Kansas City, Missouri, Streetlight Electric Vehicle Charging

Strategies and challenges for site selection of streetlight electric vehicle infrastructure in Kansas City, Missouri

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Introduction

Public streetlight charging, whether on streets in central business districts or residential areas, provides easy charging access for apartment residents and homeowners alike. While most electric vehicle (EV) drivers charge at home, they do so in garages or on driveways they own. For renters and residents of multifamily housing (MFH), however, this may not be an option. EVs have a lower cost of ownership compared to conventional vehicles, and a used EV may be an affordable option for a lower-income household. But without easy access to charging, even a low-cost used EV may not be an option for a prospective buyer. An affordable curbside charging network has the potential to expand EV adoption into neighborhoods that have to date seen minimal interest and uptake of the technology and associated charging infrastructure. Streetlight charging networks can provide an economical, scalable, and effective approach to providing equitable and convenient charging.

Metropolitan Energy Center (MEC) is dedicated to the mission of creating resource efficiency, environmental health, and economic vitality in the Kansas City region and beyond. Since 1983, MEC has provided resources, outreach, and training to make alternative fuels and energy efficiency commonplace. MEC led a streetlight charging pilot project that installed limited EV charging infrastructure on the streetlight system in Kansas City, Missouri, to demonstrate and test the benefits of curbside charging for EVs at existing on-street parking locations. The project aimed to cost-effectively expand the charging network in Kansas City to support residential charging and provide infrastructure in one or more charging deserts throughout the city. This pilot evaluates the impact and overall success of streetlight charging based on community feedback, utilization of charging infrastructure, technical feasibility, and cost. The project has pursued a data- and community-driven site selection process designed to identify sites with high demand and high opportunity for EV charging.

This project was funded by the U.S. Department of Energy (DOE) and awarded to MEC through a competitive proposal process. The novelty and complexity of this project required an organization that could facilitate collaboration across levels of government, community members, and industry partners. For the past 25 years, through Kansas City Regional Clean Cities, MEC has worked with numerous public and private fleets on a variety of projects to improve the environmental performance and efficiency of the regional vehicle fleet. To advance affordable, efficient, and clean transportation efforts, DOE Clean Cities and Communities coalitions create local networks of public and private sector stakeholders and engage communities. Rooted within their local communities, the coalitions serve as experts and ambassadors, bringing to bear the collective knowledge, experience, and practical know-how of the entire network from within DOE, its national laboratories, and diverse stakeholders in the field.

MEC and its project partners made in-kind contributions to leverage federal dollars for the benefit of the Kansas City community. Findings from this project will help determine the best applications for streetlight charging technologies to maximize funding impact and serve community needs. The team evaluated locations based on expected charging demand, technical feasibility, safety considerations, and enhanced charging network siting needs. Throughout the project, the team gathered feedback and evaluated ways to make public charging for EVs available to all community members. The insights will help Kansas City and other communities streamline future efforts to support EV drivers through public charging in the city right-of-way.

Furthermore, this project will inform citywide guidance for future installations.

MEC is committed to a transparent and publicly accessible approach that encourages the collaborative evaluation of streetlight charging. The project has engaged the community to proactively identify and evaluate the benefits and impacts of streetlight charging. It was a priority for the project to ensure the benefits of this pilot are distributed equitably to all members of the Kansas City community and that new charging opportunities and associated resources are available in diverse neighborhoods across the city. The charging infrastructure supports an affordable curbside charging network that will enable more drivers to choose EVs and provide easy charging access for all community members interested in driving an EV. The community feedback received through this project informed future resources and opportunities to make EVs more accessible to all members of the Kansas City community.

MEC worked with several community partners on this project, including Missouri University of Science and Technology (MST), Pennsylvania State University (Penn State), the National Renewable Energy Laboratory (NREL); the city of Kansas City, Missouri; Evergy; Black and McDonald (B&M); LilyPad EV; EVNoire; and Westside Housing Organization (WHO). Project partners contributed to the cost match required for DOE grants through capital expenditures, personnel, and other in-kind contributions. Detailed descriptions of project team organizations can be found in Appendix A. Project Partners.

Analysts at NREL and MST/PennState developed site maps based on demand and equity considerations. MEC conducted outreach to community members to garner input on project design and site selection, and received approval from the Missouri Public Service Commission (PSC) for Evergy's EV charging station ownership. MEC worked with all partners to gather additional siting criteria and developed a site selection evaluation checklist, and partners conducted site visits to proposed installation sites. Next, B&M, Evergy, and the city executed all site agreements, conducted site-specific engineering design, acquired associated permits, and issued notices to proceed site by site or in small batches. Finally, from January to April 2023, the project team installed 23 EV charging stations built on Kansas City's streetlight system in six council districts. Evergy will own, operate, and monitor the stations for 10 years, sharing charging data with MEC for at least 1 year.

As shown in **Figure 1**, the project was structured into five main phases, which included design and modeling, site feasibility assessment, outreach and deployment, monitoring, and analysis, spanning from 2018 to 2024. In the midst of this effort, the global COVID-19 pandemic delayed the project time frame. In particular, the pandemic altered the way MEC and project partners could conduct site assessments and engage with community members. New protocols also slowed down progress and increased the project timeline.

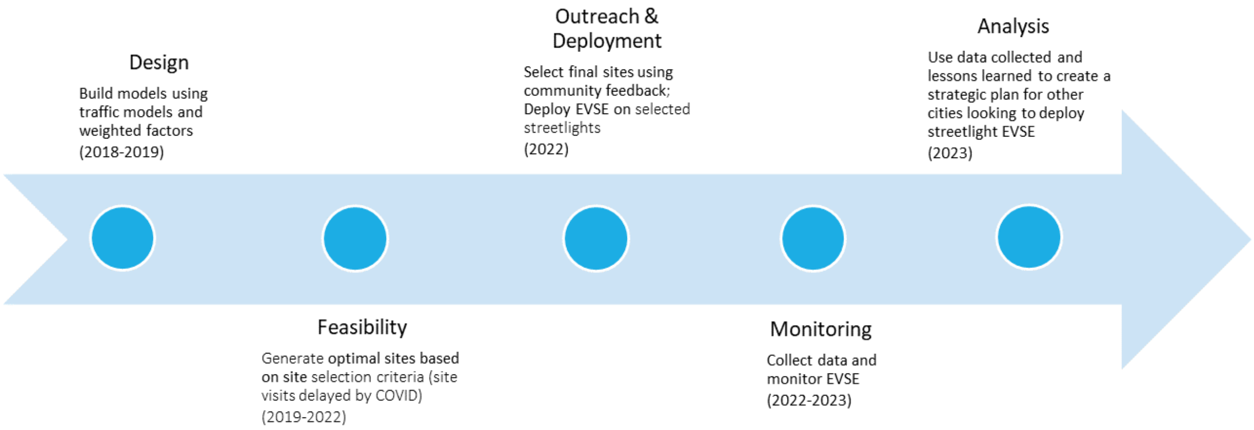


Figure 1. Streetlight EV charging project timeline for major tasks.

Source: metroenergy.org/current-projects/streetlight-ev-charging/

This report is issued to present the project process and lessons learned, and to inform future planning efforts by DOE and other communities that may have an interest in streetlight EV charging solutions.

Technology Selection

The scope of the project was limited to streetlight EV charging within Kansas City, Missouri. The objective of this project is to equitably expand the availability of EV charging at low cost in the city through the use of existing electrical infrastructure on the streetlight system to provide on-street EV charging, including charging for MFH. Initial discussions with the Kansas City Department of Public Works revealed considerable city interest in the concept. For Public Works, using standard-issue EV charging equipment—typically Level 2 installations in an on-street configuration—is problematic. Maintenance overhead, high installation costs, and the added expenses of connecting charging stations to available power supplies at varying distances make the prospect of conventional curbside charging particularly expensive. From their perspective, streetlight charging presented a potentially low-cost option to build charging networks. This approach reduces the need to lay conduit, dig trenches, cut through curbs, or jackhammer sections of sidewalk, in addition to being more aesthetically pleasing and taking up minimal space along sidewalks. And given the low-voltage, long-cycle charging streetlight systems provide, it was predicted that these networks were unlikely to contribute substantially to spikes in electricity demand during peak load periods.

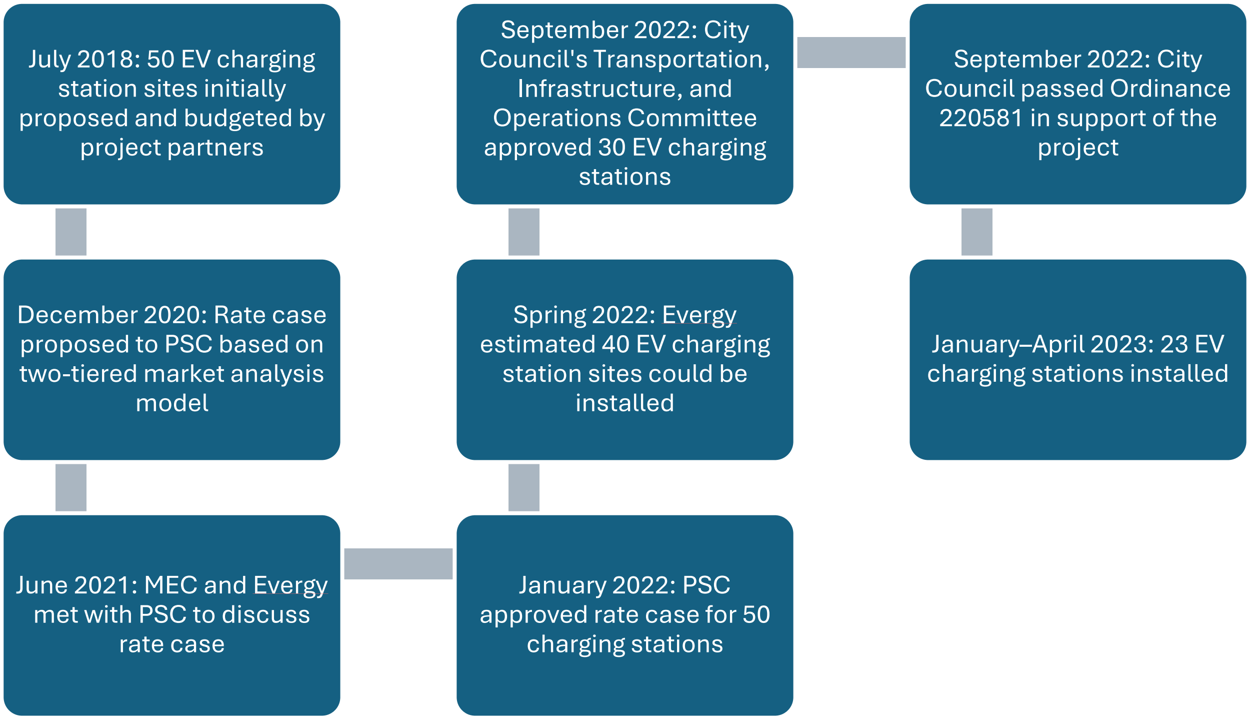


Figure 2. Streetlight EV charging project high-level approval timeline

The project required various approvals, as shown in **Figure 2**. Two paths determined the number of EV charging sites installed: a regulatory path and a cost path. At the start of the project in July 2018, project partners proposed and budgeted for 50 EV charging station sites. Through a rate case proposed to the PSC in

December 2020, PSC approved up to 50 EV charging sites in 2022. After PSC approval, Evergy's costing team estimated that approximately 40 EV charging stations could be feasibly installed based on revised cost estimates in 2022 and disapproval of high-cost sites. The City Council Transportation, Infrastructure & Operations Committee approved 30 sites in September 2022, based on other planned infrastructure projects and equity considerations. Ultimately, from January to April 2023, the engineering team installed 23 EV charging stations due to constraints on cost and the availability of well-placed poles reducing the project scope. This project is designed to create a replicable model for building out equitable EV charging networks. A successful model for streetlight-based charging will help inform the expansion of streetlight EV charging networks.

Supply

In the initial project design, it was believed that the easiest and most economically feasible way to power a pole-mounted EV charger was through overhead supply. Prior to any earnest investigation, the belief was that deploying LED bulbs in streetlights would free up power to serve an EV charger. Further, using grid-tied systems already in place from the overhead supply had the potential to cut installation costs. The idea was to create a replicable approach for flexible, affordable charging systems feasible wherever cities operate streetlights. Early on, however, engineers calculated that this would not be the case. Findings revealed that the voltage and amperage of the existing infrastructure would not support the requirements of the EV charging stations. The initial plan to directly use existing utility lines serving telephone poles was discarded.

Additionally, further investigation into the project design uncovered complications with ownership or responsibility of the wiring maintenance between the city and Evergy. Under current city and utility maintenance agreements, Evergy is responsible for maintaining the "first feed" of the streetlights from transformer to first pole. For every pole after that in the string, the city is responsible for maintaining the streetlight wiring. Project partners could not determine whether responsibility for maintaining all streetlight wires up to the charging station would fall on Evergy or the city. Instead, new infrastructure was installed to support the EV charging infrastructure with 208/240V, single-phase, 40-amp power supply.

Power for the pole-mounted charger was supplied through underground feed. In Kansas City, these locations are usually found in more densely populated areas. In addition to the difficulty of installing required conduits, it has also been generally more difficult to find an appropriate and usable nearby power source. To identify the necessary power, project partners reviewed how many services were connected to existing transformers. All streetlights required upgrades, as adding the charging station would have exceeded the electrical circuit rating for the transformers. The engineers used cable length and expected maximum load of the charging stations to

Supply Technical Considerations

1. Proximity of utility transformers (208/240V, single phase, 40 amp) compared to other locations considered.
2. Difficulty of installation—overhead, underground, distance, type of excavation, type of surface, and density of other utilities.
3. Structural capability of the pole to handle the charger and difficulty of upgrading, if necessary.

determine wire size. Although 30 sites were approved for installation by the city, based on costs for additional upgrades, the engineering team identified 208/240V, single-phase, 40-amp required power supply for 23 sites.

Equipment

The project utilized a ChargePoint CT4013 single-port, wall-mount station (Figure 3). These stations can be mounted directly on poles and are Level 2 stations, which give a meaningful charging rate for drivers of 25 miles of range per hour. Additionally, the charger is an ENERGY STAR®-certified EV charger, which means it uses on average 40% less energy than a standard EV charger when the charger is in standby mode. Further, the chargers can be monitored and diagnosed remotely and, importantly, fit into management and maintenance processes used by Evergy for the rest of their stations in the service territory. All existing stations are also ChargePoint. LilyPad consulted MEC on equipment selection.

Figure 3. ChargePoint CT4013 single-port, wall-mount station

Site Selection

Two-Tiered Market Analysis Model

A report from the International Council on Clean Transportation (ICCT), published when the site selection analysis was done in 2019, suggested that Kansas City has one of the strongest public charging networks in the country. The initial map of potential streetlight EV charging sites was developed through a modeling process that was approached as a two-tiered market analysis. The first tier was a demand model conducted by MST/PennState that evaluated travel demand data to identify locations that have the potential to be highly utilized based on points of interest, existing charging station usage, and existing traffic patterns in Kansas City. The second tier was a demographic analysis developed by NREL that showed potential for market expansion by highlighting areas with low access to residential charging and potential for increased EV adoption. Together, the demand model produced sites near companies with many employees, near retail centers, and some near apartments, and the demographic analysis identified areas of opportunity within the demand model results.

Demand Model

The demand model depicted candidate locations for streetlight charging based on predicted usage rates. A four-step model (**Table *1***) was developed to make these predictions, and incorporated 6-year charging event log data from 455 charging stations provided by ChargePoint, travel demand data from the Mid-America Regional Council, and other data sources to study the relationship between these datasets and charging frequency (Step 1). Next, a boosting-based ensemble learning model was developed and trained to study the relationship between the existing charging station's daily usage frequency and the defined features from Step 1, including land use types, existing charging station density, neighborhood traffic volume, and neighborhood trip production (Step 2).

After EV charging equipment usage frequency data were gathered, points of interest (POIs) were retrieved to identify the potential high-usage-rate locations if charging stations were to be deployed (Step 3). The rationale was that EV drivers are most likely to park and charge their vehicles at locations near their destinations, or where they could fulfill certain needs while waiting for their EVs to be charged. Such locations include apartments, shopping malls, churches, restaurants, grocery stores, or other kinds of POIs retrieved from Google Maps.

At the final step, the daily usage frequency of 1,252 candidate locations were evaluated to answer the question of what would happen if EV charging infrastructure were to be deployed at these locations (Step 4). A total of 300 streetlights at locations with the highest predicted usage rates were selected as candidates for further field survey and evaluation. For a complete list of data sources and a detailed description of the model, see Appendix B. See **Figure 4** for a depiction of the demand model results.

Table 1. The Four-Step Prediction Model

Steps	Description
Step 1: Define factors that affect electric vehicle supply equipment (EVSE) usage frequency	Features included existing charging station density, traffic volume, trip production and attraction, and land use types.
Step 2: Develop and train a boosting-based ensemble learning model	The existing charging station's daily usage frequency was the dependent variable, and the defined features (from Step 1) were independent variables.
Step 3: Identify candidate locations	POIs in Kansas City were retrieved from Google Maps as candidate locations by using the Google Maps API.
Step 4: Predict usage frequency of candidate locations	A total of 300 streetlights at locations with the highest predicted usage rates were selected as candidate locations for further field survey.

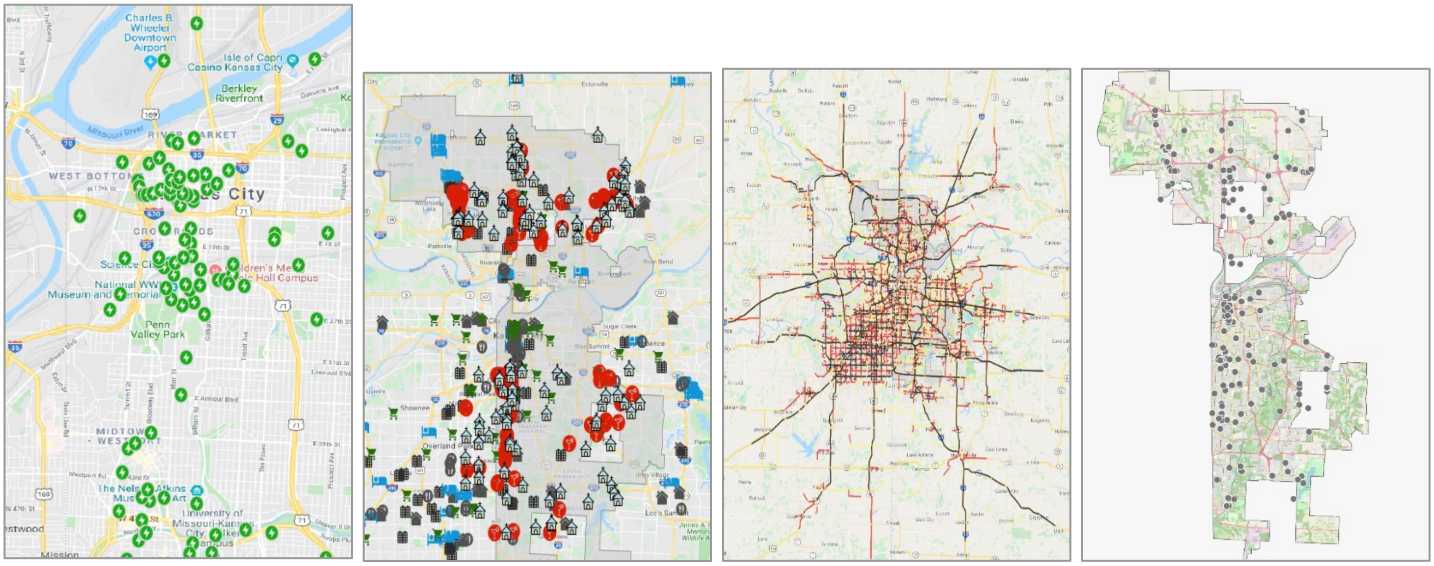


Figure 4. The first tier of the modeling effort focused on looking at existing charging data, community locations, and travel demand data to identify locations that have the potential to be highly utilized based on existing traffic patterns in Kansas City.

The modeling results suggested that charging stations in the business areas (e.g., restaurants, plazas, shopping malls) were used most often, and street charging in residential areas used least often. Additionally, results suggested that areas with denser charging infrastructure correlated with higher charging station usage per station. This suggests that charging infrastructure in the Kansas City area still has opportunity for growth, as a higher supply would induce a higher usage rate overall. It also indicates an interesting charging behavior: that EV drivers are more likely to travel to and charge their vehicles at an area with denser charging stations.

Demographic Analysis

Next, NREL layered on the demographic analysis to narrow the results of the MST/PennState analysis to locations that would also meet certain demographic criteria. As noted earlier, this project sought to support those who are without residential charging access and ensure public investment in charging infrastructure results in equitably distributed charging stations. Three additional layers (Table 2) were added to the areas where MST identified high utilization potential to highlight areas that would meet certain demographic data in support of the intended audience. The overlay developed by NREL identifies streetlight charging locations that may have potential for future adoption or additional residential utilization opportunities. These focus areas were developed using EV registration data, land use and tenure data for Kansas City, and socioeconomic indicators and environmental and demographic indicators from EPA's EJScreen tool. For a detailed overview of the methodology NREL developed, see Appendix C. NREL Modeling Overview. By incorporating criteria based on these categories, candidate locations were selected in a way that considers equitable access to streetlight EV charging equipment, in addition to market demand.

Table 2. EV Adoption Opportunity Categories

	Equity Considerations
Easy Wins – Focus Area 1: Areas with relatively high EV shares AND that are likely to have poor residential EVSE availability	Can we support residential charging demand for people that already own EVs?
Unlock Potential – Focus Area 2: Areas with relatively low EV shares AND demographics that suggest they would be amenable to EV adoption AND that are likely to have poor residential EVSE availability	Can we "unlock" areas of the city where residential charging availability is the primary barrier?
Create Opportunity – Focus Area 3: Areas with low incomes AND high MFH shares (which would imply poor residential EVSE access)	Can we target key parts of the city where vulnerable populations with limited EVSE access may reside?

The concept for Focus Area 1 (**Figure 5**) is for EV charging equipment to serve as a substitute or replacement for people that already own EVs, but may rely on charging at work, higher-cost fast charging, or other harder-to-access public charging. This would give EV drivers an affordable and convenient way to charge their EVs close to home. The goal of Focus Area 2 (**Figure 6**) was to "unlock" areas of the city where residential charging availability is the primary barrier and review opportunities for streetlight charging stations. Focus Area 3 (Figure 7) targets key parts of the city where underserved populations with limited EV charging equipment access may reside. This ensures that the public investment from this project is made in areas that may not otherwise be a high priority for private investment, creating opportunity in many areas of low EV potential.

For all these scenarios, NREL overlayed the outputs of the demographic analysis with the initial analysis conducted by MST, with the goal of identifying locations with potential for high utilization. For each of the EV adoption opportunity focus areas, NREL employed multi-criteria geospatial analysis. NREL evaluated the geographic intersection of EV adoption rates, income, housing ownership, and building parcels for the dwelling type of interest. NREL also overlayed environmental indicators such as areas of high traffic, noise, and traffic-related air pollution to identify areas where EV charging equipment and related EV adoption could help mitigate some of these impacts. Environmental justice indicators appear in all three EV adoption opportunity categories to demonstrate coincidence of air quality issues with use case scenarios.

NREL developed three separate heat maps to address each of the individual focus areas discussed above. NREL collaborated with MST to overlay these maps on the MST model output to identify locations in Kansas City that support a robust charging network, meet the residential charging needs of existing and future EV drivers, and can be reasonably expected to have high utilization.

Adding the demographic layer on top of the traditional siting analysis allows MEC to focus on specific groups of citizens the project seeks to support, including low-income, historically disadvantaged, or environmental justice communities. As a result of this overlay, the analysis helps ensure an equitable investment in charging infrastructure across Kansas City. Through the two-tiered market analysis model, MST and NREL narrowed the locations to identify areas where there may be high utilization based on daily travel demand and have the added utilization potential as a replacement or substitute for at-home charging by a diverse population of drivers.

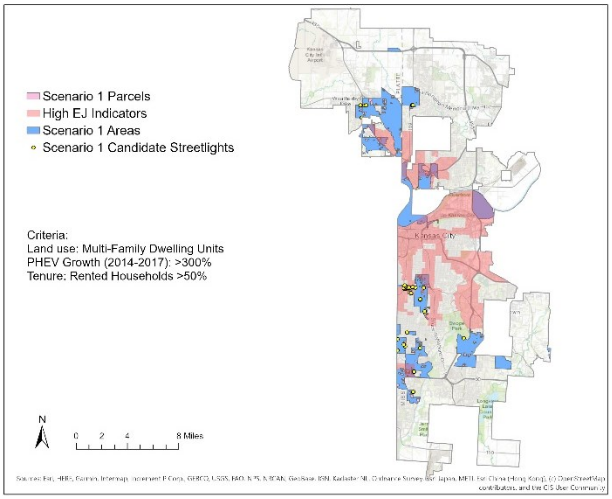


Figure 5. Easy Wins

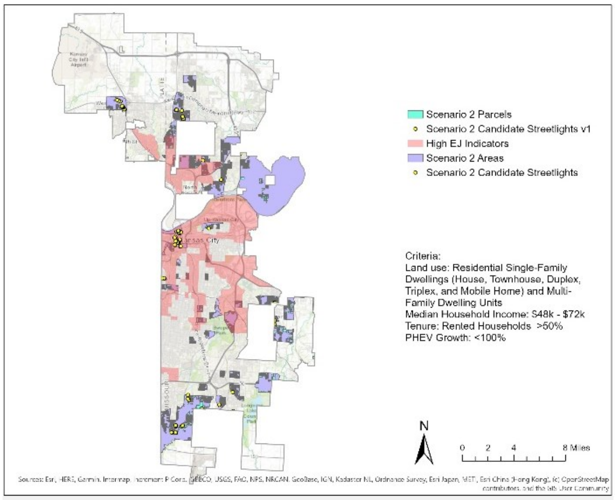


Figure 6. Unlock Potential

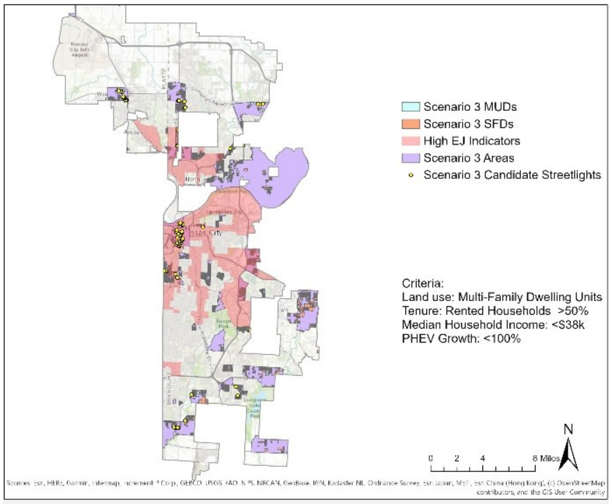


Figure 7. Create Opportunity

Ground Truthing Sites

Based on the two-tiered market analysis approach and using MST/PennState and NREL's models, 300 candidate sites were identified across Kansas City. Each site then was initially reviewed virtually (using GIS data and other mapping tools) and/or in person by project partners to assess feasibility of streetlight charger installation. Specifically, to refine candidate sites, project partners drilled down into the cost, demand, location, and other factors for each of the 300 locations. Then, specific partners reviewed the sites more thoroughly, further refining the list.

The first two primary considerations to assessing candidate sites were the nature of the streetlight poles themselves and parking restrictions. The poles were disregarded as candidate sites if they were decorative or historic poles, if controllers would require significant modification, or if the site was too far from the pole. Parking considerations that eliminated candidate sites were proximity to a fire hydrant, driveway, or an intersection; bike lanes; and other areas where parking is disallowed altogether or restricted by one-way traffic. In addition to comparison of the datasets, each site also had to be visited and evaluated for pedestrian hazards and other nearby site complications not evident from map imagery. As cost is a primary consideration in assessing a site's feasibility for an EV charging station, project partners prioritized sites with the lowest additional cost. Sites with capability to easily install equipment, such as close to a transformer and not requiring tearing up pavement or equipment, have lower overall costs.

The demand and location of the candidate sites contributed to refining the selected sites. The sites with the highest scores from the demand model were prioritized, as well as sites within a high-traffic area and those that intersected a POI. Another criterion reviewed was how the new infrastructure would complement the existing network by identifying areas with low infrastructure, as well as areas with moderate infrastructure but high demand. Other factors of concern included permitting, potential maintenance costs, and existing EV ownership surrounding the site location.

The parking site selection review criteria significantly refined the candidate sites. The project team narrowed 300 candidate sites to approximately 80 feasible streetlights by eliminating locations without safe and legal parking near streetlights. Further review was conducted on these refined sites by each partner, and each organization developed their own selection criteria to assess each site either in person or virtually (**Table *3***).

Project partners developed a comprehensive site selection checklist as the project progressed. The MEC team assessed each site in person and focused on parking accessibility, suitability (whether there would be use for a charger), and the presence of other chargers nearby. The subjective nature of this assessment was mitigated by a collaborative project partner review. The engineering team also assessed each site in person to review the technical considerations outlined in Technology Selection.

Once the initial engineering assessment was complete, the list of candidate sites was refined to approximately 40 sites. The other project partners then reviewed this list of sites. LilyPad and Evergy visited each of these sites in person, considering cell phone reception and potential orientation of the charger (LilyPad), and traffic safety and amenities (Evergy). Both partners also noted subjective experiences of each site, such as discomfort or feeling unsafe to dwell while a charging a vehicle. Other partners reviewed these sites virtually, with some field visits. These 40 sites (refined from the engineering walkthrough) persisted as the final candidate locations (**Figure 8**).

Table 3. Site Criteria Checklist for Each Partner

Black and McDonald	MEC	LilyPad	City Parking
Overhead or underground power	Adjacent business(es)	Station faces (street/traffic/building/no-go)	Parking restrictions
Existing power (120V/240V/208V)	Nearby POIs	Place to install protective bollards? (Y/N)	Front and/or rear charging
Retrofit day/night control required (Y/N)	Land use	AT&T cell strength: −85 dBm or better (−70 better, −90 worse)	
Distance to controller/transformer (LF)	NREL demographic analysis (focus areas 1,2,3)	Verizon cell strength: −85 dBm or better (−70 better, −90 worse)	Traffic safe? (Y/N)
Distance to nearest transformer location for electric vehicle charging station (EVCS) feed (LF)	National Environmental Policy Act (NEPA) requirements	Cord safety and hazards assessment	
Existing light power run through conduit (Y/N)	EJScreen demographic index		
Existing conduit suitable for installation of new EVCS feed (Y/N)	Community feedback		
Any boring or cement work required besides bollards? (Y/N)	Council district		
Description of excavation requirements			
Permits required			
Construction notes			
Overall construction difficulty (High/Med/Low)			
Constructable (Y/N)			
Estimated cost			

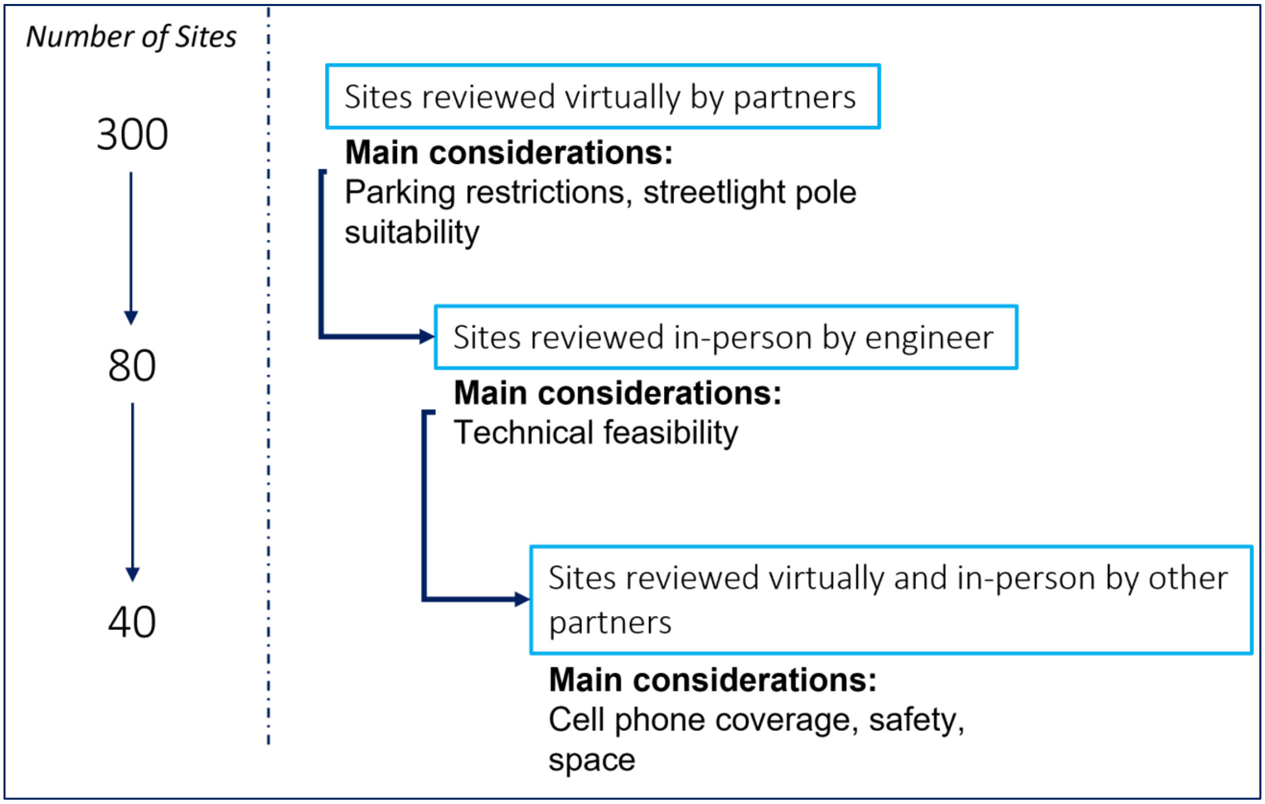


Figure 8. Candidate site review process

Community Engagement

Community Outreach and Communication

Community input is essential to any EV charging infrastructure projects, as it leverages local knowledge to identify the best sites for installation, mitigates future challenges, and creates community buy-in. NREL and MEC created a communications plan, which included two community listening sessions and presentations to share information and gather data on end-user needs, as well as interests and concerns of area stakeholders who may not necessarily become end users. The communications plan was a living document, and MEC adjusted the plan in response to input from project partners and area stakeholders. MEC developed a stakeholder matrix to identify contacts for community outreach.

In addition to diverse representation of the stakeholders to engage, it is important to offer a variety of engagement opportunities for community stakeholders. One engagement method that MEC provided was a project webpage. MEC created this webpage to share information about the project, including a map of proposed sites, project timeline, and directions for how to provide feedback and ask questions. MEC worked with community engagement partners on messaging to ensure it was accessible and understandable by community members with limited knowledge of EVs. When the project team finalized the website, several community organizations shared the webpage on their social media, and the page was shared in future communications with community stakeholders.

The MEC project team began to reach out to community-based organizations (Appendix D. Community Organization Outreach) in early 2021 to inform them of the project, invite them to share their EV charging station location ideas at a community listening session, and plan for site visits. The letter encouraged those organizations to participate in community listening sessions, gave them the opportunity to subscribe to the MEC newsletter to receive project updates, and encouraged them to visit the webpage for more information and photos and share any feedback to the email address provided. In addition to web and email content, MEC sent regular outreach letters via mail updating local neighborhoods about the pilot project, which were translated and sent in both English and Spanish. Door hangers were also translated into English and Spanish and placed on all nearby homes and businesses during construction (Figure 9). Listening session registration was also available in both languages, and a Spanish translator for the listening session was available upon request.

The site visit notification letter and invitation to community listening sessions was generally well received by the neighborhood organizations. The most interest came from small, local, community and neighborhood organizations, such as neighborhood associations and community improvement organizations. Organizations and institutions were more likely to be interested in the project if there was a proposed location near their facility. Prior to conducting the site visits, MEC explored the communities on Google Maps and added nearby community facilities to the stakeholder matrix. MEC found that these community facilities and institutions were more likely to be interested in the project than those who were not being considered for a charging station. It is a best practice to elevate the voices of those who are most impacted by a proposed project, but it is important to include diverse representation from a broader area as well.

Dear Neighbor—Over the next few weeks, construction crews will be working to install an Electric Vehicle Charger on a Streetlight pole in your neighborhood at:

(put sticker with Pole # and Address here)

Metropolitan Energy Center (MEC) is working in partnership with the City of Kansas City, Missouri to connect electric vehicle charging stations to existing streetlights. The project team chose electric vehicle charging locations based on technical logistics and listening sessions that happened in your area. The charging station will soon be installed.

We will not be doing any work on your private property—all work is performed in public right-of-way areas, pursuant to city permits. Roads may be closed and parking restricted during installation time. Notices will be posted before any closure. Our project team does not wish to be a disruption. We are grateful for your understanding and cooperation.

If you have any questions or concerns, please contact MEC at (816) 531-7283.

Sincerely,

The KCMO Streetlight Project Team

Metropolitan
ENERGY CENTER

KANSAS CITY
MISSOURI

Estimado vecino: Durante las próximas semanas, los equipos de construcción trabajarán para instalar un cargador para vehículos eléctricos en un poste de alumbrado público en su vecindario en la dirección escrita arriba.

Metropolitan Energy Center (MEC) trabaja en asociación con la ciudad de Kansas City, Missouri, para conectar las estaciones de carga de vehículos eléctricos a las farolas existentes. El equipo del proyecto eligió ubicaciones de los cargadores de vehículos eléctricos en función de la logística técnica y las sesiones publicas que ocurrieron en su área. El cargador se instalará pronto.

No haremos ningún trabajo en su propiedad privada; todo el trabajo se realiza en áreas públicas de derecho de paso, de conformidad con los permisos de la ciudad. Las carreteras pueden estar cerradas y el estacionamiento restringido durante el tiempo de instalación. Los avisos se publicarán antes de cualquier cierre. Nuestro equipo de proyecto no desea ser una interrupción. Agradecemos su comprensión y cooperación.

Si tiene alguna pregunta o inquietud, comuníquese con MEC al (816) 531-7283.

Atentamente, el equipo del proyecto de alumbrado público de KCMO

Figure 9. Door hang template that MEC and the city used as part of its community outreach

Other organization types in the stakeholder matrix did not find the provided project information as relevant, and a few requested not to be contacted on future similar endeavors. The least interest in the project appeared to come from government institutions such as police departments and schools.

MEC conducted outreach for two listening sessions via email, mail, and phone call, and a $50 gift card incentive was offered to encourage attendance and participation. Most of the attendees registered for the listening sessions as a result of direct follow-up outreach by community partners. The gift card was given to community attendees of the listening sessions to compensate for their work.

Incorporating Community Input into Project Design

Many whose neighborhoods were being considered for the project were very excited to share information about the project plans with their community members and distributed project information via social media and community newsletters. Approximately 12 individuals participated in listening sessions in June 2021, which were hosted by EVNoire. Diverse citywide neighborhoods were represented, and disadvantaged neighborhoods from the east side of Kansas City attended at higher rates than residents of other areas. Participants were encouraged to give feedback and thoughts on the site map development by MEC and NREL, and then to propose suggestions of their own.

Community residents expressed support for certain sites and discouraged others during the community engagement process. The top locations participants suggested were convenient and community-centric locations, such as grocery stores, educational institutions, community spaces, and parks. Community-centric locations were identified as ideal locations, as they provide participants with an area to safely dwell while charging. Additionally, there was interest in siting chargers at businesses to increase customer visits and revenue. Community members in attendance did not voice any opposition to the project, although there were calls for more equitable distribution across the city, especially in disadvantaged areas. Participants noted that model results overconcentrated EV charging stations in areas with higher median household incomes.

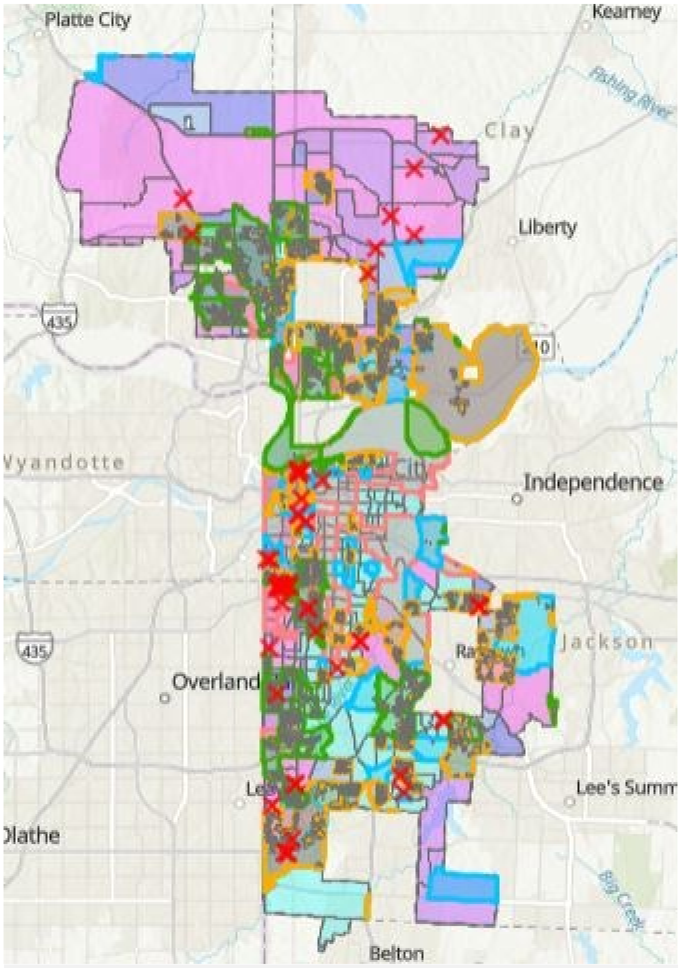


Figure 10. Revised candidate site map.

Source: nrel.maps.arcgis.com/home/webmap/viewer.html?webmap=b9145629dd284e1090ea61ba697afd92&extent=-94.7046,38.989,-94.451,39.0956

This information was compiled and captured into the existing site selection spreadsheet and informed future site exploration in new areas. A new site map was developed that featured the sites participants recommended and adjusted the concentration of proposed EV charging sites (Figure 10). Project partners explored additional

POIs as suggested by the community in these areas. Based on community feedback, the revised charging station site selections prioritized building out the EV charging network to fill charging deserts.

Figure 11. Fox 4 interview at 7203 E. Indiana Ave, Kansas City, MO 64132

Attendees also expressed an interest in more EV education, especially in disadvantaged areas with fewer EVs where people may not be as knowledgeable or aware of the technology. To respond to requests for additional community education, MEC attended community meetings and answered questions from community members about parking, businesses served, and logistics of EV charging. MEC recognizes that building relationships and remaining in close communication with community members is important for establishing trust and transparency. Additional questions and concerns were received from the community such as how the charging stations would be affected by stormwater, how community input was incorporated into the project, how traffic might be affected, and requests for additional site restoration work.

The project has generated media attention, which often stems from community outreach efforts and leads to wider reach for community outreach efforts. Local news media and social media were effective channels for getting the word out about the project and generating community interest and support in its efforts. Technical and industry news also covered the project; however, project partners found that local news made a more significant impact. By reporting on the project throughout the life cycle, local news sources such as The Missouri Times, KCUR, and Fox 4 (Figure 11) helped keep the community informed as the project progressed and maintained residents' interest and support in the project.

EV Charging Equipment Streetlight Deployment

Evergy filed a tariff case (Docket Sheet ET-2021-0151) with the PSC on Dec. 1, 2020, to review and approve the project. On June 25, 2021, MEC met with Evergy and the PSC to answer questions about the project. On Jan. 12, 2022, the Missouri Commission Order approved the streetlight project with up to 50 Level 2 EV chargers.

The team reviewed what locations made sense for these chargers based on where they can technically be located, where it is safe to locate them, and where they can fill the gaps in Kansas City's existing charging network. MEC gathered feedback and looked at ways that made public charging for EVs available to all community members. Project partners prioritized areas that overlapped between the MST and NREL models, sites with high cost-benefit ratios, and sites requested by community members and the city council.

In addition to gathering community input and getting approval from the PSC, MEC coordinated with the city council to approve streetlight charging deployments. While the project team had proposed locations that prioritized high-traffic and densely populated areas to promote equity for renters and MFH residents, the city council emphasized the need for equal installations in each district. The city council also expressed concerns about the city's new bike lane plan, which would preclude curbside EV charging for vehicles in select areas. As such, MEC reached back out to community organizations and community members to identify new locations in the recommended areas.

MEC proposed an equal number of locations in each district by eliminating those with planned bike lanes and adding new locations in some districts. MEC, LilyPad, Evergy, and B&M preliminarily reviewed each site. Before the city would review the site permits, MEC needed to confirm approvals by various city departments, depending on the site. For example, the Parks & Recreation Department only reviewed the stations near parks. In total, the departments that provided technical, parking, right-of-way, or other review included:

- Public Works Department, including Engineering Division, Streetlighting Services, Traffic Engineering Division, Capital Projects Division, and Parking Program
- Office of Environmental Quality
- Parks & Recreation Department's Development Review Committee
- Office of Sustainability within the City Manager's Office
- City Council's Transportation, Infrastructure & Operations Committee.

The city council approved 30 locations with the caveat that the engineer might determine that some locations were infeasible during engineering design. B&M completed engineering design and final cost estimates for Evergy's approval. Once approved, Evergy negotiated any necessary easements while the city reviewed permits.

Figure **12**, Figure 13, and Figure 14 are select excerpts from the work plan request developed by B&M for one of the streetlights in the right-of-way selected for installation. Once permits were approved, B&M proceeded with construction. After construction, restoration, painting, and signage were complete, the city completed final site inspections and LilyPad activated the stations. Throughout the process, some sites were eliminated. Failed easement negotiations, increased costs due to excavation and inflation, and delays stemming from pandemic-related shortages were the primary causes.

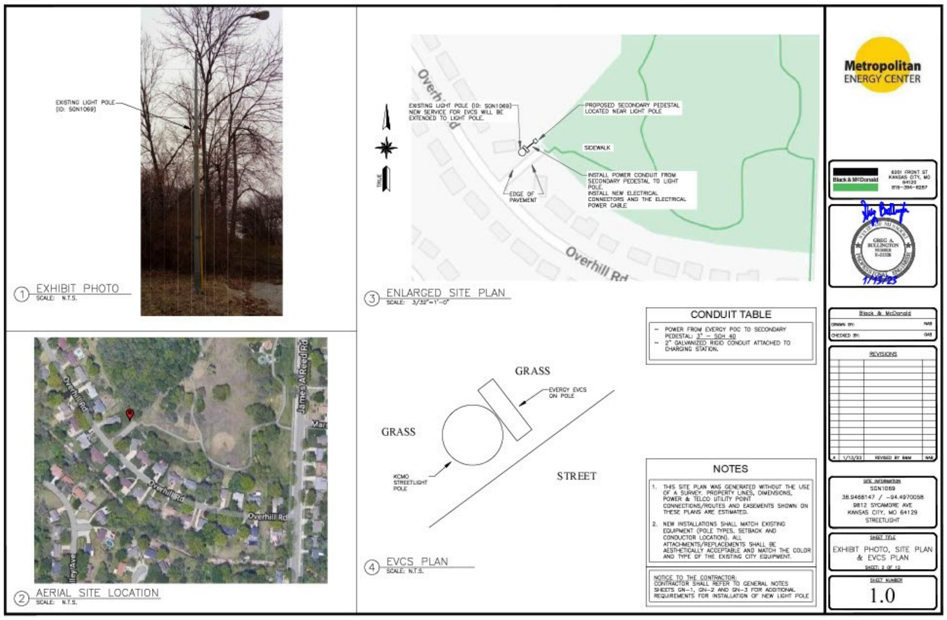


Figure 12. The exhibit photo, site plan, and EV charging station plan developed by B&M

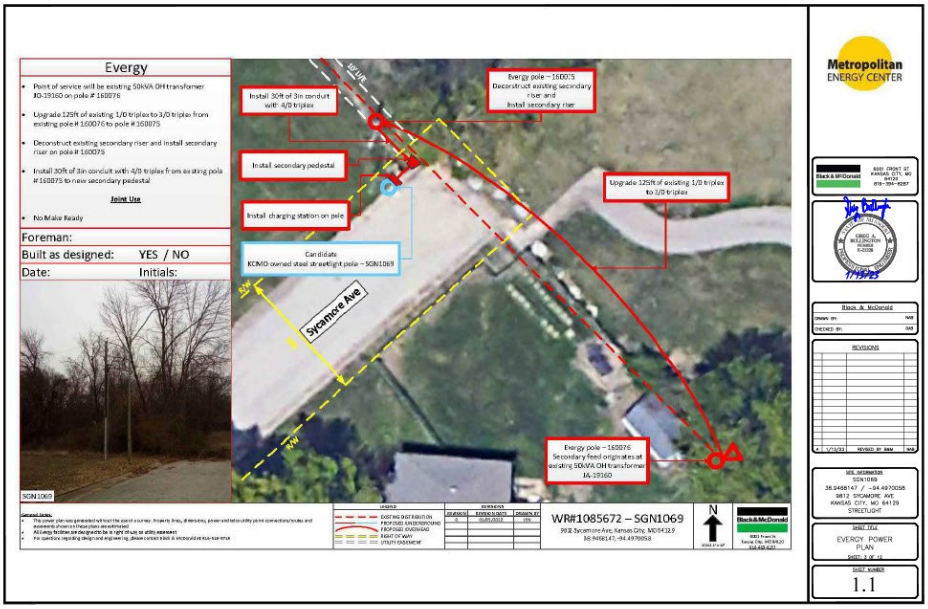


Figure 13. Evergy point of service and upgrade plan, sourced from B&M's Evergy work request

Figure 14. Depiction of pole elevations, sourced from B&M's Evergy work request

Between January and April 2023, MEC and partners installed the 23 streetlight EV charging stations. LilyPad provided project management throughout the installation and held weekly meetings with MEC, Evergy, the city, and B&M. Figure 15 depicts the site installation process. Metrics that LilyPad tracked for each site throughout the site development process included:

- Sketch/design approval
- Permits submitted
- Cost approval by Evergy
- Construction
- Work orders
- Pole material
- Pole length
- Pole height
- Easements
- Power plan approval by B&M
- City approval
- Transformer ordered
- Construction cost
- Signage
- Painting

- Restoration
- Activation
- Barriers.

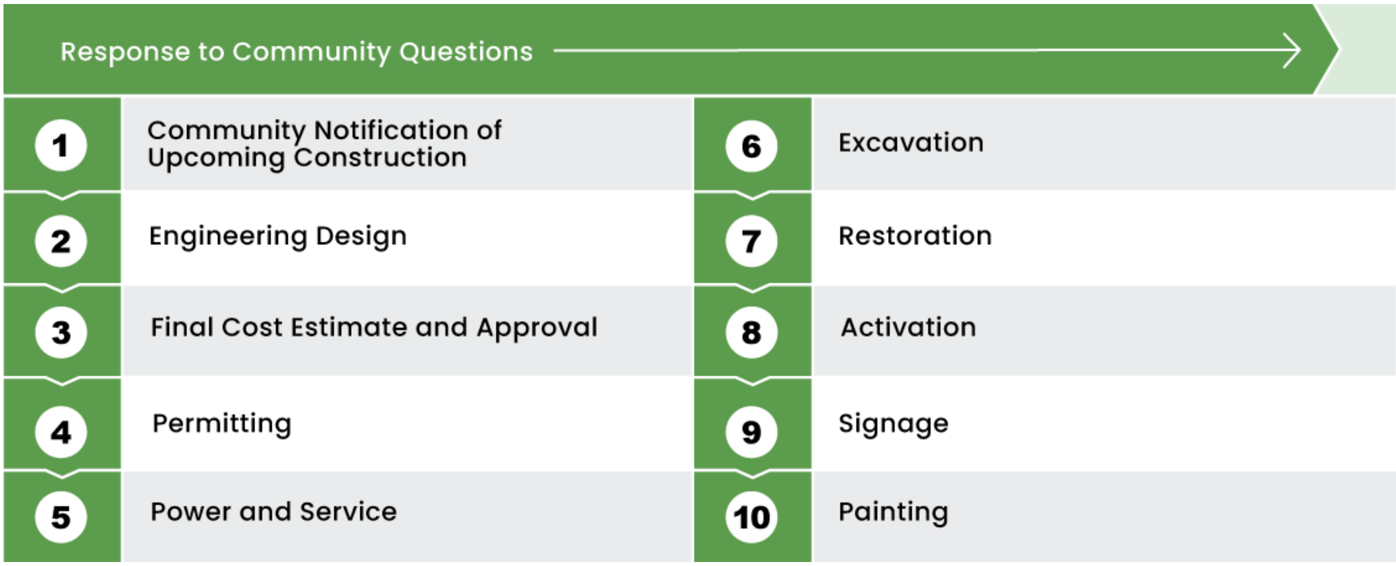


Figure 15. Site installation process

On May 24, 2023, MEC and the city held a ribbon-cutting ceremony, announcing that 23 new streetlight chargers had been installed throughout Kansas City as part of the pilot program. The chargers are sited at a variety of location types, including residential neighborhoods, downtown locations, and adjacent to parks. The chargers are distributed throughout all six council districts of the city due to the collaborative efforts of the city, MEC, and other project partners. To access the stations, EV drivers pay per kilowatt-hour at prices determined by Evergy and the PSC. **Figure 16** shows a map of the completed stations.

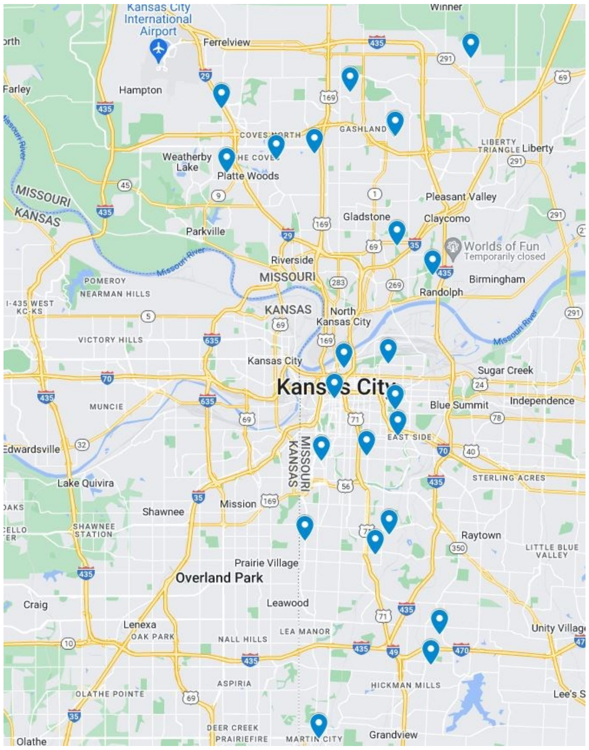


Figure 16. Final sites.

Source: www.google.com/maps/d/u/0/viewer?mid=18CuYjq1xlNlDz4WykXGvBr2FZtqQ-LM&femb=1&ll=39.091700165627756%2C-94.570598805&z=11

Project Outcomes, Measurement, and Next Steps

Outcomes and Measurement

The Kansas City EV charging streetlight project installed 23 EV chargers on the streetlight system in Kansas City, Missouri. Infrastructure upgrades were required for all sites to support EV charging on a streetlight. The average installation cost per site was in line with a traditional EV charger installation. Site installation costs ranged from approximately $13,000 to $45,000 per site, based on the electrical upgrades needed.

The project team designed a two-tiered market analysis model to identify sites with high demand and high opportunity for EV charging. To measure the accuracy of the model, future analysis will be considered that analyzes usage data compared to MST's demand prediction model and ranking. The team is also looking at the comparative usage of stations based on POI, zoning and development, community input, and equity. ChargePoint provided Evergy and MEC with quarterly reports from its data dashboard for each charging station that displayed the station location, address, energy consumption, any service issues, number of sessions, and other charging details. Evergy shared session data with MEC that shows when the stations are being used.

Figure 17. EV charger installation at 9701 N. Shannon Ave, Kansas City, MO 64513

Based on data from the first two quarters of station operation—quarter 3 (Q3) and quarter 4 (Q4) of fiscal year (FY) 2023—MEC observed that all chargers are indeed being used. Moreover, MEC found that POIs are the most significant predictor of usage. In both quarters, the most and least used stations are set apart by the different POIs around them. For instance, in Q4 FY 2023, five out of seven of the top locations for usage have multiple POIs, encompassing everything from learning centers to office buildings, apartments, convenience stores, "people" parks, and dog parks. This is reaffirmed by evidence in Q3 FY 2023 as well. The least used charging station, with 0.87 hours of charging, is only near an apartment complex and a cemetery. The second most used location, with 575.36 hours, is close to parks, dog parks, pools, and more.

Across the board, other metrics do not discriminate against usage like POIs do. In Q3 FY 2023, the chargers in low-income neighborhoods had as much usage as high-income neighborhoods. Of the top six locations identified using the demographic index percentile ((BIPOC+Low Income)/2), all of which rank 90% and above, four out of six have usage rates above the median for all locations. Conversely, the bottom six locations, of which all rank 25% or below on the index, also had four out of six above the median of usage rates for all locations. These charging stations are reaching various demographics and income levels but are not as important an indicator as POIs.

The city, MEC, and Evergy plan to continue their monitoring of the pilot program for 1 year before making plans for future streetlight charging build-out. The city is reviewing whether to approve curbside installation, looking at POIs, usage, and local land development. MEC and project partners will monitor station utilization with the understanding that there may be a lag between streetlight charging and EV adoption.

Next Steps

Figure 18. EV charger installation at 303 E. 18th St, Kansas City, MO 64108

Building on this streetlight pilot project, project partners are continuing to address EV charging gaps in Kansas City in support of EV deployment. As of April 2023, Evergy now offers a [make-ready commercial EV rebate program]() in Missouri, which incentivizes site hosts to own or operate EV charging stations in MFH, workplaces, or public settings. Evergy has a target number of ports they would like to see in each of these areas as part of a 5-year program. Evergy is conducting education and outreach to help site hosts consider the benefits of providing EV charging stations.

Through other EV charging projects, MEC will continue to collaborate with organizations to install chargers at preferred sites. For example, MEC received another grant from DOE to increase access to EVs in underserved markets. The [EVs in Underserved Markets]() project aims to reduce gasoline fumes by supporting EV purchases, charging station installations, and outreach efforts to notify communities of these resources. MEC offers grants to small businesses, MFH properties, and small towns to install EV charging stations, prioritizing [Justice40](), low-income, minority, rural, and other underserved communities. MEC is building on the lessons learned gained through this pilot project to implement the EVs in Underserved Markets project. MEC is currently working with a community-based organization in northeast Kansas City, which will be the first target community for the small-grants program.

Project Lessons Learned

The project's goal was to cost-effectively expand the charging network in Kansas City to support residential charging, and to provide infrastructure in one or more charging deserts. MEC and project partners designed a site selection process to identify sites with high demand and high opportunity for EV charging. The following section details lessons learned related to site selection and deployment efforts, as well as community engagement.

Lessons Learned from Site Selection and Deployment

Invest in the Infrastructure Stack

The most overburdened populations in Kansas City lacked the prerequisite infrastructure to even consider building out EV charging stations. The lack of streetlights or sidewalks, for example, would create an unsafe environment for the people attempting to charge their vehicles. A lack of sidewalks would put the person in danger of being hit by a car; a lack of light would make finding the charger difficult and make an individual vulnerable to nighttime threats. It might, for these reasons, discourage use of the charging station altogether.

The lack of streetlight and sidewalk infrastructure in affected communities alone narrowed the pool of possible EV charging station sites from 300 to 80, or less than 27% of candidate sites. The expected energy burden required to install charging stations, or any other requirements further down the implementation checklist, had not even come into play prior to the attenuation. MEC encourages cities interested in expanding EV charging stations to focus on meeting these basic needs first. In December 2017, Kanas City adopted the Complete Streets ordinance (Ordinance No. 170949), which sets guidelines to ensure that everyone—pedestrians, bicyclists, wheelchair users, motorists, and people who rely on public transit—are able to safely use Kansas City streets, regardless of their age or abilities. It promotes multimodal access of roadways and sidewalks to ensure easy access to employment and activity centers for people with limited mobility or access to a car, sidewalks and bicycle paths are included in capital road projects and new development, and environmental impact of the city's transportation system is minimized. This ordinance is a good first step—one cities looking to expand EV charging stations should unequivocally consider—but a focus on the marginalized communities that would most benefit from this project would expand the pool of candidate sites. MEC recommends that a city interested in expanding EV charging stations first take the initiative to build out the infrastructure stack—the infrastructure needed to support installation of an EV charging station such as a sidewalk or streetlight.

Keep Solutions to EV Charging Open

MEC recognizes that one project cannot alleviate all charging challenges within a community. This particular project was focused on installing EV charging in the streetlight right-of-way. The predetermined conditions made several sites ineligible for this effort, even though the community requested them. MEC maintained a list of such sites that ranked highly in the model and were backed by stakeholders for future installation efforts.

Although partners may not want to structure entire curbside charging programs around streetlights, this project has shown that they remain a viable, though at times limiting, option. Site selection for streetlight chargers turned out to be more difficult than site selection for traditional Level 2 charging stations. The inherent requirement of city-owned sites with both a streetlight and an adjacent parking space was often incompatible with the city's one-way streets, bike lanes, fire lanes, and other road challenges. Despite the ubiquity of curbside streetlights in residential neighborhoods, the fact that available parking spots were on opposite sides of the streets voided the project's efforts. So did the fact that at times a charging cord at a streetlight-adjacent parking space would interfere with a sidewalk. These factors alone precluded all but 80 of the 300 spaces identified in the initial stages of the project.

Solutions should reflect the needs and accessibility gaps within the target community, while site selection should be based on which communities would benefit from that particular solution. Not all communities need streetlight charging, but there are plenty that do. The latter are ideal candidates for the type of solution MEC and partners embarked on in this project.

Conduct Site Visits to Ground Truth the Predictive Model Selections

MEC and project partners identified a collection of strengths and weaknesses in the predictive model used that are important to note for future projects. Although the model identified spaces that fit the parameters it was trained on, the real-world conditions were often incompatible with the project's goals or requirements. Businesses and MFH residences in disinvested communities were less likely to be listed on Google Maps, and were therefore excluded from the model. Site visits revealed that mom-and-pop shops, especially ones that were immigrant owned, did not appear on the maps. Neither did apartments and MFH residences that were converted from older single-family homes. MST utilized the ground truth observations to adjust model expectations.

Ground truthing, community outreach, city feasibility and other considerations led to substantial changes in the site selection process. A standout example of this adjustment involved WHO. The Westside neighborhood showed up in NREL's third scenario (Table 2) but was omitted from the demand model. Because MEC originally decided to prioritize the sites that overlapped between model outputs, the team did not evaluate sites in the Westside neighborhood. The partnership with local community groups like WHO revealed that the stakeholder population was understandably upset with the decision to select sites based on modeled data and not sites that better served their community interests. WHO maintained their partnership with MEC, continuing to push for sites in their community. Now the team is exploring the community-suggested sites, and there is community enthusiasm for further development. The model also predicted potential spaces that proved unsuitable for the project upon on-the-ground inspection. Restaurants and plazas, which showed up in the model with some regularity, lacked the proper proximity between streetlights and parking or would have required excavation costs of $100,000 or more per site, and thus were not feasible.

Engage City Leadership for Project Oversight

Involving city leadership and identifying champions of the EV charging cause are essential for a project to come to fruition. Encountering hurdles is inevitable, especially when implementing a project that requires numerous and disparate levels of approval. Partners should plan for a long timeline. For example, from filing a tariff case to meeting with the PSC took 7 months, and approval another 6 months. The community and project partner support fueled the project's momentum throughout the project timeline. Educational material outlining the breadth and benefits of the project, which was disseminated through local news outlets, community partner newsletters, and other channels, led to community interest and support for the project. Involving the city manager provided MEC with necessary oversight to help the project move through the approval and permitting stages without getting mired in layers of bureaucratic paperwork.

With the city manager's support, the city council passed Ordinance 220581 on Sept. 15, 2022, in support of the project and worked with city staff on site selection and permitting. In addition, Kansas City has pledged to be climate neutral citywide by 2040. This goal outlined by the city acted as a touchstone for supporting project efforts as project partners installed EV charging stations.

Lessons Learned from Community Engagement and Benefits

When conducting community engagement, it is important to leverage diverse on-the-ground networks and to keep an open mind when their perspectives challenge preconceived notions. For the listening sessions, outreach to community members via community partners led to higher engagement. This indicates that community members trust community partners, and their invitation has more weight than other forms of outreach. Developing strong relationships with community partners is essential to effective engagement. Constructive community engagement identifies the needs of the stakeholders and builds the trust necessary for a successful operation. One key lesson learned from this step was that incorporating the locals' expertise and history early in the site selection process made it easier to address the needs of underserved communities later on. For this, MEC contracted with EVNoire, whose primary focus is e-mobility equity and diverse EV adopters. MEC also identified WHO, an affordable housing practitioner supporting Kansas City neighborhoods, to serve as an advisor to EVNoire to develop the approach to facilitating the community listening sessions. WHO, a local community outreach partner, was also compensated for their expertise. MEC concluded it would be advantageous to hire local contractors to facilitate community listening sessions, as opposed to outside partners or national organizations. Doing so would invest project funding back into the affected community and allow conversations to start from a place of trust and rapport.

Throughout the community engagement and outreach process, community members and partners wanted clarification on how the project defined and prioritized underserved communities. The stakeholders' questions and concerns were echoed by local decision-makers, such as the city council, who were key to site and project approval. With input from EVNoire and WHO, NREL adjusted some of the original income data used in the third scenario (see Table 2) for the lower cost of living and median incomes in Kansas City. Representatives for EVNoire and WHO expressed dissatisfaction with the team's site selection and equity process. They noted that the site selection process prioritized modeled data at the expense of community input, and that it did not adequately serve the communities. MEC compiled feedback from EVNoire and WHO to inform the sites selected and serve more diverse neighborhoods across the city.

The history and land development of communities is especially important for understanding the current and historical state of socioeconomic issues, which in turn must inform the project team's definition of "underserved." As essential as building trust is understanding the historical context for any prevailing lack of trust community partners may have in government-supported projects. For example, a business owner and resident lost interest in installing a charging station at his property once an easement was introduced, due to a history of redlining in the area. The property owner expressed fears that the city was seizing his property, which resulted in the individual losing trust in the process. The property owner was initially engaged with the project's development. The introduction of an easement late in the process made it seem like the process was not transparent. Transparency ensures partners remain interested and supportive of the project throughout its implementation.

Project partners learned that that another key step is sequencing of input. Soliciting community input before even determining the feasibility of a streetlight EV project will ensure its implementation aligns with the community's priorities. The local populations should have decision-making power in what projects get the go-ahead, because they are the best experts on their community's needs and concerns.

Since 2021, Kansas City Regional Clean Cities has been a participant in the Clean Cities and Communities Energy and Environmental Justice Initiative. This initiative trains coalitions how to center, work with, and benefit the most disadvantaged communities in their regions. Similar to the goals of the Kansas City streetlight EV charging pilot project, this initiative helps focus projects on meeting the needs, addressing the barriers, and realizing the aspirations of historically overburdened and underserved communities.

Conclusion

The use of EVs in Kansas City is expected to grow, bringing with it substantial public health benefits by reducing local transportation emissions, and economic benefits by reducing reliance on volatile gas prices. Kansas City will need to expand access to a robust and affordable EV charging network if it wants to meet this growing demand. Many Kansas City residents currently do not have access to garages or driveways where they can install charging equipment, and many others do not have the financial means or authority to do so even if they wanted to. For those without residential charging access, public streetlight charging networks can provide convenient charging close to home. The pilot project's installation of EV charging on the streetlight system aimed to test the efficacy of curbside charging at limited on-street parking locations. It sought to prove that an affordable curbside charging network would enable more drivers to adopt personal EVs, inspire them to use EV car-shares, and expand easy charging access for community members who are interested in driving an EV.

The installation of 23 streetlight EV charging stations across all six council districts of Kansas City ensured that the benefits of the pilot were distributed equitably to all members of the community. Community engagement and outreach was an essential step in this project. It served as an opportunity to engage with diverse populations within the city about EVs and public charging infrastructure. It was likewise necessary in making sure that everyone had equal access to charging infrastructure. Feedback collected from community listening sessions was integrated into the project scope and will inform future investment and programs.

MEC and project partners designed a data- and community-driven process for site selection, making it possible to pinpoint areas with high demand and high opportunity for EV charging. Thanks to this approach, MEC has observed utilization of all charging infrastructure installed.

The development of streetlight charging permits and agreements with the city will facilitate installation through future efforts. The models, permits, process, and lessons learned will help streamline additional installation efforts to support a diverse array of EV drivers through public charging.

In this project, MEC worked with community partners to better understand the needs and concerns of the target population, as well as the opportunities around on-street charging solutions in the city right-of-way. While this report is intended to be a reference to facilitate future installations in other municipalities in Missouri and throughout the country, it is important to emphasize that efforts like this are not a one-size-fits-all approach and need to be done in coordination with the public. Every organization pursuing these types of projects will have its own goals, so it is vital to determine what is important to each of the stakeholders. The analysis and methodology must be based primarily on said goals. For MEC, for example, it is important to consider how to increase access to high-quality mobility options, reduce air pollution, and enhance economic opportunity for all community members.

Appendix A. Project Partners

- **Missouri University of Science and Technology (MST)** built out a demand-driven model to identify potential streetlight EVSE siting locations. In 2021, the project research team from MST transferred to Pennsylvania State University (Penn State) and continued researching demand and site selection considerations.
- **National Renewable Energy Laboratory (NREL)** modeled potential EVSE siting locations based on potential for EV adoption, potential residential and MFH EVSE demand, and equity considerations, which were combined with the findings from MST to create initial site recommendations.
- **LilyPad EV** is a provider of EV charging stations that provides turnkey site design, electric engineering, installation, and signage for EVSE infrastructure. LilyPad assisted with the schematics design for the EVSE infrastructure, as well as the overall site design. They surveyed proposed sites to assess select additional criteria and commissioned all selected sites.
- **Black and McDonald (B&M)** assisted with pre-deployment analyses and developed EVSE schematics and site designs. B&M visited prospective sites to assess for select additional criteria and used the data gathered to determine per-site cost estimates. B&M oversaw permitting for construction at selected locations, installed charging units, and continues to monitor maintenance costs for selected sites.
- **Evergy**, previously Kansas City Power & Light Company, operates the Clean Charge Network, a series of more than 1,000 charging units across their Missouri and Kansas service area, inclusive of the Kansas City metro area. Evergy engaged with pre-deployment analyses, visited prospective sites to assess for select additional criteria, supported the creation of a site design and installation of charging units, and continues to monitor usage statistics.
- **City of Kansas City, Missouri,** is undertaking an effort to evaluate its policies related to EVSE and provide a list of best practices. The city sent a survey team to visit each prospective site to assess for select additional criteria, was involved with site design, and provided permitting for each completed streetlight EVSE site.
- **EVNoire**, a communications strategy consultant organization, helped identify additional site criteria through community listening sessions.
- **Westside Housing Organization (WHO),** a local community outreach partner focused on housing and community improvement, reviewed outreach materials for cultural competency for local audiences.
- **Metropolitan Energy Center (MEC)** provided project management and administration. MEC worked with all partners to gather additional siting criteria (i.e., costs, community interest, and impact on resiliency) and developed a site selection evaluation checklist. MEC provided environmental quality oversight and expertise regarding EV charging stations, community development, and EV-readiness policy through Clean Cities and Communities staff.

Appendix B. EVSE Siting: Demand Prediction Model

Modeling Approach Overview

This document presents the siting criteria from the demand approach to identify 300 streetlights as the candidate locations for new EVSE charging infrastructure deployment. These candidate locations were chosen based on their predicted usage rates. In other words, assuming a new charging station will be deployed at a candidate location, its daily usage frequency was predicted with a boosting-based ensemble learning model considering multiple contributing factors including traffic volume, land use types and others. A total of 300 streetlights at locations with highest predicted usage rates were selected as the candidate location for further field survey.

Technically, this was achieved by the development of 4-step prediction model with the help of 6-year charging event log data from ChargePoint, travel demand data from Mid-America Regional Council (MARC) and other data sources. The model works in the following steps.

1. In step 1, features, or contributing factors that affect the usage frequency of EVSE charging infrastructure were defined. These features included existing charging station density, traffic volume, trip production and attraction, and land use types and will be further explained in this document.
2. Next, a boosting-based ensemble learning model was developed and trained, with the existing charging station's daily usage frequency as dependent variable and the defined features as independent variables.
3. In step 3, a list of Point Of Interests (POIs) in Kansas City Missouri were retrieved from Google Maps as candidate locations by using Google Maps API.
4. At the final step, the usage frequency of these candidate locations were predicted, and a total of 300 streetlights at locations with highest predicted usage rates were selected as the candidate location for further field survey.

In the sections below, two main data sources, including the charging event log data from ChargePoint and the travel demand data from Mid-America Regional Council will be presented first. We will then walk through the demand prediction model step by step.

Data Description and Feature Definition

This research uses a multi-source dataset collected in KCMO, which includes the charging event log data, travel demand model data, and climate data. A detailed description of each data source is provided below. In total, 67,576 data samples are extracted, and 15 features are defined in Table 4. These features can be categorized into four main categories: 1) spatial context information, 2) weather information, 3) charger type and 4) traffic information. A detailed definition of these features is presented in the subsections below. Notably, some variables are continuous numerical data, while others are categorical data.

Table 4. Definition of 15 Features and Response Variable

Category	Notation	Definition and Unit	Data Type
Response Variable	$D_{i,w}$	The number of charging events of CS i on week w	Numerical
Spatial Context Information	$NHCS_i$	The density of charging stations in the same zip code area of CS location i (#CSs/sq mile)	Numerical
	$LDU1_i$	Land use type: if CS location i is in an institutional area	Binary
	$LDU2_i$	Land use type: if CS location i is in a transportation area	Binary
	$LDU3_i$	Land use type: if CS location i is in a commercial area	Binary
	$LDU4_i$	Land use type: if CS location i is in a residential area	Binary
	$LDU5_i$	Land use type: if CS location i is in a recreational area	Binary
	$LDU6_i$	Land use type: if CS location i is in a vacant area	Binary
	$LDU7_i$	Land use type: if CS location i is in an industrial area	Binary
Weather Information	$PRCP_w$	Weekly precipitation of week w (mm)	Numerical
	TMP_w	Weekly average temperature of week w $(°C)$	Numerical
	WD_w	Weekly average wind speed of week w (m/sec)	Numerical
Charger Type	$PT1_i$	Port type of DC fast charger for CS location i	Binary
	$PT2_i$	Port type of level 2 charger for CS location i	Binary
Traffic Information	$AADT_i$	Annual average daily traffic on CS location i's nearby roads	Numerical
	TP_i	Trip production of the TAZ where CS location i is located	Numerical

With these 15 features defined, $a_{i,w}$, representing the array of features for charging station i during week w as defined in the stage one model, can be rewritten with Eq. (1) below.

$$a_{i,w} = [NHCS_i, PRCP_w, TMP_w, WD_w, PT1{\sim}2_i, LDU1{\sim}7_i, AADT_w, TP_i] \tag{1}$$

Charging Event Log Data

The charging event log dataset comprises 22,0231 charging records, collected from 444 public charging stations in KCMO (i.e., $N_e = 444$), from January 2014 to December 2019. The spatial distribution of existing CSs is shown in Figure 19. The concentration of charging stations (CSs) is notably prominent in the downtown area, where most of the high-demand CSs are also observed.

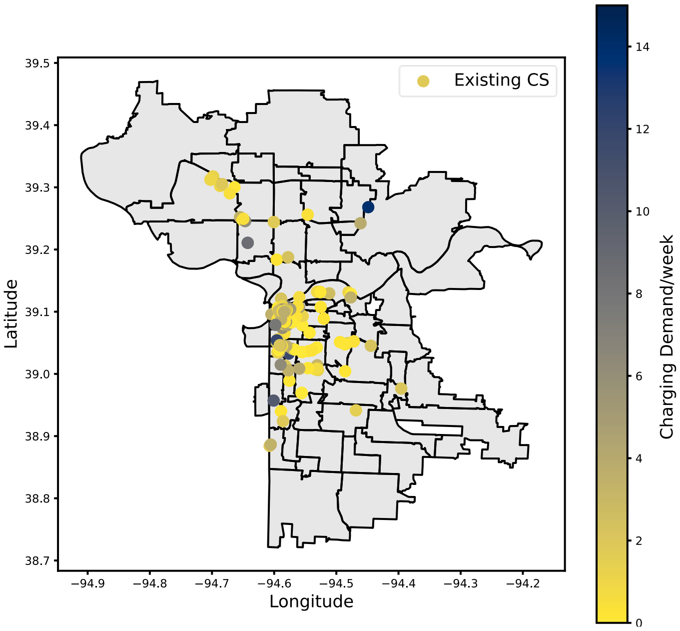


Figure 19. The spatial distribution of existing CSs in Kansas City, MO

For the charging event dataset, the available attributes include start date, end date, latitude, longitude, plug type, and postal code of a charging event. With this information, we can derive the response variable and features including spatial context information and port type. The response variable is the weekly charging rate, which is shown in Eq. (2), where $count(CE_{i,w})$ denotes the total number of charging events from charging station i on week w. Its distribution is shown in Figure 20. It can be observed that for each CS, the number of charging events is mostly under 10 times per week, with a longtail where the maximum reaches 58.

$$D_{i,w} = count(CE_{i,w}) \qquad (2)$$

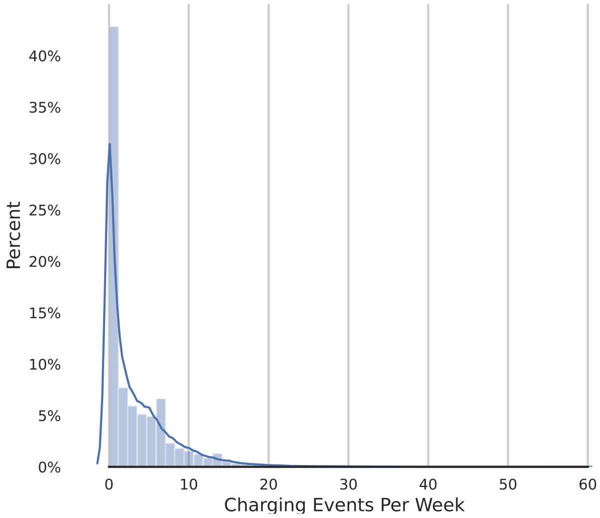
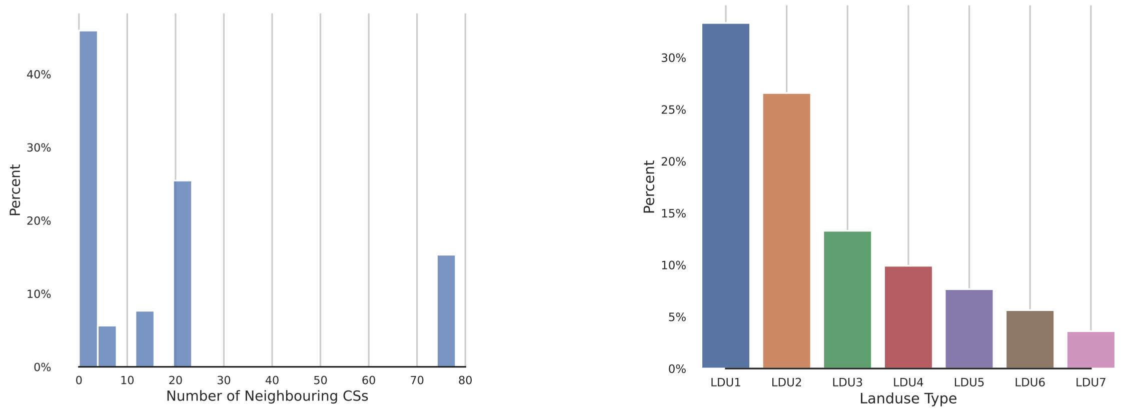
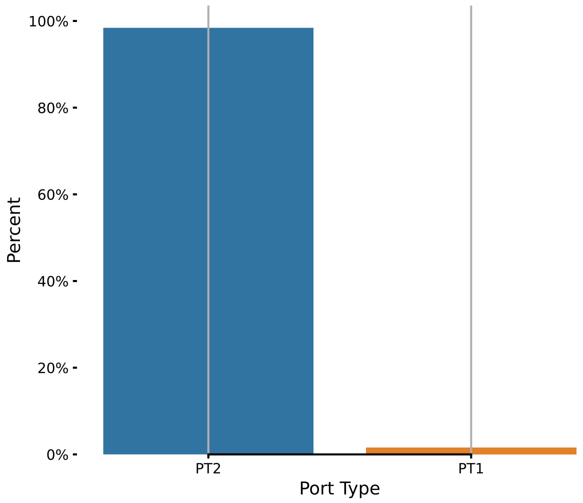


Figure 20. The distribution of response variable, charging demand

When it comes to relevant features, the number of neighboring existing CSs, $NHCS_i$, is defined as the density of charging stations (number of CSs per sq mile) in the same zip code area of CS location i. Of all 444 stations, the distribution of $NHCS$ is given in Figure 21-(a), where we can find three clusters. Such clusters denote that the density of CSs may be below 10, around 20, or over 70 per sq mile. $LDU1{\sim}7$ are the land use type of the parcel where the CS i is located. In Figure 21-(b), the distribution of seven land use types of 444 CS locations is presented. Most of the CSs are located in $LDU1$ and $LDU2$, i.e., institutional areas such as offices and schools, transportation areas such as stations and airports. As Figure 21-(c) illustrates, the majority of charging stations are equipped with the level 2 chargers ($PT2_i$), whereas $PT1_i$ is the fast charger and accounts for only about 5% of the charging stations.



(a) Number of Neighboring CSs (b) Land use Type



(c) Port Type

Figure 21. The distribution response variables

Travel Demand Model Data

The travel demand model data is sourced from Mid-America Regional Council (MARC), which is the Metropolitan Planning Organization (MPO) for the bi-state Kansas City region. The data encompasses a daily origin-destination (O-D) demand matrix and a road network of Kansas City, featuring assigned peak hour traffic volume. Kansas City is divided into 2,510 Traffic Analysis Zones (TAZs) with a total of 10,533 nodes and 24,601 links. The trip production value for each TAZ can be calculated through summarizing the OD demand matrix by rows. Therefore, the feature TP_i, representing the trip production of the TAZ where CS i is located, can be calculated using Eq. (3), where $TPSUM_i$ is the summation of trip production generated within the zip code area where CS i is located; $ARSZ_i$ denotes the area size of the zip code zone of CS i. It should be noted that the obtained O-D demand matrix is for ICE vehicles and EV combined, and an EV-only O-D demand is not available nor needed for this case study.

$$TP_i = TPSUM_i / ARSZ_i \tag{3}$$

$AADT_i$, the annual average daily traffic on CS location i's nearby roads, is calculated by Eq. (4), where $AADTSUM_i$ represents the total daily traffic volume summed across the roadway segments within the zip code zone where CS location i is situated. Though TP_i and $AADT_i$ are both traffic-related features, it should be noted that TP_i focuses on the number of vehicles originating from a particular zone, while $AADT_i$ includes both the local traffic and the bypass traffic.

$$AADT_i = AADTSUM_i / ARSZ_i \tag{4}$$

Climate Data

The climate data is retrieved from NCEI via open access API, and includes weather station location, record date, average wind speed in m/sec, precipitation in mm, and the average temperature in $°C$. For the weather-related features, the weekly average temperature of week w, TMP_w can be calculated by Eq. (5), where $Tavg_w$ is the average daily temperature of date in week w. Similar calculation is also performed to get WD_w, the weekly average wind speed of week w.

$$TMP_w = sum(Tavg_w)/7 \tag{5}$$

The weekly precipitation of week w, $PRCP_w$, can be derived by Eq.(6), where $Prcp_w$ is the precipitation value of each day in week w.

$$PRCP_w = sum(Prcp_w) \tag{6}$$

After data processing, the total number of data records is 67,576, each including the 15 defined features and the response variable. Such dataset is randomly divided into a training subset which has 80% of the data (54,061 samples), and a testing subset with 20% data (13,515 samples).

Prediction Model Description

Boosting-Based Ensemble Learning Model Development and Training

In this section, a boosting-based ensemble learning model is developed to predict the charging demand for CSLP, represented by the number of charging events each week, at each charging station. The input data of this model is $O = \{(a_{1,1}, \widehat{D}_{1,1}), (a_{1,2}, \widehat{D}_{1,2}), \dots, (a_{i,w}, \widehat{D}_{i,w})\}$, where $a_{i,w}$ is an array of features for charging station i during week w. The features that are included in $a_{i,w}$ are categorized into four groups, including spatial context information around the charging station, weather information, charging port type, and traffic information. A detailed definition of each feature is given in Table 4 of the case study section. $\widehat{D}_{i,w}$ is the response variable, which is defined as the number of charging events at charging station i during week w. The target of the developed boosting-based ensemble learning model is to train optimal functions that minimize the prediction error between demand predictions and actual data that is obtained from the field.

A boosting-based ensemble learning model is developed and trained at this stage to improve the prediction performance. Among different kinds of machine learning techniques, ensemble learning models have been shown to be effective in improving the accuracy of predictions over traditional regression or classification models. This is achieved by training multiple sub-models on the same dataset and combining their results to obtain a more accurate prediction (Dong et al. 2020). Boosting is a popular ensemble learning technique that focuses on improving the accuracy of weak sub-models by iteratively adjusting the weights of the training data based on the errors made by previous sub-models. The final model is a combination of all sub-models, and its predictions are based on a weighted average of the sub-models' predictions.

The formulation of the stage one charging demand prediction model is given from Eq. (7) to Eq.(11). The objective function, $L(\Theta)$, is formulated as Eq. (7), with the goal of minimizing the loss function l with a regularization term Ω to avoid overfitting.

$$Min\ L(\Theta) = \sum_{i=1}^{N_e} \sum_{w=1}^{W} l(D_{i,w}, \widehat{D}_{i,w}) + \sum_{k=1}^{K} \Omega(f_k) \tag{7}$$

Therein, Θ represents a set of K regression sub-trees that are denoted by f, as shown in Eq. (8). Each sub-tree, or regression model, in the set is designed to capture a unique aspect of the charging demand data and make a prediction based on a specific set of input variables. The output of each sub-tree is then combined to produce the final prediction of the model. the charging demand for a given set of input variables.

$$\Theta = \{f_1, f_2, \dots f_K\} \tag{8}$$

The loss function, denoted as l, is an important component in the charging demand prediction model. It is formulated as the squared error between the predicted charging demand $D_{i,w}$ and the actual value $\widehat{D}_{i,w}$ obtained from the field data, as shown in Eq. (9). This means that the performance of the prediction model is evaluated by how well it can minimize the difference between the predicted and actual values of the charging demand. By reducing this difference, the bias of the prediction model can be reduced, resulting in more accurate predictions.

$$l\left(D_{i,w}, \widehat{D}_{i,w}\right) = \left(D_{i,w} - \widehat{D}_{i,w}\right)^2 \tag{9}$$

The regularization term Ω is computed by Eq. (10), where T is the total number of leaf nodes in the base tree f_k. Parameter γ is designed to avoid tree structure from becoming too complex; Wt is the weight of leaf nodes; the parameter λ controls the regularization level of f_k. The calculation of Wt will be discussed in the solution algorithm section.

$$\Omega(f_k) = \gamma * T + \frac{1}{2}\lambda * \|Wt\|^2 \tag{10}$$

Eq. (11) represents the final step in the proposed charging demand prediction model, where the predicted charging demand $D_{i,w}$ is obtained. Specifically, the predicted charging demand is calculated as the summation of the output of all base regression trees f_k, given the input feature vector $v_{i,w}$.

$$D_{i,w}(v_{i,w}) = \sum_{k=1}^{K} f_k(v_{i,w}) \tag{11}$$

With a sufficient number of sub-regression trees f_k built, the charging demand model in stage one will lead to a well-trained model that will then be integrated into the stage two model to generate an accurate charging demand value for each CS location. As the number of sub-trees increases, the accuracy and performance of the model will improve, therefore, the process of building and training sub-regression trees is crucial to the success of the charging demand model in stage one. Additionally, it is also important to select appropriate hyperparameters and regularization techniques to ensure that the model does not overfit or underfit the training data.

Ensemble Learning Model Training Results

With the scenario setting as described above, a total of 51,896 sub-regression trees are built. The prediction performance of the model on the training and testing dataset is measured by R square, root mean squared residuals (RMSE), and mean absolute error (MAE). As shown in Figure 22, R square values are 0.72 and 0.63, RMSE are 2.38 and 2.77, and MAE are 1.62 and 1.85, on the training and testing subsets, respectively. Compared with the charging demand prediction models from the literature, whose training and testing r square values were shown to be between 0.567 and 0.519 (Almaghrebi et al. 2020), the proposed model is shown to give satisfactory performance in generating accurate charging demand predictions.

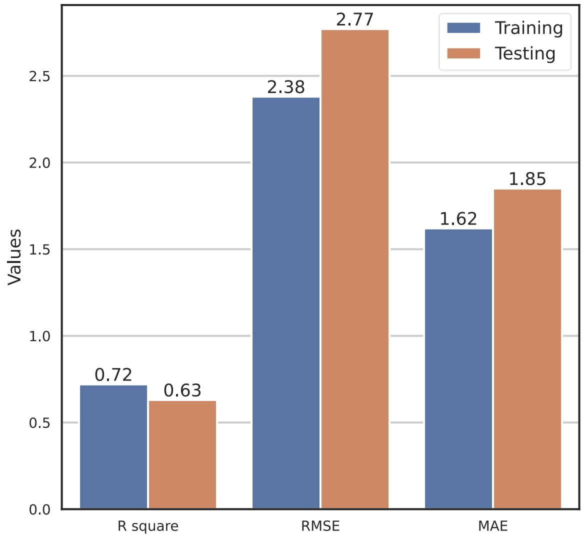


Figure 22. The prediction performance on training and testing sets

To further validate the prediction performance of the stage one model, three other representative prediction models are implemented using the same data set for comparison, namely Multiple Linear Regression (MLP), K-Nearest Neighbors (KNN), and Neural Networks (NN). The comparison results on the testing set are given in Table 5. It can be observed that the proposed model outperforms the other prediction models with the highest R square value and the lowest RMSE and MAE. Thus, the stage one model could give relatively accurate prediction results because of its ability to utilize the boosting techniques to combine weak learners into a strong predictive model.

Table 5. Performance Comparison among Four Models

Models	R square	RMSE	MAE
Proposed	0.63	2.77	1.85
MLP	0.20	4.09	2.92
KNN	0.29	4.13	2.42
NN	0.40	3.57	2.51

To assess the influence of the utilized features on charging demand, the importance of each feature is quantified by the Shapley Additive Explanation (SHAP) method, which produces consistent output by averaging all possible orderings of input feature permutations (Lundberg et al. 2018). The top ten features with the largest importance value are given in Figure 23, with X-axis being the mean SHAP value that measures the average impact of a specific feature on modeling output, and Y-axis being the features. It is found that the two most important predictors are both traffic-related, nearby traffic $AADT_i$ and trip production TP_i. The number of neighboring CSs, $NHCS_i$ ranks fourth, which validates the demand-supply coupled relationship, as charging demand is shown to be affected by the density of CSs in the same neighborhood.

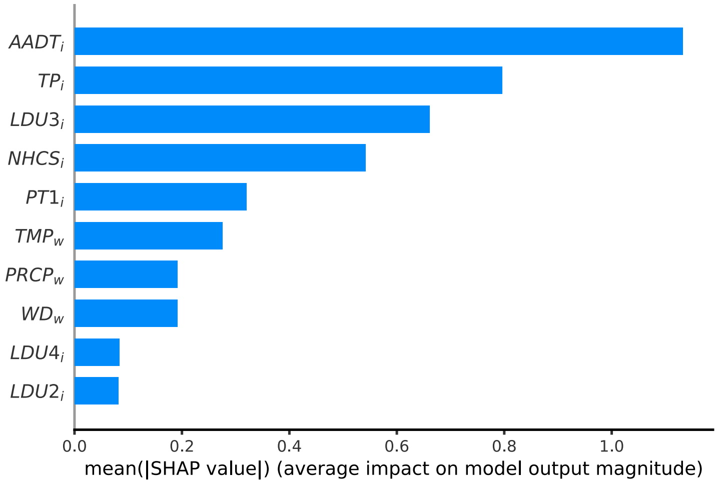


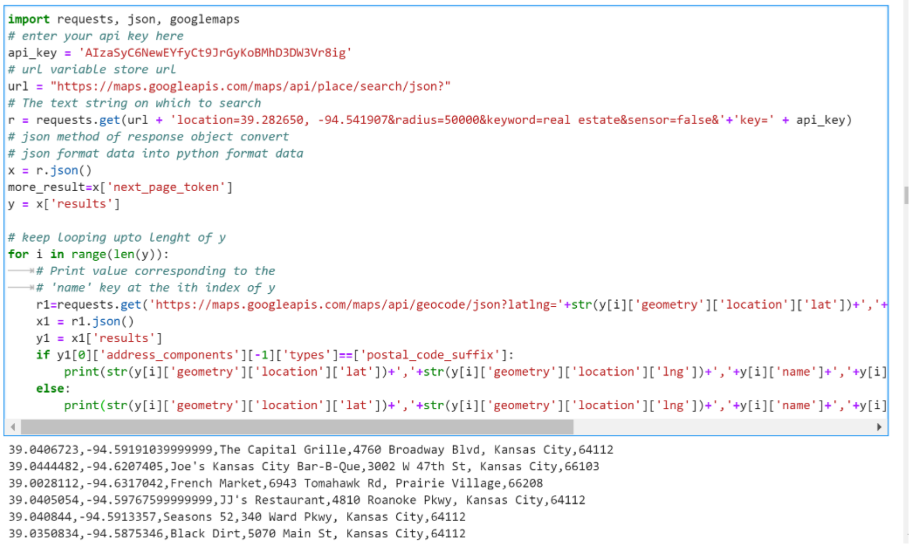
Figure 23. The mean SHAP value for the 10 most important features

Point of Interest Data Retrieval

Point of interest, or POI, is a specific point location that someone may find useful or interesting. It is a term used in cartography (and therefore in reference to maps or geodatasets) for the choice to represent a particular feature using an icon that occupies a particular point. The idea is that, as opposed to linear features like roads or areas of land use, some features might be suited to being indicated as a point in a particular context. For example, if one wanted to send a letter, it would be relevant to see all the post offices and mailboxes nearby, and if they are all represented by an envelope icon, it is easy to see.

In this project, to identify the potential high-usage-rate locations if charging stations were to be deployed, point of interest locations were retrieved to serve as the candidate sites for further evaluation purposes. The rationale was that EV drivers are most likely to park and charge their vehicles at locations near their destinations, or where they could fulfill certain needs while waiting for their electric vehicles to be charged. Such locations could be apartments, shopping malls, churches, restaurants, grocery stores or other kind of POIs.

Such POI locations were retrieved from Google Maps by searching with corresponding keywords. Specifically, we firstly chose 14 kinds of POIs (with 14 keywords), including apartment, grocery store, hotel, plaza, house, restaurant, shopping mall, theater, real estate, school, park, community, church and bar. Then, we drew three circles with the radius of 31 miles in the north, middle and south part of KCMO. For every POI type, all the related sites within these three circles were downloaded after sending requests to Google by using Google Maps Application Program Interface (API). The returned responses from Google Maps included the name, address, latitude and longitude of these sites and can be used for further analysis. A sample of API request is shown in Figure 24, while Figure 25 shows a sample of returned response from Google Maps.



```python
import requests, json, googlemaps
# enter your api key here
api_key = 'AIzaSyC6NewEYfyCt9JrGyKoBMhD3DW3Vr8ig'
# url variable store url
url = "https://maps.googleapis.com/maps/api/place/search/json?"
# The text string on which to search
r = requests.get(url + 'location=39.282650, -94.541907&radius=50000&keyword=real estate&sensor=false&'+'key=' + api_key)
# json method of response object convert
# json format data into python format data
x = r.json()
more_result=x['next_page_token']
y = x['results']

# keep looping upto lenght of y
for i in range(len(y)):
    # Print value corresponding to the
    # 'name' key at the ith index of y
    r1=requests.get('https://maps.googleapis.com/maps/api/geocode/json?latlng='+str(y[i]['geometry']['location']['lat'])+','+
    x1 = r1.json()
    y1 = x1['results']
    if y1[0]['address_components'][-1]['types']==['postal_code_suffix']:
        print(str(y[i]['geometry']['location']['lat'])+','+str(y[i]['geometry']['location']['lng'])+','+y[i]['name']+','+y[i]
    else:
        print(str(y[i]['geometry']['location']['lat'])+','+str(y[i]['geometry']['location']['lng'])+','+y[i]['name']+','+y[i]
```

```
39.0406723,-94.59191039999999,The Capital Grille,4760 Broadway Blvd, Kansas City,64112
39.0444482,-94.6207405,Joe's Kansas City Bar-B-Que,3002 W 47th St, Kansas City,66103
39.0028112,-94.6317042,French Market,6943 Tomahawk Rd, Prairie Village,66208
39.0405054,-94.59767599999999,JJ's Restaurant,4810 Roanoke Pkwy, Kansas City,64112
39.040844,-94.5913357,Seasons 52,340 Ward Pkwy, Kansas City,64112
39.0350834,-94.5875346,Black Dirt,5070 Main St, Kansas City,64112
```

Figure 24. Google Maps API query (a) API request, (b) returned response

In total, 1,252 POIs were collected and a breakdown is shown in Table 6. The categories with most POIs were restaurants, churches, real estates, schools and bars.

Table 6. Breakdown of all Returned POIs from Google Maps

POIs	Count
apartment	59
bars	115
church	120
community	99
house	59
real estate	120
grocery store	58
hotel	60
park	91
plaza	58
shopping mall	56
school	119
restaurant	178
theater	60

With the latitude and longitude of these sites, these POIs were plotted in QGIS software. It can be found that these POIs pretty much covered the entire geographic area of KCMO, so they could serve as the candidates sites for charging demand prediction with the above mentioned MLR model.

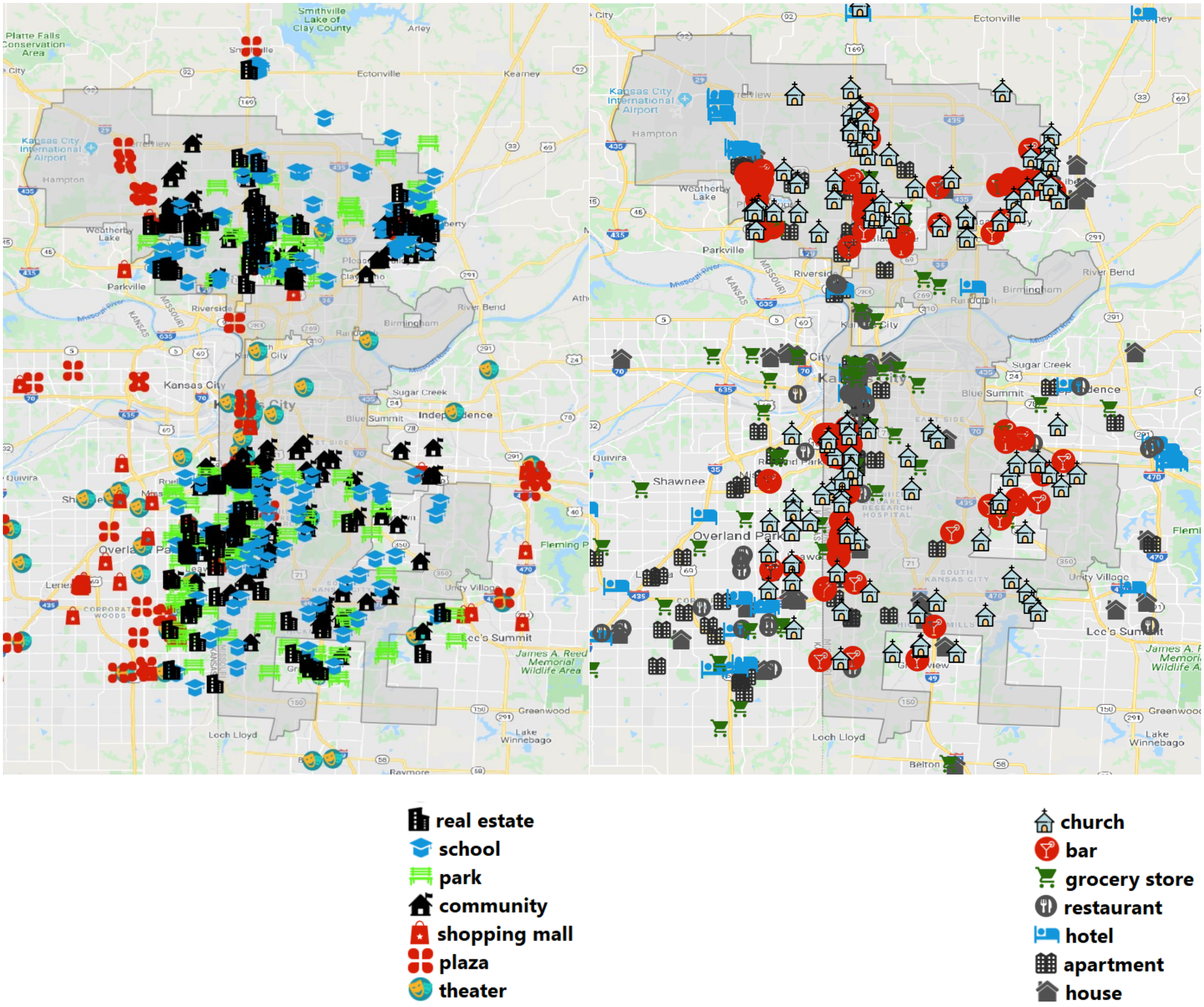


Figure 25. The Location of all POIs in Kansas City

Usage Rate Prediction

In this last step, the daily usage frequency of the charging stations on these 1,252 potential sites were calculated, to answer the question of what would happen if EVSE charging infrastructure were to be deployed at these locations. For the land use type, the original 14 POI categories were divided into 3 types. Apartment, hotel, house, real estate and community were considered as residential area; grocery store, restaurant, shopping mall and theater were categorized as business area, while school, job-related locations and churches were assigned as office zone. For the other three variables, i.e. the neighborhood charging station density, neighborhood traffic volume and trip production, since the latitude and longitude of each site have been retrieved, the value of these three independent variables can be obtained from the original datasets directly.

Then, based on the trained MLR model, the usage frequency of charging stations at these 1,252 POI locations can be predicted. The prediction results for each POI category were shown in the figure below, in which X axis is the predicted usage frequency (unit: times/day), and Y axis is the number of POIs that fell into a particular range. It can be found that plaza, restaurant and theater were predicted to have the highest usage frequency, while school and church were found to have the lowest predicted usage.

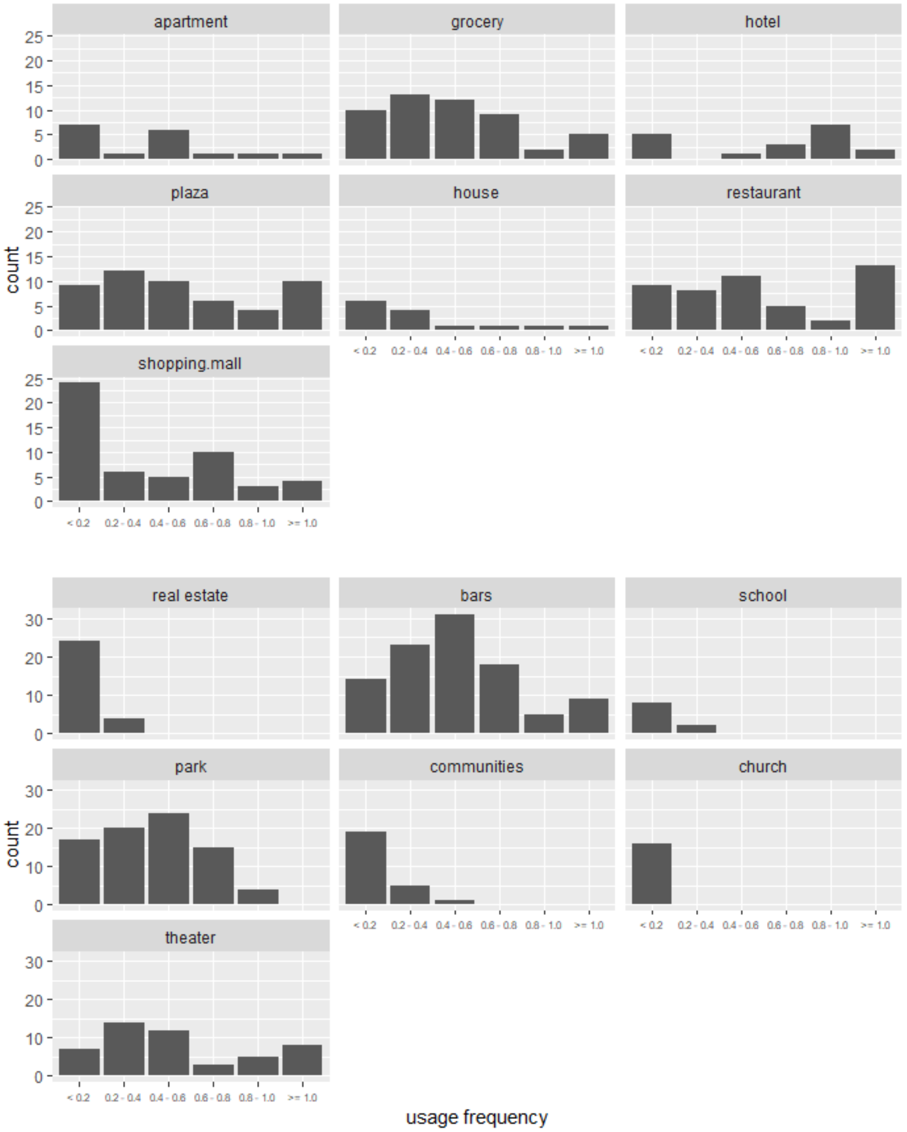


Figure 26. The prediction result for all POIs

To identify 300 candidate sites for further evaluations purposes, the top 250 POIs with highest predicted usage frequency were used. Specially, for the top 50 POIs, 3 closest street lights were selected as the candidate lights for charging stations. For these sites with highest demand potential, one or multiple charging stations can be considered. For the top 51-150th POIs by the predicted usage frequency, 2 street lights were chosen as the candidate sites for charging stations. For the remaining 100 POIs that ranked 151-250th, one street light was chosen as the candidate sites. These generated a total of 310 candidate street lights, as some streetlight locations were repeated and the duplicate ones were removed. The locations of these candidate streetlight were shown in Figure 27. Compared with the location of existing charging stations that were illustrated in Figure 28, it can be found that geographically, these new locations would complement the existing infrastructure and form a holistic charging network in the KCMO region.

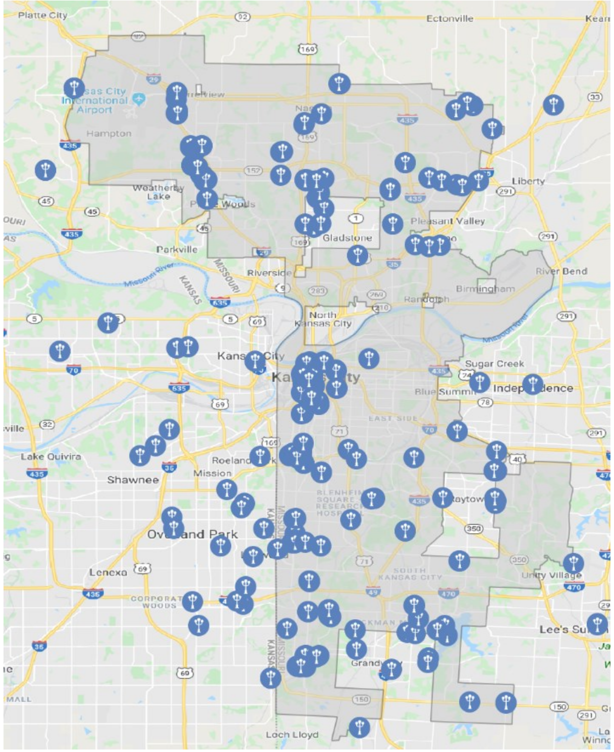


Figure 27. 310 selected candidate street lights in KCMO

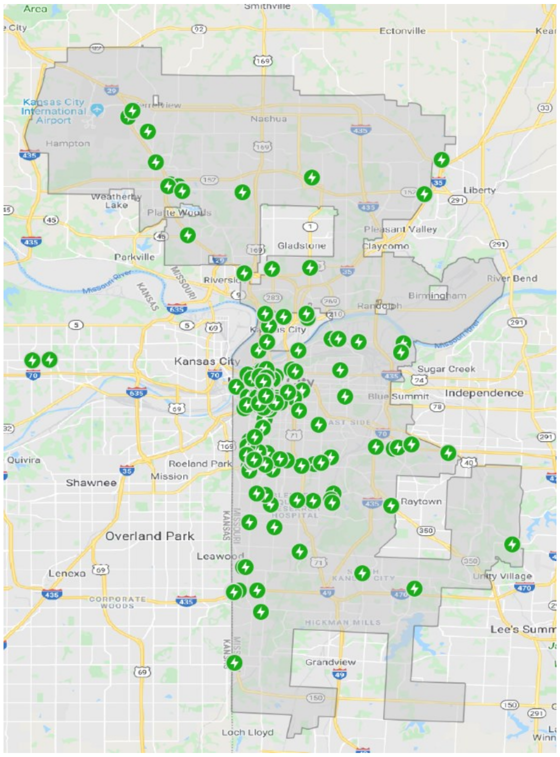


Figure 28. Existing charging stations in KCMO

For more detailed description of the modeling approach and the analysis results, interested readers may check out a few articles that the research team have published.

1. Song, Y., Hu, X. (2023). Learning-Based Demand-Supply-Coupled Charging Station Location Problem

for Electric Vehicle Demand Management. *Transportation Research Part D: Transport and Environment*. https://doi.org/10.1016/j.trd.2023.103975

2. Song, Y., Hu, X. (2021). Learning Electric Vehicle Driver Range Anxiety with An Initial State of Charge-Oriented Gradient Boosting Approach. *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations* *https://doi.org/10.1080/15472450.2021.2010053*
3. Chen C., Song Y., Hu, X., Guardiola I. (2020). Analysis of Electric Vehicle Charging Behavior Patterns with Function Principal Component Analysis Approach. *Journal of Advanced Transportation*. https://doi.org/10.1155/2020/8850654

Appendix C. NREL Modeling Overview

Reason for Methodological Approach

A 2019 ICCT report suggests that Kansas City has one of the strongest public charging networks in the country: "Of the 50 largest metropolitan areas, only Kansas City has sufficient total charge points to serve the projected electric vehicle fleet in 2025." MST's modeling approach will confirm this by identifying all potential locations for EVSE in Kansas City to ensure a robust network of EV charging to accommodate future adoption scenarios. Considering this, NREL will focus its analysis on identifying streetlight charging locations that primarily support residential charging. This analysis will generate heat maps that will be overlaid on MST's model output. Together, MST's model and NREL's analysis should identify locations that will have high utilization because they contribute to a robust network while also serving residential charging demands. NREL will further supplement this analysis by providing additional geographic regions of focus based on specific groups of citizens the project seeks to identify (e.g., low-income, disadvantaged, or environmental justice communities). The output of this analysis will offer an additional layer of potential charging locations that can help ensure an equitable investment in charging infrastructure across Kansas City.

Focus Areas

1. Areas with relatively high plug-in electric vehicle (PEV) shares AND that are likely to have poor residential EVSE availability.
    a. Can we get home chargers to people that already own EVs? This would likely be the easiest "win."
2. Areas with relatively low PEV shares AND demographics that suggest they would be amenable to PEV adoption AND that are likely to have poor residential EVSE availability.
    a. Can we "unlock" areas of the city where residential charging availability is the primary barrier? It could be a year or more lag between streetlight charging and EV adoption, so it is important to keep utilization expectations in check for this application.
3. Areas with low incomes and high shares of multi-unit dwellings (which would imply poor residential EVSE access).
    a. Can we target key parts of the city where vulnerable populations with limited EVSE access may reside? Again, we need to consider the lag between charging and EV adoption.

Output

NREL will develop three separate heat maps that address each of the individual focus areas discussed above. NREL will collaborate with MST to overlay these maps on the MST model output to identify locations in Kansas City that support a robust charging network, meet the residential charging needs of existing and future EV drivers, and can be reasonably expected to have high utilization.

Data Layers

1. EV and plug-in hybrid electric vehicle (PHEV) from 2014–2017 (IHS Market data).
    - Weight PHEVs higher than EVs, as it is likely PHEVs will use Level 2 chargers more.
    - Weight ZIP codes where growth is faster over time (implying faster adoption).
2. Multi-unit dwelling/land use (Kansas City, MO, data).
    - Building type of individual buildings in Kansas City.
3. Rental data (TIGER database and American FactFinder).
    - Block and block group housing data in Jackson County, Missouri.
4. Sociodemographic indicators for "likely to adopt" groups.
    - Demographic data that align with EV ownership (e.g., income, family type, homeownership, age, education).
5. EJScreen layers (ejscreen.epa.gov/mapper/); suggest using ALL.
    - Environmental indicators
        i. Particulate matter ($PM_{2.5}$)
        ii. National Air Toxics Assessment (NATA) cancer risk
        iii. Lead paint indicator
        iv. Hazardous waste proximity
        v. Ozone
        vi. NATA respiratory hazard index (HI)
        vii. Superfund proximity
        viii. Wastewater discharge indicator
        ix. NATA diesel PM
        x. Traffic proximity
        xi. Risk management plan (RMP) proximity.
    - Demographic indicators
        i. Minority population
        ii. Low-income population
        iii. Linguistically isolated
        iv. Less than high school education
        v. Under age 6
        vi. Over age 64.

Appendix D. Community Organization Outreach

Streetlight Charging in the Kansas City Right-of-Way

Overview

The use of plug-in electric vehicles (PEVs) in Kansas City is expected to grow significantly and presents substantial public health benefits. As new electric vehicle models become available and the used market grows, our community will need to make sure that drivers have access to a robust and affordable electric vehicle charging network. To this end, the city is conducting a pilot project to explore the potential to connect charging stations to existing streetlights. An affordable curbside charging network will enable more drivers to choose PEVs and provide easy charging access for all community members interested in driving an electric vehicle.

What We Are Doing

As part of this pilot, we are determining locations for streetlight charging stations that will best serve the needs of the community. The team is looking at what locations make sense based on a number of considerations, including where they can technically be located, where it's safe to locate them, and where they need to be to fill the gaps in Kansas City's existing charging network. We are gathering feedback and looking at ways to make public charging for electric vehicles available to all community members.

Funding and Partners

This project is funded by the U.S. Department of Energy and was awarded to Metropolitan Energy Center (MEC) through a competitive proposal process. MEC is a local nonprofit that works to create resource efficiency, environmental health, and economic vitality in the Kansas City region. MEC and its project partners are making in-kind contributions to leverage these federal dollars for the benefit of the Kansas City community. Project partners include Evergy, The City of Kansas City, MO, the National Renewable Energy Laboratory (NREL), EVNoire, local community organizations, Black and McDonald, LilyPad EV, Missouri University of Science and Technology, and you!

Purpose

This is an opportunity for us to work in collaboration with the Kansas City community to identify the best solution for electric vehicle charging. Streetlight charging for PEVs, whether curbside in central business districts or on residential streets, may provide easy charging access for apartment residents and homeowners alike. This project will demonstrate and evaluate the benefits of curbside charging for plug-in electric vehicles at existing on-street parking locations.

Benefits to the Community

Pollution from vehicle tailpipes are the leading cause of climate change and air pollution. Transportation pollution has a significant negative impact on our health, increasing our risks of cancer and asthma, along with a host of other illnesses. As PEVs replace conventional vehicles, members of the community could see health benefits such as decreased pollution from vehicle tailpipes. PEV drivers can also see financial benefits from lower fuel and maintenance costs than what they may see with conventional gasoline vehicles.

Community Impacts

The project will engage the community in a collaborative effort to identify and evaluate the benefits and impacts of streetlight charging. It is a priority for the project to ensure the benefits of this pilot are distributed equitably to all members of the Kansas City community and that new charging opportunities and associated resources are available in diverse neighborhoods across the city. Engagement with the community will allow us to proactively identify potential impacts, and work collaboratively with you to implement solutions. This project will not affect or interrupt your current utility service.

Next Steps

In the coming months, our team will be speaking with you and your fellow community members to listen to your thoughts about this project. You may also see our team out in the community reviewing potential locations. Once this work is done, we will have a better understanding of the challenges and opportunities for these charging stations. Findings from this project will help us streamline future efforts to support a diverse array of EV drivers through public charging in the city right-of-way.

Get Involved

MEC is committed to a transparent and publicly accessible approach that encourages the collaborative evaluation of streetlight charging.

- Subscribe to our email newsletter to receive important updates about the project and learn about opportunities to share your feedback.
- Visit our webpage (https://metroenergy.org/programs/clean-cities/projects/streetlight-ev-charging/) to see photos of streetlight charging, view proposed locations, and see the project timeline.
- Participate in a listening session where you can learn more about the project and engage with project leaders to discuss concerns and opportunities to expand access to EV charging.
- Share your feedback or ask questions by contacting us at:

Metropolitan Energy Center, Inc.
300 E 39th St
Kansas City, MO 64111
Metroenergy.org
Phone: (816) 531-7283
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Appendix E. Data Analysis

Upon the installation of the streetlight chargers, a detailed log of usage patterns began to accrue, capturing essential information about the electric vehicles utilizing the service—such as the timing of charges, the duration of each charge, energy charged, and GHG savings. To gain insights into the operational dynamics of the charging stations, our team obtained the comprehensive charging event log data from Evergy. We leveraged this dataset to monitor and analyze utilization trends. This section presents a thorough analysis of the collected data, which spans from April to December 2023, covering a period of 256 days. From this data, we have curated a set of 1,708 distinct data samples, the particulars of which are elaborated upon in the ensuing segments.

Benefits of streetlight chargers from this project

Our initial assessment focuses on the energy efficiency and the environmental benefits brought forth by the implementation of the 23 streetlight EV charging stations, which symbolize a progressive step towards sustainable refueling infrastructure. The analysis encapsulates the energy consumption metrics and quantifies the subsequent reduction in emissions, delineating the ecological advantages of this novel charging paradigm.

Figure 29 serves as a visual representation of the energy consumption, greenhouse gas (GHG) savings, and the offset of gasoline usage attributable to the operations of a typical streetlight EV charging station within this network. Through a comprehensive evaluation, the data underscores the propensity of these charging stations to be well-received and actively used by the EV community in Kansas City, thereby amplifying their positive impact on urban environmental health. In quantifiable terms, the data from the stations depict a significant energy throughput of 30,465 kWh. This energy utilization translates into a notable mitigation of greenhouse gas emissions, achieving a total GHG savings of 21,711 kg. Furthermore, the stations have facilitated a substantial gasoline offset, equivalent to 3,823 gallons. This reduction not only echoes the shift towards cleaner energy but also aligns with broader goals of reducing reliance on fossil fuels. The data analysis results further highlight the positive impact of streetlight EV charging stations on urban environmental health. This suggests that these charging stations are well-received and actively used by the EV community in Kansas City.

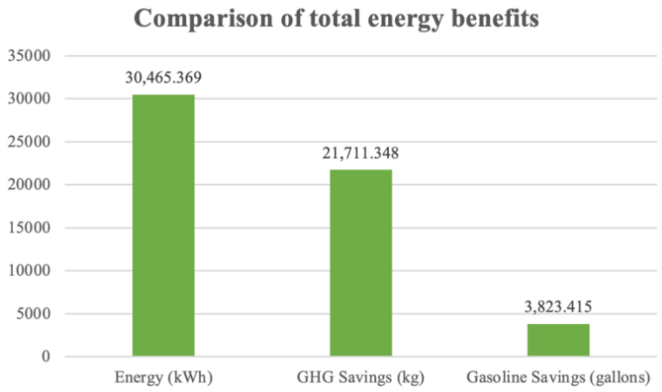

Figure 29 The comparison of total benefits of streetlight EV charging

Usage frequency of streetlight chargers

In our subsequent analysis, we delve into the utilization rates of each streetlight charger to discern the patterns of EV driver preferences and charging behavior. On average, each charger was employed approximately 74 times over the observation period, equating to roughly 0.3 uses per day. The standard deviation, a robust statistical measure capturing the extent of variance from the mean, stands at 86.10. This substantial deviation underscores the diverse usage rates across different chargers, suggesting a wide range of EV driver charging needs and preferences. Such variability emphasizes the multifaceted nature of charger utilization, highlighting that while some chargers are frequently sought after, others are less favored or possibly less conveniently located for potential users.

At the higher end of utilization, the EVERGY/@MOD GLLRY-517 station stands as a testament to optimal charger placement, commanding the network's highest usage with an impressive 409 instances. This figure could be indicative of an exceptionally strategic location with superior accessibility, or perhaps the presence of amenities that cater to the needs of EV drivers. Such high usage rates highlight the station as a benchmark for successful integration within the urban fabric, falling within the "Easy Wins – Focus Area 1" category, which targets areas with existing high EV adoption and poor residential EVSE availability. Conversely, the low frequency of charging events at stations like EVERGY/@MERSHNGTN-507, with only 4 uses, may signal underutilization issues that warrant a closer examination. Factors contributing to its scant use could range from obstructions by gasoline vehicles, insufficient visibility of the station, or technical difficulties.

Such disparities seem to be consistent with our prior two-tiered market analysis, which strategically positioned chargers by balancing demand and equity considerations, thereby catering to the diverse needs across various community strata. The contrast between the high-usage “Easy Wins” locations and the low-usage “Create Opportunity” areas underscores the importance of a nuanced approach to infrastructure development, emphasizing both market demand and the potential for stimulating new growth within the EV ecosystem.

Table 7 The frequency of usage of the 23 streetlight charging stations

Station Name	Frequency of use	Station Name	Frequency of use
EVERGY/@MOD GLLRY-517	409	EVERGY/@MINIMRT-505	33
EVERGY/@WSTPRT -523	158	EVERGY/@FOX HLL-519	31

EVERGY/@BNINGTON-503	137	EVERGY/@ETHNS APTS-513	28
EVERGY/@ARNO PK-516	135	EVERGY/@STARLIGHT-524	23
EVERGY/@N PLT PRK-512	134	EVERGY/@ESSEX PRK-515	20
EVERGY/@SYCMR PRK-514	110	EVERGY/@N HMPTN-508	20
EVERGY/@SDA LFTS-509	102	EVERGY/@BNSTR PRK-511	14
EVERGY/@GRNWY-502	97	EVERGY/@ASHLND-526	13
EVERGY/@EXTDSTAY-501	84	EVERGY/@NE TATTOO-504	10
EVERGY/@DUBOIS-506	55	EVERGY/@PARK FRST-510	8
EVERGY/@ROSEHLL-520	43	EVERGY/@MERSHNGTN-507	4
EVERGY/@WBSH ALDI-521	40		

Total charging time of streetlight chargers

Subsequently, we shift our focus to the temporal aspect of charging station usage. By compiling the cumulative charging durations for each EV at every station, we have generated a comprehensive portrait of station engagement, the details of which are cataloged in Table 6.

The data reveals a striking variance in charging durations across the network. EVERGY/@BURLINGTON-503 emerges as the preeminent leader in this metric, with a total charging time amassing 53,638 minutes or a substantial 894 hours. This indicates not just frequent use but prolonged engagement, suggesting that once an EV begins charging, it tends to do so for an extended period.

In stark contrast (and similar to Table 5 above), EVERGY/@MARSHINGTON-507 registers at the other end of the spectrum with a notably brief cumulative charging time of 586 minutes, or just about 9.8 hours. The gulf between the highest and lowest charging times points to a broad spectrum of user engagement levels, further exemplified by contrasting these durations with the frequency data presented in Table 5.

Intriguingly, despite its position as the most frequented charger, EVERGY/@MOD GLLRY-517 does not top the list for the longest charging times—in fact, it ranks third in Table 6. This discrepancy suggests that while it attracts a large number of charging events, the individual sessions tend to be shorter. This could reflect a trend of brief, yet frequent, charging sessions, possibly indicative of a busy locale where drivers prefer quick top-ups to long charging cycles. In the continuous attention of streetlight charging stations, it might be interesting to conduct further examination of those stations with low frequency of usage and low total charging time to determine the reasons for their low efficiency. This will enable us to propose effective measures to improve their utilization rate.

Table 8 Total charging time of the selected 23 stations

Station Name	Total Charging Time (Minutes)	Station Name	Total Charging Time (Minutes)
EVERGY/@BNINGTON-503	53,638	EVERGY/@ETHNS APTS-513	5,137
EVERGY/@N PLT PRK-512	50,875	EVERGY/@ESSEX PRK-515	3,441
EVERGY/@GRNWY-502	46,116	EVERGY/@N HMPTN-508	2,890

EVERGY/@MOD GLLRY-517	42,258	EVERGY/@FOX HLL-519	2,509
EVERGY/@EXTDSTAY-501	22,668	EVERGY/@NE TATTOO-504	2,425
EVERGY/@SYCMR PRK-514	20,068	EVERGY/@WBSH ALDI-521	2,264
EVERGY/@ARNO PK-516	16,751	EVERGY/@STARLIGHT-524	2,248
EVERGY/@DUBOIS-506	15,814	EVERGY/@PARK FRST-510	941
EVERGY/@SDA LFTS-509	14,261	EVERGY/@BNSTR PRK-511	626
EVERGY/@WSTPRT -523	13,582	EVERGY/@ASHLND-526	606
EVERGY/@MINIMRT-505	5,861	EVERGY/@MERSHNGTN-507	586
EVERGY/@ROSEHLL-520	5,569		

Charging time and duration time analysis

The comprehensive data analysis from Tables 5 and 6 provides a springboard for an in-depth examination of each charging event's duration and charging time. In the following section, we further explore the various patterns of charging time and duration.

Charging time analysis

We begin by assessing the charging time, calculated from the initiation to the conclusion of a charging session, which may end for different reasons such as reaching full battery capacity or through manual termination by the user. The collected data, showcased in Figure 28, provides a wealth of insights into the charging habits of electric vehicle users. The average charging time, or mean, is recorded at 193.88 minutes, offering a baseline for typical charger use. This figure, however, is only the surface of a more complex picture of charging behaviors. An examination of the standard deviation, which amounts to 199.35 minutes, highlights a broad distribution of charging times. This suggests that there is no single 'typical' charging session duration but rather a wide range that could be influenced by various factors such as the type of EVs, charger speed, or user behavior.

The data's range is further illustrated by the minimum charging time of just 0.63 minutes—potentially reflecting instances where the charging session was initiated but immediately stopped, perhaps due to user error or a change in plans. On the opposite end of the spectrum, the maximum charging time reaches an impressive 1,002.37 minutes, showcasing scenarios where vehicles are connected for extended periods, possibly indicating full charging cycles or extended parking durations. The 25th percentile, at a concise 49.42 minutes, indicates that a quarter of the charging sessions are relatively brief, likely accommodating short-term needs or top-up charges. Meanwhile, the 75th percentile, at a more generous 266.80 minutes, reveals that a significant number of sessions are considerably longer, potentially accommodating complete charging cycles for EVs with larger battery capacities or serving users who prefer to charge less frequently. Through analyzing the distribution of charging time, we can consider enhancing the user interface of charging stations and implementing other measures to offer more intuitive operation guidance or error prompts, thereby reducing the incidence of situations such as short charging times or errors.

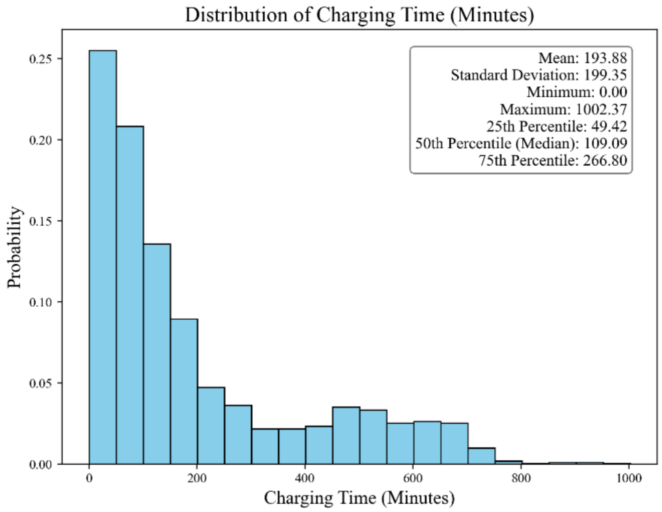

Figure 30 Distribution of charging time

Session duration analysis

We then delve into the duration of each charging session. This duration measures the time from when the charger is connected to when it is disconnected. Notably, if a vehicle remains parked after charging is complete, the recorded duration will exceed the actual charging time.

An examination of the dataset reveals the distribution patterns of total duration, as illustrated in Figure 29. The mean total duration is recorded at 230.58 minutes, providing an average measure of utilization. However, this mean is accompanied by considerable variability, as shown by the standard deviation of 244.51 minutes. This high variability indicates a wide range of session lengths, from very short to extended periods.

The range of durations spans from a minimum of just 0.63 minutes, likely reflecting interrupted or aborted charging sessions, to a maximum of 1,429.42 minutes, indicating instances where chargers are occupied for lengthy periods.

Analysis of the distribution quartiles shows that the 25th percentile is at 54.04 minutes, indicating that many charging events are relatively brief. In contrast, the 75th percentile reaches 320.41 minutes, highlighting that a significant portion of sessions involve extended charger use. The median duration, at 132.95 minutes, provides a central point, dividing the dataset into two equal halves and reflecting a typical session length.

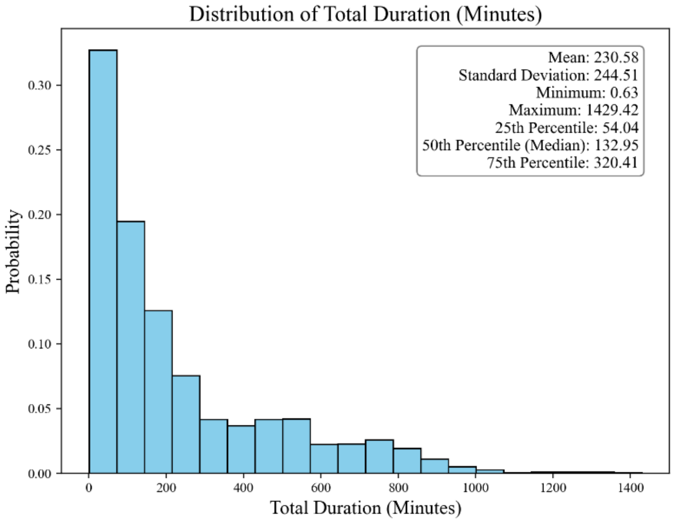

Figure 31 Distribution of total charging duration

Additional parking time analysis

Upon comparing the average charging time of 193.88 minutes, as illustrated in Figure 30, with the average total duration time of 230.58 minutes shown in Figure 31, we observe a notable difference. This discrepancy reveals that, on average, drivers remain parked for approximately 40 minutes after their vehicles have completed charging. This behavior suggests that while the charging infrastructure is used efficiently, parking spaces continue to be occupied even when the charging process has concluded.

Figure 32 delves deeper into this phenomenon by presenting a statistical analysis of the variance between total duration and charging time. The analysis indicates that the likelihood of the variance being 60 minutes or less is as high as 84%. This high probability suggests that for the vast majority of instances, the charging time and the total duration are closely aligned, pointing to a high utilization rate of the charging stations. This alignment implies that the duration for which vehicles are parked, both charging and post-charging, closely matches the time they are actively charging.

This observation underscores the effective use of charging stations, but it also highlights an area for potential improvement in managing parking behavior post-charging. Optimizing this aspect could further enhance the availability and efficiency of EV charging stations, particularly during peak times when demand is higher. Such insights are crucial for informing future policies or technological solutions aimed at maximizing the utility of EV charging infrastructure.

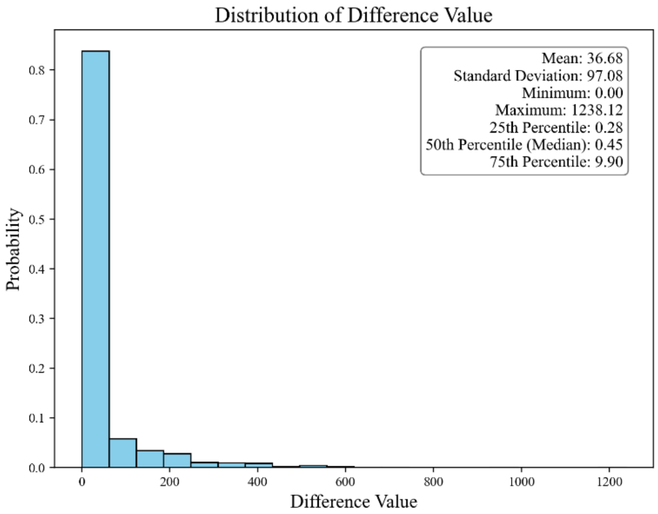

Figure 32 Distribution of the difference between total duration and charging time

Comparison with Conventional Charging Stations

This section is dedicated to evaluating the performance of the 23 streetlight charging stations in comparison to traditional charging stations. Our analysis will begin by examining the charging speeds of these installations and then progress to assess their energy efficiency metrics. This comprehensive comparison aims to highlight the technological and environmental advantages of the streetlight chargers over their conventional counterparts.

Charging speed comparison

To determine the charging speed of the charging stations, we employ Equation (12) outlined below for our calculations.

$$Charging\ speed = \frac{Energy}{charging\ time} \tag{12}$$

In our detailed examination of charging speeds, we have compiled data for both streetlight EV charging stations and conventional charging stations, as outlined in Table 7. The findings indicate that streetlight EV charging stations achieve an average charging speed of 3.231 kW/h, compared to the conventional charging stations, which maintain an average speed of 2.975 kW/h. This data clearly shows that streetlight charging stations exceed the performance of their conventional counterparts by approximately 8.6%.

The comparison of charging speeds illustrates that when appropriately chosen and engineered, streetlights can be effectively retrofitted to function as EV charging stations, often with comparable or superior performance. This utilization of existing urban infrastructure not only boosts charging speeds but also delivers wider societal advantages. The integration of streetlight charging stations streamlines the charging process, promotes a more sustainable and efficient use of urban spaces, and represents a notable progression in EV charging technology. This strategy not only optimizes resource use but also enhances the functionality of urban environments, demonstrating the practical benefits of innovative infrastructure solutions.

Table 9 The comparison of the average charging speed

EV Charging Station Types	Average charging speed (kW/h)
Streetlight	3.231
Normal	2.975

Average energy savings metrics

Next, we assess and compare the average energy efficiency metrics between streetlight EV charging stations and conventional EV charging stations. Figure 33 illustrates that during a charging session, the 'Streetlight EV charging station' consumes 17.837 kWh of energy, which leads to a reduction of 12.712 kg in greenhouse gas (GHG) emissions and saves 2.239 gallons of gasoline. In comparison, the conventional EV charging station utilizes 15.834 kWh of energy, reduces GHG emissions by 11.308 kg, and saves 1.987 gallons of gasoline. In other words, the streetlight EV charging stations demonstrate notable enhancements over their conventional counterparts, showing increases of 12.647% in energy consumption, 12.410% in GHG emissions reduction, and 12.648% in gasoline savings. These metrics not only highlight the superior energy efficiency of streetlight chargers but also underline their environmental benefits.

Additionally, the data reveals that streetlight chargers deliver 12.5% more energy compared to conventional chargers, even though their charging speed is only 8.6% faster. This suggests an additional advantage of 3.9%, which likely stems from either more frequent usage or extended charging sessions. This enhanced performance means that streetlight chargers not only facilitate quicker charging processes but also encourage longer periods of connectivity. Such efficiency allows electric vehicles to maximize their charging opportunities, optimizing the use of streetlight charging stations and underscoring their increased utility in urban settings.

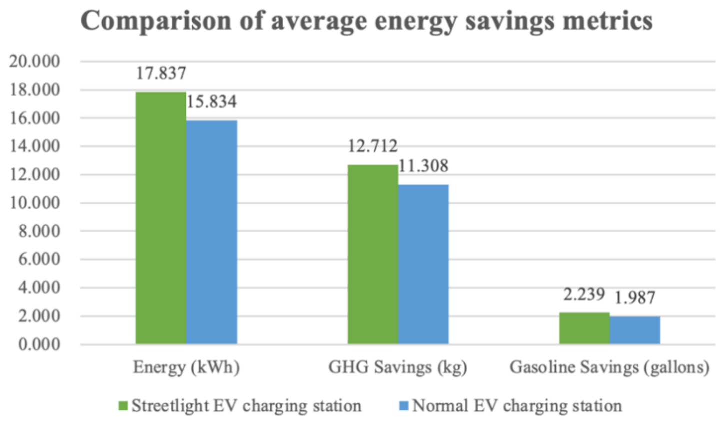

Figure 33 The comparison of the average energy savings metrics