Multi-Unit Dwelling Plug-in EV Charging Innovation Pilots

Final Scientific/Technical Report

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Executive Summary

Nearly one-third of residences in the U.S. are multi-unit dwellings (MUDs), e.g., apartments and condominiums, and MUDs with five or more units account for approximately 45% of rental households.[1,2] While 80% of EV charging takes place at home,[3] less than 5% of home charging takes place at MUDs.[4] With public electric vehicle (EV) charging still underdeveloped, lack of access to reliable home charging is a major barrier to EV adoption for MUD residents. Challenges to siting electric vehicle supply equipment (EVSE) at MUDs include the high upfront cost of EVSE installation, physical and/or electrical infrastructure constraints, a lack of clear incentives for property managers to invest in installing EV charging for tenants, and a limited number of EV charging service providers that offer solutions adapted to the unique needs of MUDs.

Through award DE-EE0008473 from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Center for Sustainable Energy (CSE), Energetics, and Forth, along with a diverse team of partners, led a three-year project to address barriers to EV charging at MUDs by developing an online toolkit geared toward residents, homeowner associations (HOAs), and property managers. The project, referred to as Vehicle Charging Innovations – Multi-Unit Dwellings (VCI-MUD project), engaged stakeholders across the country to identify real and perceived barriers to EV charging at MUDs and explored innovative technologies that attempt to alleviate the identified barriers. Over the course of three and a half years, the project conducted 60 interviews with industry stakeholders, compiled findings in an easy-to-use toolkit, and disseminated the toolkit across national, regional, state, and local channels.

The VCI-MUD project developed an innovative toolkit to aid MUD site hosts in choosing appropriate EV charging technology

Key findings and outcomes of the VCI-MUD project include:

- Identifying six primary barriers to the installation of EV charging at MUDs.
- Developing five fact sheets and eight case studies highlighting innovative charging solutions to address barriers, including real-world operational and financial data.

[1] National Association of Home Builders, https://www.nahb.org/other/consumer-resources/types-of-home-construction/Multifamily, accessed on 2022-04-26

[2] National Multifamily Housing Council, 2019 American Community Survey, 1-Year Estimates, US Census Bureau. Updated 11/2020https://www.nmhc.org/research-insight/quick-facts-figures/quick-facts-data-download/, accessed on 2022-04-26

[3] NRDC, Electric Vehicle Charging 101, July 2019 https://www.nrdc.org/experts/patricia-valderrama/electric-vehicle-charging-101, accessed on 2022-04-26

[4] NOVA Workforce Development, Electric Vehicle Charging in Apartment-Based Housing, April 2015. EVS35 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium 1

- Developing a user-friendly, online empowerment toolkit with five important points for "making your pitch" to support EV charging to assist residents, property managers, building managers, and HOAs explore options for MUD charging.

The VCI-MUD online toolkit was designed with replicability in mind. It includes general tools and guides to evaluate EV charging demand, gauge readiness for EV charging installation, and develop actionable plans. The fact sheets and case studies highlight the diversity of emerging MUD EV charging solutions, featuring different geographic and structural installation scenarios and providing interested parties with a menu of options, rather than prescribing a one-size-fits-all solution. The following resources are included in the toolkit to provide MUD stakeholders with all the information needed to navigate EV charging installation at their MUD location:

- **Empowerment Toolkit** – Easy-to-read FAQ overview, stakeholder roles and responsibilities, and additional resources for MUD EV charging installations.
- **Charging Basics** – Glossary of terms and descriptions of charging features, installation and operating expenses.
- **EV Charging Survey Templates** – Resident-to-Resident, Property Manager-to-Resident and HOA-to-Resident template letters with pre-populated template questions.
- **Technology Selection Tool –** Charging barrier fact sheets and case study examples.
- **Installation Checklist –** Submittal document requirements for EVSE installations.
- **MUD Building Self-Evaluation Survey –** Self-guided evaluation of potential barriers to EV charging installation at MUD locations.
- **Curbside Resources –** Case studies and fact sheets for curbside charging options.
- **Find a Certified Electrician –** Approved list of certified EV charging installers.
- **"Right-to-Charge" State Legal References –** Legal requirements for charging equipment at MUD locations.

The online toolkit was promoted extensively in the final six months of the project and will continue to be disseminated by the Clean Cities Coalitions and other partners after the end of the VCI-MUD project to encourage, support, and demonstrate viable solutions for vehicle charging infrastructure in MUDs.

Project Background

Problem Statement

According to the Department of Energy (DOE), more than 80% of electric vehicle charging occurs primarily at owner-occupied single-family homes due to convenience and lower cost of residential charging options.[5] The process for the homeowner to install EV charging is fairly straightforward and involves hiring qualified contractors and electricians who are typically knowledgeable about charging equipment installation regulations and permitting for single-family homes. However, those living in MUDs face significant challenges if they want to charge at home. This is especially true for lower-income households and those in dense metropolitan areas who disproportionately rent their residence.

Reliable and affordable access to charging is critical for increasing EV adoption and is needed for a strong secondary (used EV) market to flourish. Range anxiety and uncertainty about where to charge remain significant concerns among prospective EV buyers – even though most EV charging needs can be met by home charging and more than 95% of daily driving activities can be accomplished with 100 miles of electric range.[6] Creating greater access to charging for the multitude of MUD residents will help overcome these perceptions and stimulate electric mobility growth.

Whereas installation of EV charging at detached, owner-occupied, single-family homes has well established processes and protocols, MUDs face several unique additional barriers including:

- **Parking Operations & Limitations**: MUDs may have limited on-site parking and rules related to shared, assigned, or deeded parking spaces.
- **Electrical Barriers**: Locations where charging is desired may have inadequate or limited power capacity or be distantly located from existing power sources.
- **Installation Costs**: MUDs without sufficient electrical capacity for the planned number of chargers may require costly electrical infrastructure upgrades to tie in existing or new power.
- **Ongoing Operational Costs**: This includes maintenance, repair, networking, access, and billing costs that MUD property managers will want to minimize and may want to recoup through billing for charger usage.
- **Networking Barriers**: Equipment installation and ongoing operational costs of connecting to networks to monitor EV charging, bill for usage and other activities can be expensive. Limited connectivity issues may be difficult or costly if chargers are in a remote site or underground parking structure.

DOE's Office of Energy Efficiency and Renewable Energy (EERE) issued Funding Opportunity Announcement DE-FOA-0001919, which included Area of Interest (AOI) 3e, requesting applications ***that describe the barriers of MUD and/or curbside EV charging to be addressed by the project, perform analysis to quantify the size of the problem and how proposed solutions may address the problem,***

[5] "Charging at Home — Department of Energy." [Online]. Available: https://www.energy.gov/eere/electricvehicles/charging-home

[6] Kempton W, Pearre NS, Guensler R, Elango VV. Influence of Battery Energy, Charging Power, and Charging Locations upon EVs' Ability to Meet Trip Needs. *Energies*. 2023; 16(5):2104. https://doi.org/10.3390/en16052104

identify software and/or hardware solutions or innovative approaches to the problem, and test and validate proposed solutions.

CSE and its partners, Forth and Energetics, developed and executed the Multi-Unit Dwelling (MUD) Plug-in Electric Vehicle Charging Innovation Pilots in Multiple Metropolitan Areas project, which is alternatively referred to as the Vehicle Charging Innovations – Multi-Unit Dwellings (VCI-MUD) project.

Project Approach

The VCI-MUD project aimed to address AOI 3e by identifying barriers to MUD charging installation, conducting pilot projects that demonstrated advanced technologies, and developing and disseminating a toolkit to aid site hosts in identifying appropriate solutions for installing EV charging.

CSE, with Forth and Energetics, assembled a diverse project team, which included:

- 8 site hosts with EV charging installed
- 7 technology providers
- 1 investor-owned utility
- 9 Clean Cities Coalitions
- 2 Project Advisory Committee members

A complete list of project partners is included in **Appendix A** in this report. These partner organizations made up the Project Advisory Committee (PAC) that met quarterly to review progress, share feedback, and review deliverables. Over the course of the project, the PAC met 14 times.

From April 2019 through December 2022, the project proceeded in three phases, or Budget Periods.

Budget Period 1: Baseline Characterization and Demonstration Planning (4/8/19 – 6/30/20)

During BP1, the project team identified common barriers to installing EV charging at MUDs, identified sites, and gathered tools to assist residents, property managers, property owners, and condominium associations with their journey to install EV charging. The project team corresponded with several communities working on establishing curbside charging to understand their unique experiences and challenges.

During BP1, the team obtained baseline data and performed analysis of existing installations and usage data, identifying best practices and lessons learned and engaging with relevant interested parties. Additionally, the project team researched needs and opportunities for innovation in MUDs, curbside charging technologies, and business cases and developed a plan for demonstration projects to generate learnings on emerging solutions. Finally, during BP1 the project team laid the foundation for development of the VCI-MUD toolkit by establishing an advisory committee and ensuring stakeholder buy-in on the overall toolkit framework.

Budget Period 2: Demonstrate Charging Infrastructure Innovations (7/1/20 – 6/30/21)

During BP2, the project team built upon the data collected from existing MUD EV charging sites, developed a set of case studies and fact sheets highlighting innovative solutions to MUD EV charging barriers identified during BP1, and began to develop tools for residents, property managers, owners, and condominium associations. The team focused on demonstrating how eight innovative EV charging technologies and curbside charging technologies addressed common barriers in real-world settings. The findings from these demonstration projects were used to further refine the toolkit and create a down-selection tool to help site hosts evaluate the most suitable charging options and locations.

Budget Period 3: Toolkit Development and Dissemination (7/1/21 – 12/31/22)

In BP3, the project team finalized five key tools that form the foundation of the online toolkit. The VCI-MUD toolkit and website were launched on August 20, 2022. Following toolkit launch, the project team focused on information dissemination to MUD owners and residents through a series of webinars and events to drive users to the site, led by the nine Clean Cities Coalitions and Forth.

The following section includes a detailed description of work completed during each Budget Period, challenges encountered, key lessons learned, and findings related to the research questions for AOI 3e.

Project Delivery

The VCI-MUD project commenced in April 2019 and ended in December 2022. The project experienced a few challenges, including delays in contracting with project partners; issues at each of the proposed demonstration sites due to construction, permitting and/or equipment contingencies; and complications from the Covid-19 pandemic, resulting shelter-in-place restrictions, and subsequent global supply chain disruption. Nevertheless, the project team was able to adapt and overcome these challenges by identifying alternative and existing demonstration sites, replacing project partners as necessary, and obtaining operational data and developing case studies.

Beginning in March 2020, the project was significantly impacted by the onset of the Covid-19 pandemic. Many EV charging site projects were put on hold, and new sites initially proposed for demonstration projects had to be replaced with existing sites. New agreements had to be obtained, as well as operational data from these existing sites.

The pandemic impacted the amount of session data that was collected in BP2 due to the shelter-in-place restrictions and the high number of nonessential employees working from home. This dramatically reduced the reported miles driven by survey respondents in their personal vehicles commuting to and from work as well for leisure and nonessential activities.

The project team was able to identify these impacts, adapt strategies and account for variables, and with a few delays in the project, complete all the requirements by the end of December 2022.

Budget Period 1 – Baseline Characterization and Demonstration Planning (4/8/19 – 6/30/20)

Throughout Budget Period 1 (BP1), the project team formed the Project Advisory Committee (PAC) and executed a series of master services agreements with project partners, enabling the collection of qualitative data on common barriers to installation through surveys and interviews, as well as baseline EVSE operational data from current MUD and curbside residential charging installations. This data was used to characterize existing usage limitations (e.g., installed cost, operational cost, demand charge impact, EVSE utilization, etc.), understand opportunities for improvement, and begin to develop case studies and fact sheets that would eventually be included in the VCI-MUD toolkit.

BP1 Focus Area 1 – Engaging Interested Parties

A primary focus of BP 1 was contracting with the various project partners and establishing the PAC – a diverse group of stakeholders, including Clean Cities Coalitions, technology providers, government agencies and associations (e.g., the National Association of State Energy Offices, or NASEO), MUD owners/managers, and electric utilities. Project partners and PAC members were selected from throughout the country, to ensure that the project captured a diversity of perceptions and experiences and that project outputs would be broadly replicable.

The PAC served as the platform through which the project engaged key stakeholders and received feedback and guidance on project approach and work products. The PAC met each quarter during the project. After each PAC meeting a newsletter was sent out to committee members with relevant project reminders, news, and notices of upcoming events.

Additionally, members of the project team presented on the VCI-MUD project at various industry events and webinars, including those listed in Table 1.

Table 1 Outreach engagements during BP1

Event Date	Event/Engagement Name
2/10 – 2/12/20	Energy Independence Summit 2020, Washington D.C.
2/6/20	Radio Interview with South Shore Clean Cities on Northern Indiana's NPR station
5/7/20	Tech Integration Data Collection Projects Webinar
6/18/20	Smart Electric Power Association (SEPA) Working Group meeting

BP1 Focus Area 2 – Stakeholder Discussions and Baseline Data Collection

During BP1, the project team developed a survey instrument, referred to as the Stakeholder Discussion Summary Form, that partner Clean Cities Coalitions (CCCs) used to conduct over 60 interviews with a variety of stakeholders, including housing authorities, EVSE providers, MUD owners/property managers, utilities, and government agencies. These interviews aimed to improve understanding of perceptions of charging at MUD and curbside residential sites and included questions about existing installations, plans for future installation, motivations for these installations, and the key barriers they experienced or

perceived. The project team synthesized the results of these interviews and identified significant common barriers to EV charging (Figure 1).

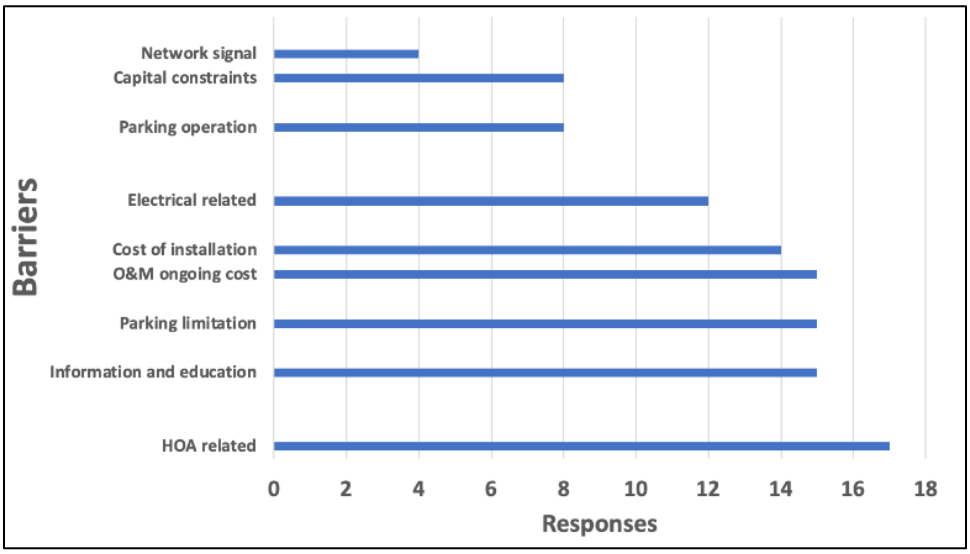

Figure 1 Number of responses mentioning specific barriers to MUD EV charging.

These identified barriers were further refined into the following six key areas that informed the design of the Technology Selection Tool: 1) Parking Limitations, 2) Parking Operations, 3) Electrical Barriers, 4) Installation Costs, 5) Ongoing Costs, and 6) Network Barriers. The Technology Selection Tool became a key feature of the online VCI-MUD toolkit that directs users to relevant guidance documents, charging fact sheets, and case studies based on specific barriers identified through their self-evaluation survey.

BP 1 Focus Area 3 – Baseline Data Collection

In addition to surveys and interviews, a primary focus of BP1 was collection of baseline data from a diverse set of data providers that included different sizes of MUD properties (e.g., small to large) and different parking situations (e.g., open, restricted, and dedicated parking spaces, and curbside residential parking). The project team secured data sharing agreements with a variety of project partners, including: Los Angeles Bureau of Street Lighting, Electric Vehicle Institute, FreeWire Technologies, OpConnect, PowerFlex, Rocky Mountain Power, St. John's Properties, Liberty Plugins, and Cyber Switching.

The team experienced challenges acquiring data from some partners but was able to adapt and substitute data providers. Below is a list of substitute data providers that had planned EV charging installations and agreed to provide preliminary data for the baseline analysis:

- GIV Development (replaced a portion of the Rocky Mountain Power)
- Salt Lake City (replaced a portion of the Rocky Mountain Power)
- Bozzuto Management Company (replaced St. John's Properties)

Unfortunately, due to delays in construction timelines these project sites were not operational within the life of the VCI-MUD project. Data from existing EV charging sites was substituted for the purposes of the baseline analysis.

The project team secured EVSE operational data from three data providers and two EV charging network operators, with data from eight states and Washington, D.C. To analyze the data, project partner Energetics created a database to securely house the raw EVSE operational data.

The EVSE operational data was sorted into the following categories:

- MUD-Located AC Level 2 EVSE – EV charging stations indicated as MUD stations by the data provider; this dataset included data from 23,925 charging sessions from 223 EV charging station ports.
- MUD-Supporting EVSE – EV charging stations located within 300 feet of a MUD property, as determined by the project team's analysis of GPS data and proximity to MUDs. This dataset was further broken down into AC Level 2 EVSE and DCFC EVSE and included data from 2,699 sessions at 6 Level 2 EV charging stations and 2,022 charging sessions at 8 DCFC charging stations.

The EVSE operational data was scrubbed of personally identifiable information (PII), so the project team developed a methodology to determine what data from MUD-supporting sites was most likely to have come from MUD residents. This methodology included identifying charging sessions that occurred after 6 p.m. and filtering for users with more than 10 visits, as these usage characteristics were determined to be most consistent with a MUD resident who frequently charges at the same location, after normal business hours. Limitations of this approach include the fact that the project team could not be certain these charging sessions were in fact by MUD residents and that the project team did not have any information on other charging behavior – for example work charging or usage of other public EVSE.

The results of this analysis were summarized in the "Baseline Multi-Unit Dwelling Charging Infrastructure Data Analysis" report first created in June 2020, and later updated in September 2022.[7]

Key findings and lessons learned from BP1

1. **Barriers to installing EV charging vary across property types and classes.** Class A and high-end Class B properties typically serve higher-income households that are more likely to own an EV and seek housing with access to EV charging. Some of these properties are already offering EV charging as an amenity. These are typically newer or recently renovated buildings, with electrical infrastructure better suited to accommodate the additional power needs of EV charging, often as a result of recent updates to building codes. Lower-end Class B and Class C properties, however, are typically older properties and more likely to be occupied by low- and moderate-income households who are less likely to currently own an EV. The age of these buildings can complicate installations and require more expensive electrical upgrades. Without a resident base seeking EV charging, there is little incentive for property managers to pursue EV charging. This can create a negative feedback loop, where lack of access to reliable home charging further discourages the purchase of a new or used EV by low- and moderate-income households. Additionally, some project stakeholders raised concerns of gentrification – i.e.,

[7] Available at: https://vci-mud.org/sites/default/files/tools-resources/CSE%20DE-EE0008473_Baseline%20Data%20Analysis.pdf

installation of EV charging may attract a more affluent resident base, placing upward pressure on rents.

2. **Cost and return on investment are major concerns for property owners and their managers, but innovative financing solutions exist.** Not surprisingly, property owners and managers need to see a clear return on investment to justify the installation and ongoing costs associated with EV charging. One case study identified during BP1 provides a model for addressing ongoing networking and maintenance costs. The network provider leveraged funding from multiple sources, including the local utility, the state, and the local air district, to furnish, install, own, and operate 125 L2 EVSE at a condominium. The ongoing operational costs are funded by Low Carbon Fuel Standard credits earned by the site. These credits are only generated if the site is operational, creating a clear incentive to ensure ongoing operations and maintenance.

3. **Knowledge about EV charging varies drastically.** Some property managers were very well informed on the current state of EV charging and the process for installation, some were only curious, and others harbored misconceptions. There is significant opportunity for education and guidance to ensure property managers are aware and knowledgeable about EV charging solutions and fully understand what is required to install EV charging at their properties.

4. **Charging installations have been largely resident driven.** Surveys and interviews with stakeholders at various sites indicated most HOAs and apartment charger installations were driven by resident request. The toolkit includes a step-by-step guide that includes information on understanding fellow stakeholders, charging programs and incentives, stakeholder engagement activities, and a template for submitting an EV charging proposal or presentation that can be customized for a particular HOA board or property manager, as well as additional templates and surveys to engage other residents.

5. **MUD charging sessions were consistent with overnight charging but did not deliver as much electricity as the project team expected.** Analysis of baseline EVSE operational data showed a clear correlation between the number of charging sessions and total energy delivered, with an average of 18.4 kWh of electricity delivered per charging sessions. While the typical MUD charging session lasted an average of 12.2 hours, the typical charge duration was only 3.6 hours (Figure 2). This is consistent with long-dwell overnight charging sessions where the vehicle is plugged in longer than required to obtain a full charge. This suggests there is strong potential for charge management solutions that allow multiple vehicles to meet their needs overnight through managed charging or load sharing across a bank of Level 2 chargers.

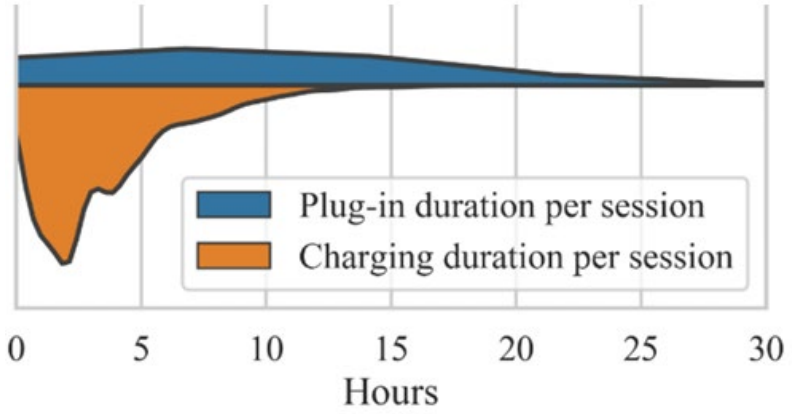

Figure 2 Distribution and comparison of charge session time for charge sessions equal to (orange) and longer than (blue) the plug-in time for MUD-located AC Level 2 EV charging stations. (*Reproduced from the Baseline Multi-Unit Dwelling Charging Infrastructure Data Analysis report.*)

Work completed during BP1 provided the project team a strong foundation to move into BP2 and continue to develop pilot projects and case studies and refine the structure and content of the VCI-MUD toolkit.

Budget Period 2 – Demonstrate Charging Infrastructure Innovations (7/1/20 – 6/30/21)

The final months of BP1, and the duration of BP2, were significantly impacted by the ongoing response to the Covid-19 pandemic, making installation of demonstration and pilot projects at MUDs exceptionally difficult. Both the construction of new properties and/or the installation of charging at existing sites was paused. With assistance from the PAC, the project team was able to pivot its approach and identify existing sites with recent charging installations to use as case studies and pilot projects. These existing sites provided charging data, however, usage patterns and overall utilization were impacted by the shift to working from home and a resultant in reduction in automobile usage for many nonessential workers.

Despite these challenges, the project team was able to assemble a suite of case studies and technology fact sheets that would form the core of the VCI-MUD online toolkit.

BP 2 Focus Area 1 – Case Studies and Technology Fact Sheets

During BP2, the project team developed five fact sheets that highlighted emerging technology solutions to specific MUD EV charging challenges. These fact sheets are available on the VCI-MUD website.

- **Fact Sheet 1**: *Off-site Owned-Operated Charging Stations* – This addresses the barriers of cost and limited parking spaces, as charging stations are located off-site and owned/operated by a third-party. These sites are typically open to charging by non-MUD residents and may be in mixed-use commercial/residential settings. Additionally, users will pay public charging rates, which may be significantly higher than they would pay per kWh with dedicated home charging.

- **Fact Sheet 2**: *Power Management Systems* – These systems typically share electrical current across a bank of Level 2 chargers and allow for charging of multiple vehicles over time where electrical infrastructure is limited and/or demand charges are a concern. Power management systems can be employed in either dedicated or shared parking systems.

- **Fact Sheet 3**: *Community Charging Station Management* – Community charging stations are located in shared, rather than dedicated, parking spaces and can help reduce cost. Community charging may operate through a reservation system and can allow for long-dwell or shorter charging sessions. The system will notify the user when the charge session ends. As a shared resource, these technologies help address barriers by providing access to multiple EVs through one installation.

- **Fact Sheet 4**: *Shared Electric Circuit/Rotational Charging* – These systems use multiplex technology to share and/or manage the available power between multiple non-networked chargers. These solutions are capable of power sharing to a bank of either Level 1 or Level 2 chargers and can greatly reduce upfront equipment costs and avoid expensive electrical infrastructure upgrades.

- **Fact Sheet 5**: *Mobile Charging* – Mobile charging addresses a number of barriers by physically bringing the charging to the vehicle – typically through a mobile battery pack with charging ports. Instead of installing infrastructure in a dedicated or shared parking space, the mobile charging station can move to where the EV needing to be charged is located.

During BP2, the project team also developed eight case studies that described the different demonstration sites and how each site overcame their barriers to EV charging with technology solutions. These case studies are described in the Innovative Technologies Pilot Demonstration Evaluation report produced by the project team, and each individual case study is available on the VCI-MUD website. The case studies included the following:

Case Study 1: *Cyber Switching Electric Vehicle Master Controller: The Henry Condominiums* – Case study and financial analysis of a 123-unit condominium in Portland, Oregon, that installed dedicated outlets specifically for EV charging in deeded tenant spaces using **Cyber Switching's Electric Vehicle Master Controller (EVMC)** managed charging solution to minimize equipment costs and electrical infrastructure costs. The owner of each parking space must request and cover the cost for installation. The electricity is billed to the HOA and the owner of the space pays an additional monthly fee for electricity. Recent condominium sales in the building indicate that units with outlets command a price premium that exceeds the original cost of the installation.

Case Study 2: *Liberty Plugins HYDRA-R: The Brookwood* – This is a 219-unit residential apartment building in Atlanta, Georgia. It has three underground parking levels for residents and two levels above ground for commercial tenants. The 33 guest parking spaces are rarely fully occupied. There are 15 residents who drive electric vehicles, many of whom had requested charging in their assigned spaces. It would have been very costly to run separate electrical wiring to the individual spaces. The solution to this barrier was to install **Liberty Plugins' HYDRA-R** smart controller system to create multiplexes of up to 10 charging stations on a shared single power line. Two chargers were installed in guest spaces with the provision to add a third to accommodate growth. The chargers are available

to residents only. Access and usage rely on the resident's cellphone's Bluetooth instead of a network. Residents pay $1 per hour, which covers the cost of the electricity.

Case Study 3: *Electric Vehicle Institute: RS Automotive* – This case study highlights a traditional gasoline service station that was converted to an EV charging plaza, offering four 50-kW DCFC and two 7.6-kW Level 2 chargers, as well as a drivers lounge offering amenities. Charging plazas like this can be effective solutions to MUD charging if they are located near MUDs and can be easily accessed by residents and/or are near desirable amenities. Data collected during the study showed approximately 85% of the 1,200 reported charging sessions were by MUD-identified residents.

Case Study 4: *Electric Vehicle Institute: Takoma Park Community Center* – Similar to the RS Automotive case study, the Takoma Park Community Center is a centrally located, publicly available charging hub featuring three 7.2-kW Level 2 charging stations and one 36-kW DCFC. It has approximately 10 MUD properties representing more than 1,000 units within half a mile of the complex. While not specifically designed to serve MUDs, over 75% of charging sessions were reported to be by MUD residents according to billing data collected. As a non-MUD property, the **Electric Vehicle Institute (EVI)**, covers all costs associated with installing and operating the charging stations. There are no cost impacts to nearby MUD properties, which is an additional benefit to residents of the community.

Case Study 5: *Op Connect: The Ko'olani Condominiums* – This case study featured a 376-unit residential high-rise with extensive underground parking. After researching networked charging providers, The Ko'olani installed **OpConnect** charging stations as an amenity to attract and retain residents. Covering operational costs was the goal of the property management, as opposed to generating a profit. OpConnect has a locally authorized repair staff and response service, which was a key factor during the vendor selection process. As of 2021, approximately 10% of the building residents drive EVs, and the site has three Level 2 charging ports dedicated to residents that utilize a load management system. Property management has planned for future electrical upgrades to allow every condo owner (at their own expense) to install a charging station if desired.

Case Study 6: *FreeWire Technologies Mobi EV Charger: FreeWire Technologies Headquarters* – This case study highlighted the use of a mobile charging solution, the FreeWire Technologies **Mobi EV Charger**. The unit includes an 80-kWh battery and can be navigated to where EVs are parked using a joystick or stationed near shared parking spaces. FreeWire claims that, with average daily charging needs, the Mobi can support up to eight EVs per day. In the case of very expensive or technically unfeasible installations, this type of solution could offer a more affordable and practical alternative for certain MUD locations.

Case Study 7: *PowerFlex: The Madrone* – This case study highlights a 330-unit high-rise condominium building in San Francisco, California, with underground parking that did not have reliable Wi-Fi or cellular signal, making traditional networked solutions challenging. Initial cost for installation was another barrier to charging installation. The Madrone selected **PowerFlex,** a turnkey charging and network provider who worked with property management to set pricing policies to meet their exact needs. To optimize power consumption across charging stations, PowerFlex utilizes an **Adaptive Load Management** algorithm, which balances load management to reduce peak demand and enable enhanced operation without the need for additional infrastructure costs. The

charging solution employed in The Madrone featured adaptive power management across a bank of 60 Level 2 charging ports.

Case Study 8: *EVmatch: The Revere* – This case study features a 168-unit apartment building with ground-floor retail in Campbell, California. The property owners wanted to offer charging as an amenity. With uncertain demand for charging, the property looked for a low-cost shared use solution to test the technology and monitor demand. **EVmatch** was the selected vendor for their reservation-based shared system that: 1) ensures EV drivers will have charging when and where they need it and 2) maximizes charging station throughput to fully utilize the hardware and electric infrastructure. The Revere employed this reservation-based shared charging solution and benefited from electrical infrastructure tailored to their EV charging needs, as a result of recent building code requirements. As newer construction, the property was built with the electrical capacity for charging based on the California Green Building Code. Grant funding from Silicon Valley Clean Energy, the community choice energy provider, helped to offset the cost of the stations. The charging fee is set to recover average electricity costs and could offset service fees with more usage.

Table 2 Innovative Technologies Pilot sites

Technology Provider	MUD Host Site	Location
Cyber Switching	The Henry (Condominiums)	Portland, OR
OpConnect	The Ko'olani Condominium	Honolulu, HI
PowerFlex	The Madrone (Condominium)	San Francisco, CA
Electric Vehicle Institute	Takoma Park Community Center	Takoma Park, MD
Electric Vehicle Institute	RS EV Fueling and Automotive Service Station	Takoma Park, MD
FreeWire Technologies	FreeWire Headquarters (simulated MUD)	San Leandro, CA
Liberty Plugins	The Brookwood Apartments	Atlanta, GA
EVmatch	Revere Apartments	Campbell, CA

In addition to these demonstrable case studies, the project team learned important lessons on the challenges of installing curbside EV charging, which is a substantial barrier for MUDs in densely populated urban areas in particular. This experience was with project partner Commonwealth Edison (ComEd), an investor-owned utility servicing more than 4 million customers in Chicago, Illinois. According to Drive Electric Chicago, 69% of residents in the city live in MUDs.[8] ComEd planned to install five Level 2 curbside charging stations at three adjacent MUD locations in the Bronzeville neighborhood of Chicago. However, the City of Chicago did not have approved standards or a permitting process in place specifically for curbside charging, leading to significant delays in the project throughout BP2.

[8] https://www.chicago.gov/content/dam/city/progs/env/CACCEVGuide.pdf

Eventually, one site was installed toward the end of BP3. As part of this free-to-use community MUD charging project, ComEd will eventually install the utility's first solar-powered microgrid, which will allow the community to provide backup power in the event of an outage if needed.[9]

The ComEd case study stood in stark contrast to the Los Angeles Bureau of Street Lighting (LABSL) project to install easily accessible curbside charging stations throughout high-density MUD neighborhoods in Los Angeles. Between 2016 and 2022, LABSL worked with their EVSE charging partners **ChargePoint**, **Flo, Shell ReCharge, and Tellus** to install 550 curbside Level 2 chargers.[10] LABSL oversees the city's lighting infrastructure, which includes over 220,00 individual light poles. The most innovative part of the project was the installation of EV charging stations on already existing city streetlights. This leveraged existing electrical infrastructure and streamlined EV charging installation deployment timelines. The City of Los Angeles was able to achieve rapid installation of chargers through strong coordination across citywide agencies, with the mayor's office holding bimonthly meetings between all concerned departments. This ensured alignment between agency goals and allowed potential obstacles to be identified immediately and addressed proactively.

Lessons learned from these curbside charging initiatives are available on the VCI-MUD website and can be found at: **ComEd EV Charging Lessons Learned** and **Los Angeles Bureau of Street Lighting: Curbside Charging Analysis**.

BP2 Focus Area 2 – Toolkit Development
During BP2, the project team began developing five tools that would become the foundation of the online toolkit and help guide users on their EV charging journey. Development of these tools, which were finalized in the first quarter of BP3, was heavily influenced by the results of stakeholder interviews conducted during BP1 and was informed by ongoing feedback from the PAC and project partners.

These tools include: 1) MUD EVSE Journey Roadmaps, tailored to distinct audiences, 2) MUD resident Empowerment Toolkit, 3) a MUD Building Self-Evaluation Survey, 4) a Technology Selection Tool, and 5) an Outreach Presentation tool. These tools are discussed in more detail in the BP3 section.

The facts sheets and case studies developed in BP2 became the outputs of the Technology Selection Tool in the final VCI-MUD online toolkit. The Technology Selection Tool along with the rest of the online toolkit is described in more detail in the BP3 section of this report.

BP2 Focus Area 3 – Engagement and Outreach
During BP2, the project team presented a series of webinars to increase awareness and knowledge about the VCI-MUD project, generate interest in the forthcoming toolkit, and highlight lessons learned from case studies. The webinars completed in BP2 are listed in Table 3.

9 https://chicago.suntimes.com/metro-state/2022/7/7/23197246/electric-vehicles-illinois-comed-charging-station-bronzeville
10 https://lalights.lacity.org/connected-infrastructure/ev_stations.html

Table 3 Webinars conducted by the project team during Budget Period 2

Webinar/Event title	Webinar/Event date	Presenter(s)
What is VCI-MUD?	February 25, 2021	Kevin Wood, CSE
VCI-MUD Innovative Charging Technologies: Video Site Tours (Part 1)	May 27, 2021	Kevin Wood, CSE
VCI-MUD Innovative Charging Technologies: Video Site Tours (Part 2)	June 23, 2021	Kevin Wood, CSE

Key findings and lessons learned from BP2

- Utilities or other project promoters should **engage with community-based organizations (CBOs) and local authorities having jurisdiction (AHJ), and other key stakeholders early and often** to ensure there is strong support for the project design and siting. This is especially true for curbside EV charging projects, where public rights of way are involved and parking and traffic flow for adjacent properties may be impacted.

- There are several innovative solutions emerging, including **load management systems, mobile solutions with integrated energy storage**, and even **off-site, MUD-adjacent EV charging stations** that can help avoid or defray expensive electrical infrastructure upgrades, overcome physical limitations on parking spaces and HOA restrictions, and accelerate installation timelines.

The case studies and fact sheets developed throughout BP2 provided a strong foundation for the creation, and eventual dissemination, of the VCI-MUD toolkit – drawing on real-world experiences installing EV charging at MUDs. In BP3, the project team turned its attention to finalization and dissemination of the toolkit.

Budget Period 3 – Toolkit Development and Dissemination (7/1/21 – 12/30/22)

During BP3, the project team finalized the five tools described in the section on BP2, and disseminated the toolkit through webinars, presentations, and journal articles.

BP3 Focus Area 1 – Toolkit Finalization

The final toolkit featured five primary tools, tailored to three key audiences: 1) MUD residents, 2) apartment building management, and 3) homeowner associations. The steps of each audience journey are unique to the needs of the user and each step of the EV Charging Roadmap contains its own specific information with tools to help the user.

The five tools include:

1. **MUD EVSE Journey Roadmap** – tailored to each of the three primary audiences and serving as a guide to the user's experience with the online toolkit.
2. **MUD resident Empowerment Toolkit** – a guide for how MUD residents can effectively engage with their landlord or homeowners association (HOA) to advocate for installation of EV charging.
3. **MUD Building Self-Evaluation Survey** – a survey to be completed by MUD decision-makers to gauge business readiness, identify barriers, and orient them to useful tools within the VCI-MUD toolkit.
4. **MUD EVSE Technology Selection Tool** – utilized by a MUD decision-maker who has completed the self-evaluation survey. The user selects the barriers they face, and the tool provides facts sheets and case studies that present solutions to those barriers.
5. **Outreach Presentation tool** – a resource and presentation template for EV charging advocates to engage with interested parties on overcoming MUD EV charging barriers.

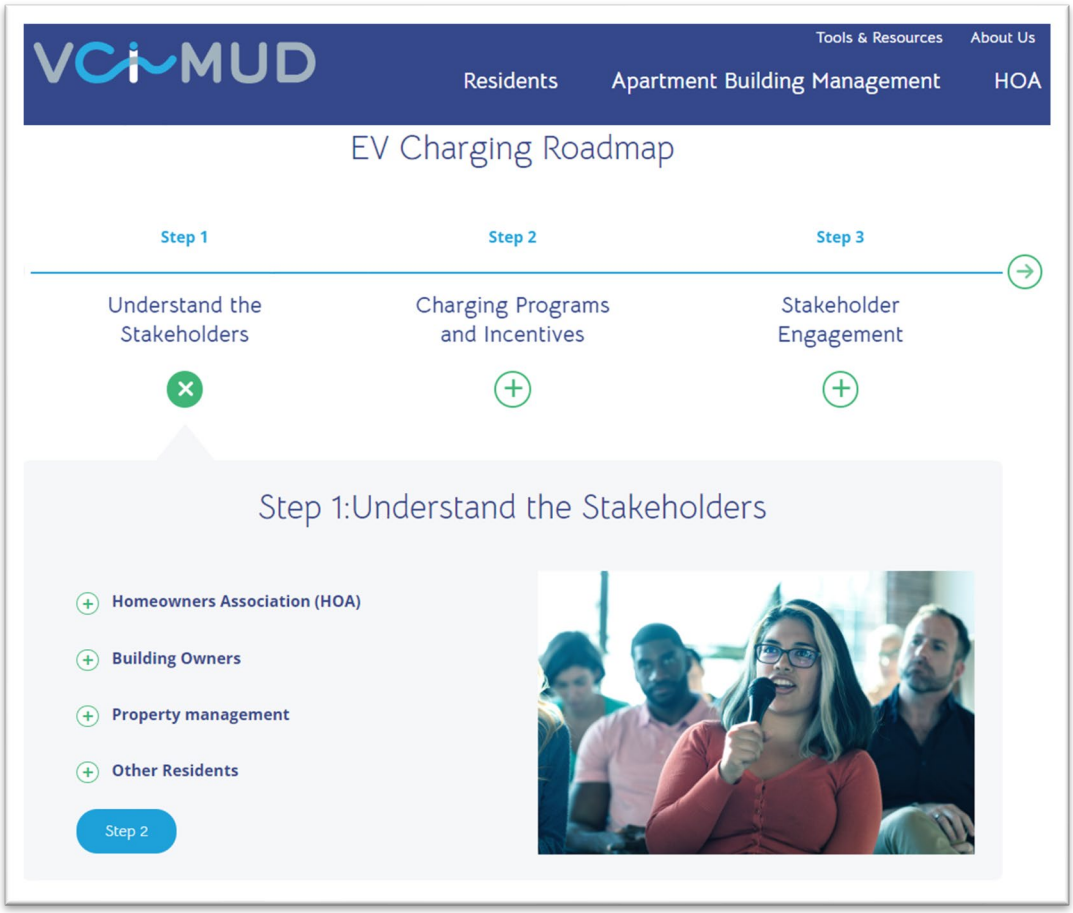

Figure 3 EV Charging Roadmap for a resident of a MUD. Available at https://vci-mud.org/residents.

Figure 4 VCI-MUD Technology Selection Tool. Available at https://vci-mud.org/Technology-Selection-Tool.

In addition to the five core tools, the toolkit also contains the following resources:

- **Charging Basics document** – explains the basics of EV charging, including common terminology, a description of the different "levels" of EV charging, and considerations of parking arrangements.
- **Installation Checklist** – a checklist including commonly required plans and documents, pre-installation work, equipment and scheduling guidance, and installation steps.
- **Curbside Charging Resources** – includes three resources for curbside charging, including lessons learned from the ComEd curbside charging case study, the Los Angeles Bureau of Street Lighting's experience installing over 550 curbside Level 2 chargers, and a working paper from the World Resources Institute examining the use of streetlights and utility poles for curbside EV charging.
- **Find an Electrician** – contains links to a list of Electric Vehicle Infrastructure Training Program (EVITP) certified installers and Qmerit's commercial services.
- **"Right-to-Charge" States** – a website highlighting states with "right-to-charge" laws that aim to ensure MUD residents face fewer barriers in installing EV charging.
- **Business Case Document** – a template that assists property owners/managers in understanding their needs and working with a contractor to develop an understanding of upfront and ongoing costs of installing EV charging.
- **EV Charging Demand Evaluation** – an Excel-based template that helps property owners/managers understand the electric panel needs related to different configurations of Level 2 charging.
- **Baseline Data Analysis** – comprehensive analysis of EVSE operational data provided by project partners, evaluated during BP1, and subsequently updated during BP3. The report provides both

quantitative data on EVSE operational data and charging patterns, as well as results of stakeholder interviews conducted to understand common barriers to MUD EV charging.

- **MUD Toolkit** – A toolkit developed by the National Association of State Energy Officials (NASEO) to inform state energy office investment, policy, and program strategies.

The toolkit was finalized and launched in late August 2022. From website launch through the end of the project period, the website was viewed 3,258 times by 1,277 users.

BP3 Focus Area 2 – Dissemination of the Toolkit

Once the toolkit was launched, the project team and partners focused on disseminating the online toolkit to key audiences, including electric utilities, MUD managers and developers, state/local governments, and more. This was done primarily through the Clean Cities Coalitions (CCCs), with support from Forth. The CCCs and project team completed over 50 webinars and presentations to stakeholder groups during BP3. For a complete list of webinars and presentations by the CCCs, see Appendix B.

The toolkit also was presented at several industry conferences, including:

- **Forth Roadmap Conference** – This conference, organized by project partner Forth, focuses on electric transportation and is where clean mobility thought leaders meet to transform the transportation sector.

- **DISTRIBUTECH** – This conference bills itself as the leading annual electricity system transmission and distribution event and is highly attended by utility professionals and EV charging service providers.

- **Greater Washington Regional Clean Cities Coalition Annual Conference** – An annual conference aimed at promoting clean transportation fuels and climate equity.

- **RE+** – Formerly known as "Solar Power International," RE+ is a joint effort by the Smart Electric Power Alliance (SEPA) and the Solar Energy Industries Association (SEIA) that brings together thousands of clean energy professionals and covers a variety of topics across the clean energy landscape.

- **OPTECH Conference & Expo** – The OPTECH conference specializes in identifying improvement and innovations in operations of multifamily housing.

Key findings and lessons learned from BP3

- Through the course of the project, Clean Cities Coalition members became far more familiar with MUD EV charging, and as a result are better positioned to advise MUD managers and tenants in their areas. Due to their broad geographic distribution and reach, **CCCs are valuable partners** to engage diverse groups of stakeholders.

- **Different audiences have different needs** when it comes to starting the MUD EV charging journey. Successful projects require strong cooperation and alignment of incentives. Tools to support this process cannot focus solely on one audience.

- The VCI-MUD toolkit assembles insights from interviews, operational data analysis, and case studies from stakeholders and EV charging installations from across the country, in an easily accessible online toolkit, making the **outputs of this project highly replicable.**

Conclusion

The VCI-MUD project made an important contribution to the ongoing effort to bring EV charging to MUDs and ensure equitable access to electrified transportation for MUD residents. Throughout the course of this project, the market for EVs and for MUD EV charging continued to evolve and grow. Nationally, EVs were less than 2% of new light-duty vehicle sales in 2019. Today EVs are approaching 20% of new car sales in early-mover markets like California and exceeded 7% of new car sales nationally in January 2023.[11] As the used EV market begins to emerge, the need for EV charging solutions at MUDs will be even more pronounced, as many low- and moderate-income families, who disproportionately purchase used vehicles, also live in MUDs.

Traditional charging solutions have been expensive to install, maintain, and operate. This project identified a number of cost-effective solutions that reduce installation and operating expenses and helps make installing chargers easier through a user-friendly online toolkit. These solutions put charging within the reach of more MUD property owners and residents. The project also documented successful off-site charging and curbside charging solutions, further expanding the array of options available to utilities, EV charging providers, and government agencies that wish to expand public EV charging networks in a way that supports MUD charging.

Replicability

From the outset, the project team engaged with a diverse group of partners and stakeholders from across the country, including Clean Cities Coalitions in various regions. This ensures the analyses, case studies, and resulting toolkit resources are representative of a spectrum of experiences, not just those from early-mover states, and that the project outputs are highly replicable.

Next steps

The VCI-MUD toolkit remains accessible online, with project partners promoting it as opportunities arise. In February 2023, ComEd and the Chicago Clean Cities Coalition held a webinar on lessons learned for curbside charging, as highlighted in the toolkit.

The toolkit would benefit from regular content refreshes, as well as addition of new case studies and fact sheets on emerging innovative technologies. The project partners will continue to seek funding opportunities, whether from the Department of Energy or other sources to make this possible.

[11] https://insideevs.com/news/657660/us-electric-car-sales-january2023/

Appendix A – Project Partners

Organization	Category	Primary Role
Center for Sustainable Energy	Project Awardee	Program Management & Planning
Energetics	Project Lead	Data Evaluation & Demonstration Planning
Forth	Project Lead	Outreach & Communications
Chicago Area Clean Cities	Clean Cities Coalition	Advisory & Outreach
Clean Communities of Central New York	Clean Cities Coalition	Advisory & Outreach
Columbia-Willamette Clean Cities	Clean Cities Coalition	Advisory & Outreach
Greater Washington Region Clean Cities	Clean Cities Coalition	Advisory & Outreach
South Shore Clean Cities	Clean Cities Coalition	Advisory & Outreach
Tulsa Clean Cities and Indian Nations Council of Governments (INCOG)	Clean Cities Coalition	Advisory & Outreach
Virginia Clean Cities	Clean Cities Coalition	Advisory & Outreach
Western Washington Clean Cities	Clean Cities Coalition	Advisory & Outreach
Wisconsin Clean Cities	Clean Cities Coalition	Advisory & Outreach
City of Los Angeles	Government/Association	Data Provider
National Association of State Energy Officials (NASEO)	Government/Association	Advisory & Outreach
St. John Properties/Bozzuto	MUD Stakeholder / Site Host	Data Provider & Demonstration Site
Cyber Switching Solutions, Inc.	Technology Provider	Technology Provider
Electric Vehicle Institute	Technology Provider	Data Provider & Technology Provider
FreeWire Technologies	Technology Provider	Data Provider & Technology Provider
Liberty Plugins	Technology Provider	Technology Provider
OpConnect, Inc.	Technology Provider	Data Provider & Technology Provider

PowerFlex	Technology Provider	Technology Provider & Demonstration Site
ComEd	Utility	Data Provider & Demonstration Site
Rocky Mountain Power/Pacific Power	Utility	Data Provider & Demonstration Site
Electrify America	Market Advisory	Advisory & Outreach
Plug In Connect	Market Advisory	Advisory & Outreach
Puget Sound Electric	Utility	Advisory & Outreach
Seattle 2030 District	Market Advisory	Advisory & Outreach

Appendix B – Clean Cities Outreach Events

Clean Cities Coalition	Event/webinar Name	Speakers	Date
Grtr Wash Reg CCC	Women in Alternative Fuels- webinar	Multiple Speakers- View Announcement: htt	March 3, 2022
Drive Clean Indiana	Indiana Utility Group Meeting	Carl Lisek, Ryan Lisek, Kyle Lisek	March 8, 2022
Clean Communities of CNY	Greenspot Site Selection	Barry Carr / Loral Wilson	April 1, 2022
Clean Communities of CNY	Tompkins County Used EV Event	Barry Carr / Loral Wilson	April 6, 2022
Clean Communities of CNY	Energy 21 Presentation	Barry Carr	April 8, 2022
Drive Clean Indiana	USGBC Board Meeting	Carl Lisek	April 19, 2022
Grtr Wash Reg CCC	Earth Week -Webinars	Multiple Speakers: https://conta.cc/3jyYCU8	April 19, 2022
Clean Communities of CNY	Earth Day - Cazenovia Presentation	Chris Carrick	April 23, 2022
Wisconsin Clean Cities	Transportation & Innovation Conference & Expo	Lorrie Lisek	April 28, 2022
Clean Communities of CNY	Sustainable Manlius Presentation	Barry Carr	April 30, 2022
Clean Communities of CNY	Annual Stakeholders Meeting	Barry Carr / Veronica Cason	May 6, 2022
Grtr Wash Reg CCC	Spring Policy Virtual Conference	See details: https://conta.cc/3m27Eyb	May 17, 2022
Columbia-Willamette	Reliable Autonomous Charging Solutions	Erin Galiger	May 25, 2022
Clean Communities of CNY	City of Syracuse Planning Board	Barry Carr / National Grid	June 15, 2022
Clean Communities of CNY	Livingston Energy Presentation	Barry Carr	June 22, 2022
Wisconsin Clean Cities	WI Government Opportunites Business Conference	Matthew Christman	July 13, 2022
Drive Clean Indiana	Indiana Utility Group Meeting	Carl Lisek, Ryan Lisek, Kyle Lisek	July 21, 2022
Virginia Clean Cities	Toolkit webinar	Working with a property management compar	July 22, 2022
Columbia-Willamette	Making EVs Work For Low to Moderate Individuals	Ben Macneile	July 26, 2022
Drive Clean Indiana	IN Office of Energy Development	Kyle Lisek	July 26, 2022
Drive Clean Indiana	Ports of Indiana EV Demonstration	Ryan Lisek, Kyle Lisek, Carl Lisek	August 2, 2022
Grtr Wash Reg CCC	EV Charging in Apts and Condo Webinar	Brian Gillespie, Sheryl Ponds, Luis McDonald, and Whit Jamieson	August 9, 2022
Columbia-Willamette	Green Transportation Summit & Expo	Kevin Hachey	August 19, 2022
Wisconsin Clean Cities	SE WI Electrical Inspector Meeting	Lorrie Lisek	September 7, 2022
Wisconsin Clean Cities	Prospect Management Company	Lorrie Lisek	September 8, 2022
Wisconsin Clean Cities	EV Roundtable	Lorrie Lisek	September 13, 2022
Tulsa Clean Cities	Tulsa Apartment Association webinar announcement	Michelle Merchant	September 14, 2022
Drive Clean Indiana	Drive Clean Indiana Annual Conf	Carl Lisek	September 20, 2022
Drive Clean Indiana	SAE Comvac Conference	Ryan Lisek	September 20, 2022
Clean Communities of CNY	19th Annual Alt Wheels Conference	Barry Carr	October 3, 2022
Chicago Area Clean Cities	Transportation Technology and Operations Coalition Meeting	Samantha Bingham	October 6, 2022
Chicago Area Clean Cities	Cooperator Expo Chicagoland	Samantha Bingham	October 13, 2022
Tulsa Clean Cities	MUD Charging Webinar	Michelle Merchant	October 13, 2022
Chicago Area Clean Cities	Webinar: Vehicle Charging Innovations	VCI-MUD Project Team	October 19, 2022
Grtr Wash Reg CCC	Annual Meeting	AV Charging in Apts., Condos, and Hotels	October 20, 2022
Consortium	Clean Cities North Central Regional Call	Lorrie Lisek, Carl Lisek, and Sam Bingham	October 20, 2022
Wisconsin Clean Cities	Webinar: Electric Vehicle Charging for Multi-Unit Dwellings	Lorrie Lisek	October 20, 2022
Chicago Area Clean Cities	City of Elmhurst Sustainability Day Event	Samantha Bingham	October 26, 2022
Drive Clean Indiana	Environmental Justice and Climate Justice	Carl Lisek	October 28, 2022
Clean Communities of CNY	Climate Change Action Committee	Barry Carr	November 12, 2022
Wisconsin Clean Cities	WI Sustainable Business Council		November 16, 2022
Central New York	CNY Property Manager Association	Barry Carr	November 28, 2022
Chicago Area Clean Cities	EV Webinar promoted by our utility to their	Samantha Bingham	December 1, 2022
Wisconsin Clean Cities	WCC Annual Meeting	Lorrie Lisek	December 8, 2022
Virginia Clean Cities	Meeting with Harrisonburg Housing Authority	Matthew Wade & Bruce Vlk	December 13, 2022
Puget Sound Clean Air Agency	Webinar: EV Charging in Multi-Family Housing in the Puget Sound Region	Kelly O'Callahan	December 14, 2022
Greater Washington Region Clean	Multi-Unit Dwelling Development for Property	Antoine Thompson	December 15, 2022

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