across the parking lot. The automated management system would share the existing power among all four charging ports, but would only allow one EV to charge at the full 6.6 kW capability of the AC Level 2 for each station. When a third or fourth EV is plugged in, the automated power management system can be configured to either divide power equally between all the vehicles or wait until after the first vehicles are fully charged before charging the other EVs. The system will determine the most efficient approach.

Figure 66. Proposed Strategy for the Multifamily Dwelling Location to Expand the Existing Charging Infrastructure



Estimated costs for installing and operating one additional dual-port AC Level 2 charging station with an automated power management system (using the existing electrical circuit), compared to the baseline case of adding one dual-port AC Level 2 charging station on a new circuit are shown in Table 11. The initial total installed cost savings are low ($500) due to the automated power management system's upfront costs. However, future stations added at this location will use the automated power management system and the existing power supply, so the incremental cost will be significantly less. The automated power management system will maximize annual savings by minimizing demand charges ($10 per kW used in these calculations with maximum demand from the charging stations aligning with the facility's peak demand). The resulting decreased annual demand charges could be as high as $1,650, with the five-year savings reaching as much as $8,840. The savings could then be used to fund charging infrastructure expansion to satisfy increased demand.

Table 11. Estimated Charging System Costs for Multi-Family Dwelling Parking Location Example

Hardware	Hardware Cost	Installation Cost	Automated Power Management System Cost	Total Installed Cost	Maximum Annual Demand Charges	5-Year Costs
Add One Dual-Port AC Level 2 EVSE (baseline)	$3,200	$10,000	$0	$13,200	$3,168	$29,040
Add One Dual-Port AC Level 2 EVSE and an Automated Power Management System (proposed)	$3,200	$1,500	$8,000	$12,700	$1,500	$20,200
Potential Savings	**$0**	**$8,500**	**-$8,000**	**$500**	**$1,668**	**$8,840**

*Includes service fees for automated power management system

4.3.3 Workplace Test Case

Six Level 2 EV charging ports (two dual-port and two single-port stations as shown in Figure 67) have been installed in an employee garage at a large workplace. The stations are all located in a section of the parking garage that is well-protected from the elements and does not interfere with other parking requirements. The charging stations are located near the electrical power source, which minimizes the initial installation costs. More employees are driving EVs and the demand for charging is increasing. The workplace would like to increase the daily EV charging potential, but there is a limited budget as well as concerns about increasing the electrical demand.

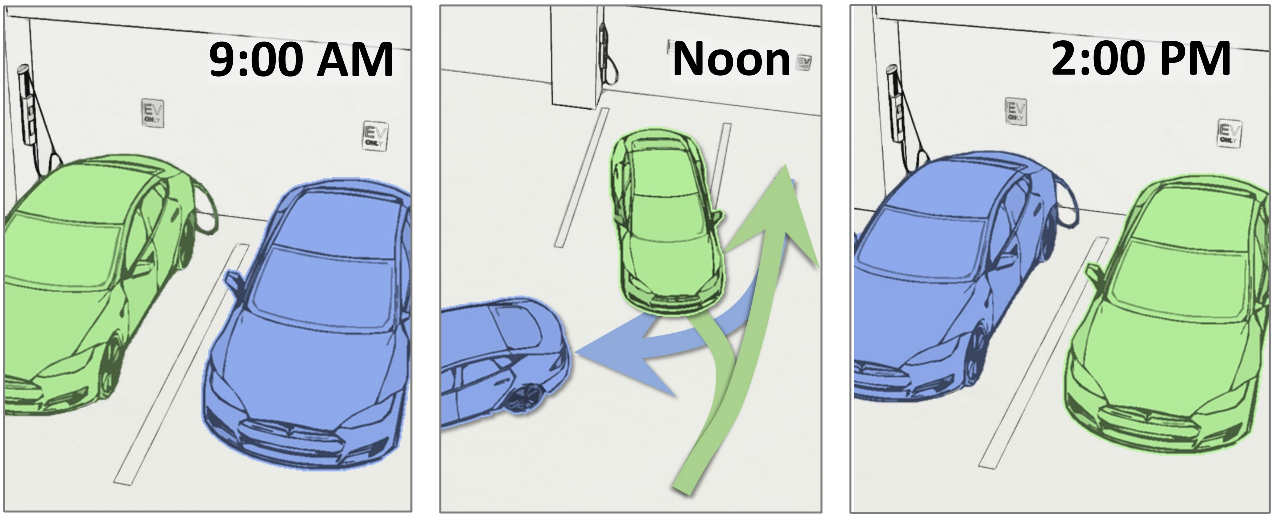
Figure 67. Existing Workplace Charging Scenario

Using the strategies for existing stations flow chart to determine an effective strategy for increasing charging capacity at this site, would have the following results:

- Would it be feasible or convenient for drivers to return to the EVs after they are charged?
    - YES. The parking garage is close to the main office building and employees could easily return to their vehicles after being charged. Some employees already use their cars mid-day and could park in a different space when returning.
- Recommendation
    - Additional charging can occur without increasing the number of charging stations if the company implements a policy for EV drivers to move after being fully-charged so another EV can utilize the station. This plug sharing strategy can be further facilitated by providing additional parking spaces (with no EVSE) for EVs near the current charging spaces and setting up an interoffice calendar or communication chain for EV drivers to coordinate their charging times.

Since the existing charging stations were already installed in spaces most convenient to the electrical power source, installation costs for additional stations would be somewhat higher. There is limited available electrical service capacity, so adding charging stations may require electrical service upgrades. A plug sharing solution that allows sharing of the existing stations is a good option in this situation because the EV drivers can access this parking garage easily during the day and extra EV parking (but not charging) spaces can be reserved nearby for added convenience. By encouraging employees to move their EV once fully charged to allow another to plug in (as outlined in Figure 68), daily charging capacity could be doubled, if not tripled. This strategy does not require any additional equipment and could be accomplished through policy adoption, which would be straightforward to implement among employees.

Figure 68. Strategy for the Workplace Location to Expand the Existing Charging Potential



The costs to implement the plug sharing strategy would be minimal. The workplace may invest in additional signage and markings to identify the spaces reserved for EVs while not charging. The comparable baseline costs shown in Table 12 are estimated for installing six more charging ports to double the daily EV charging potential (similar to plug sharing). Electrical demand costs are based on $10 per kW with maximum charging station power draw aligning with the facility's peak demand.

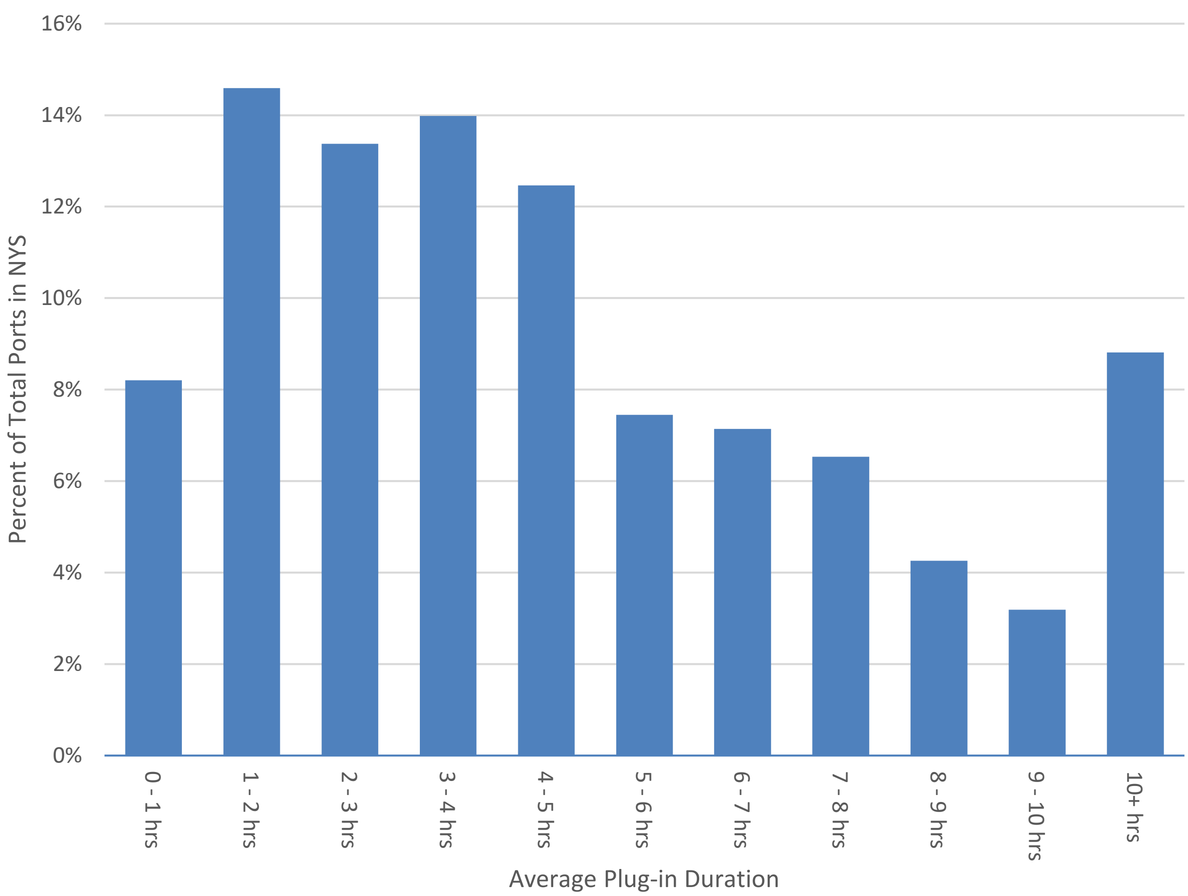
Table 12: Estimated Charging System Costs for Workplace Location Example

Hardware	Hardware Cost	Installation Cost	Total Installed Cost	Maximum Annual Demand Charges	5-Year Costs
Add Six AC Level 2 EVSE Charging Ports (baseline)	$9,600	$10,000	$19,600	$9,504	$67,120
Implement Plug Sharing Strategy with Existing AC Level 2 EVSE (proposed)	$0	$1,000	$1,000	$4,752	$24,760
Potential Savings	**$9,600**	**$9,000**	**$18,600**	**$4,752**	**$42,360**

5 Potential Impacts of Low-Cost EVSE Strategies

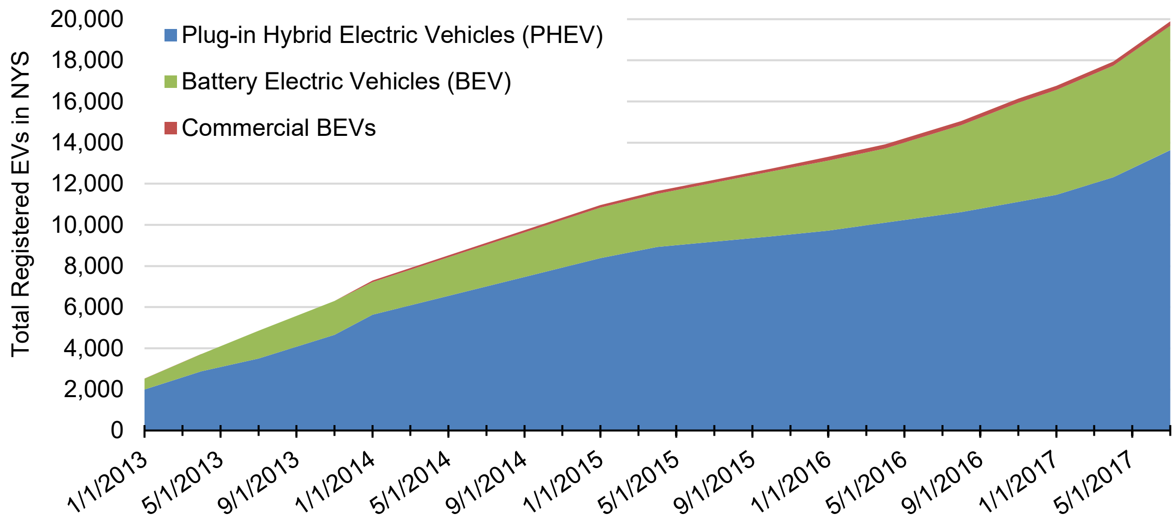
There are currently more than 1,500 publicly accessible AC Level 2 EV charging ports available throughout the State. EVSE usage data analysis revealed that approximately 33% of these charging ports have an average plug in duration of six or more hours per charge event (more detail is shown in Figure 69). As described earlier, long-dwell for the project was defined as six or more hours per day per parking event. Therefore, approximately 500 currently installed EVSE (33% of the current EVSE population) could have utilized one of the low-cost charging strategies evaluated in this study when originally installed or could be used to expand charging port availability. Using the strategies described in this project, the amount of charging provided at these long-dwell locations could be increased with minimal cost.

Figure 69. New York State EV Charging Port Average Plug-in Duration



The number of EVs in the State is steadily increasing as shown in Figure 70. This trend will increase the demand for charging and the need for cost-efficient strategies for long-dwell parking venues to provide charging will become more important. The performance of each of the low-cost EVSE strategies studied in the project are summarized as follows.

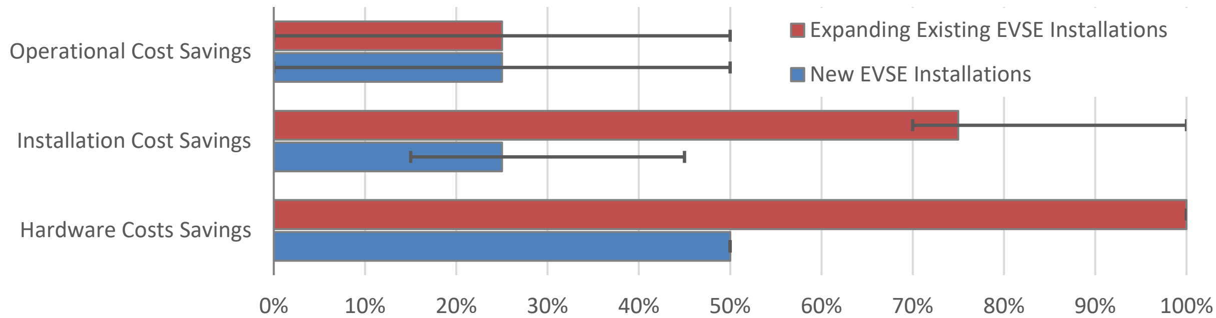
Figure 70: New York State EV Population Trends



5.1 Manual Plug Sharing

Configuring AC Level 2 charging stations and parking spaces to allow for manual plug sharing by EV drivers is an extremely simple and low-cost strategy that is applicable to some long-dwell parking venues. In new build applications one charging station can be installed between two parking spaces to allow access from both parking spots. This approach requires half the number of stations and electrical service capacity as using one EVSE per parking spot. If existing stations can be reconfigured, or policies be enacted, to enable plug sharing, adding a new station(s) to increase charging opportunities may not be necessary. This approach will provide significant savings since only policy development, signage, and perhaps parking space changes would be needed. This strategy relies on optimizing and maximizing the use of fewer charging stations to charge more vehicles. This preserves the maximum charging capacity of the station. This approach can result in significant savings as illustrated in Figure 71. This strategy is not viable for all situations and requires drivers to be more actively involved in the charging process since they cannot leave their plugged-in vehicle unattended for long durations.

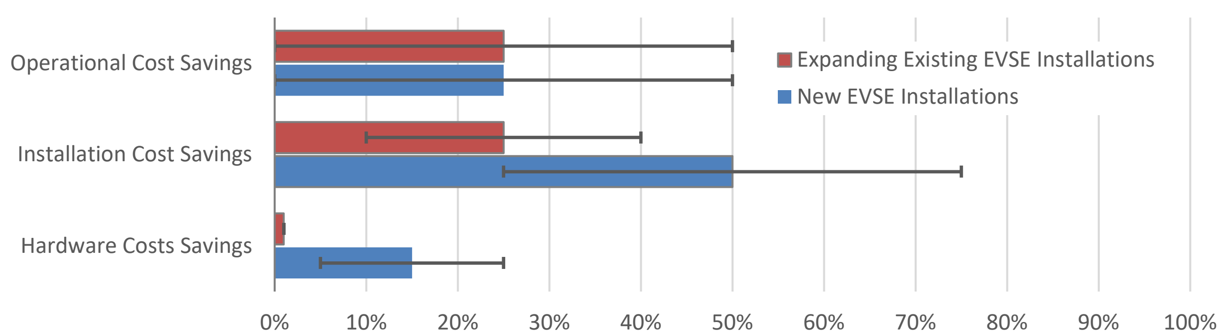
Figure 71. Manual Plug Sharing Strategy Cost Savings Potential



5.2 Low-Power Charging

Lower-power charging solutions, such as AC Level 1 (1.9 kW) or low-power AC Level 2 (3.3 kW), are a low-cost infrastructure solution that allows drivers to plug in for longer durations while ensuring the station is providing a charge for most of the time the EV is connected. Because of the long-dwell parking, lower-power stations will provide the required charging for drivers' typical daily commute while reducing the facilities' power demand. Station hardware costs vary, but AC Level 1 or low-power AC Level 2 stations are slightly less expensive than an AC Level 2 station with similar features. Installation costs are typically lower because they use smaller wires and conduit. However, installation cost savings can be quite significant if the available electrical service capacity at the site is limited and service or panel upgrades are required for an AC Level 2 station installation. Operational costs for low-power options can be as low as half of AC Level 2 stations due to demand reduction. Cost savings for the low-power charging option are estimated in Figure 72.

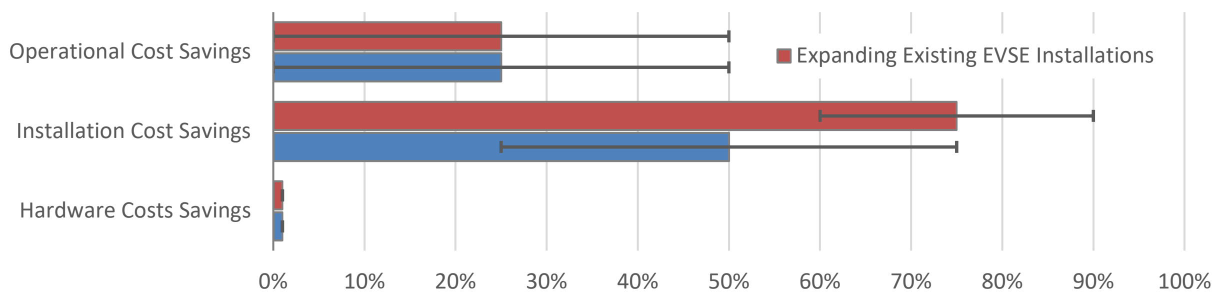
Figure 72. Low Power Charging Strategy Cost Savings Potential



5.3 Automated Power Management Systems

Automated power management systems for AC Level 2 stations optimize the system operation with intelligent control to reduce peak demand, take advantage of time of use electricity rates (where available), meet each vehicle charging needs (start/stop time and charge needed) via charge scheduling, and other energy management approaches. Automated charge management systems have relatively high upfront hardware costs and more complicated overall infrastructure. The overall cost savings estimates to implement this option with new or existing charging station installations are shown in Figure 73 as compared to installing AC Level 2 stations without automated management. This solution is best for facilities that currently have a building energy management system that can integrate charging infrastructure. It can be cost-effective when the electrical service capacity is limited, and costly electrical service upgrades are required to reach the desired EV charging capacity. Driver convenience is high since the systems requires no behavioral compromises other than providing the system with departure time information. The systems' potential for future demand savings may make this a desirable option.

Figure 73. Automated Charge Management Strategy Cost-Savings Potential



6 Conclusions

As can be expected, no single low-cost solution is appropriate for all long-dwell situations. For optimized installations and lowest installation and operational costs, each application must be evaluated and have the options compared to choose a suitable strategy. The outlined strategies can fulfill most l ong-dwell charging requirements at several common long-dwell parking venues where charging stations are typically installed. These short-term parking customers may require higher-power stations, so EV charging site hosts cannot fully take advantage of the low-cost charging solutions if the site host wants to meet these needs. Costs can still be reduced by following installation best practices and lower cost stations.

Widespread use of these low-cost charging strategies throughout the State will result in more charging availability with minimal investment. At existing charging station locations, an estimated 30% of the 500 charging ports at long-dwell parking locations could expand their EV charging capacity using manual charging, which requires almost no capital expenses. Others charging station locations could double their EV charging capacity using the other strategies at approximately half of the investment that was used for the original installation. Using a combination of these strategies at new installation locations would likely result in twice as much charging availability for the same cost. The benefit of increasing charging capacity at lower costs will become even more critical as EV adoption increases and there is higher demand for this infrastructure.

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