APRIL 2024

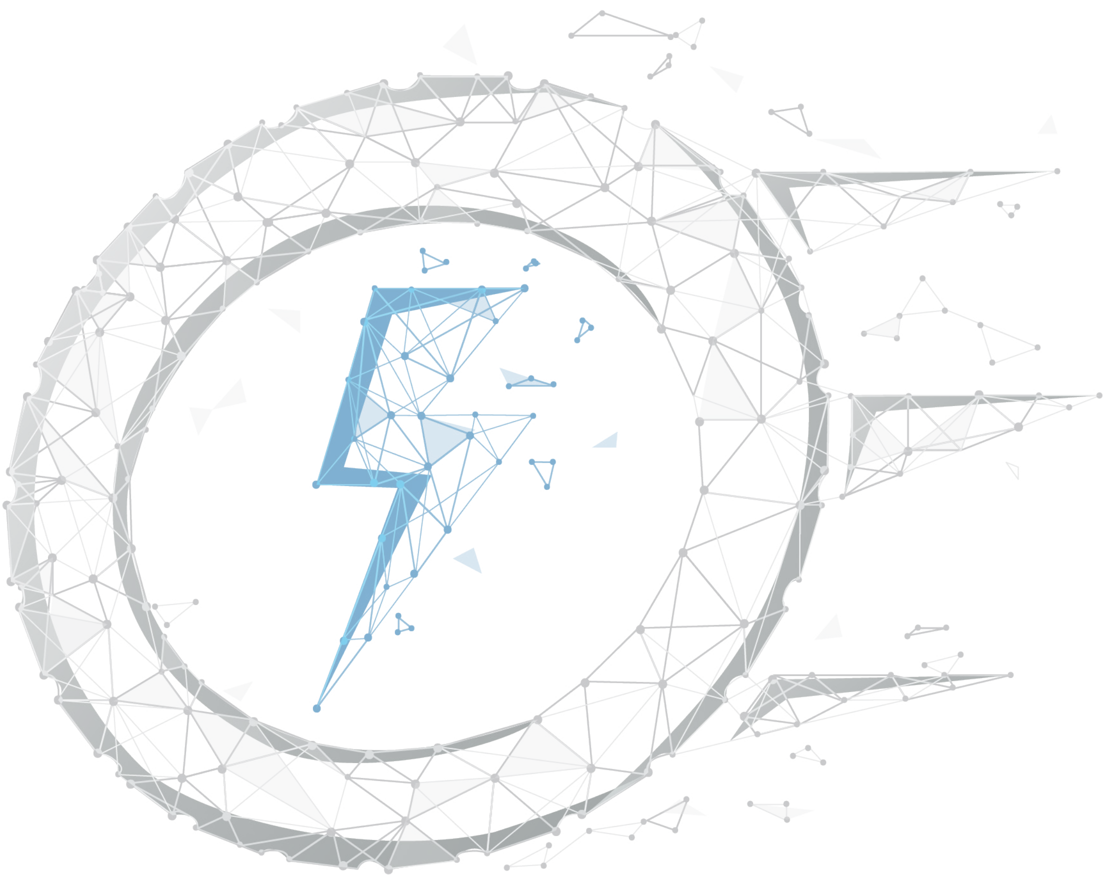
energetics
Clean Energy Consulting

EV WATTS
WHITEPAPER SERIES

Public Charging Station Peak Demand

EV WATTS
WHITEPAPER SERIES

Public Charging Station Peak Demand



Acknowledgment

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Vehicle Technology Program, Award Number DE-EE0008890.

Public Charging Station Peak Demand

Introduction

Charging station utilization analyses typically look at the amount of time an electric vehicle (EV) is occupying a station (plugged into it) because other vehicles would view the station as available only when a vehicle is not parked there. In some situations, the EV driver is also occupied during this period and not able to move the EV once it is fully charged.

Actual charging time is often shorter than plug-in time. EVs typically charge at maximum available rates as soon as they are plugged in and maintain this rate until the battery is sufficiently charged. Charging management strategies could be used to 1) reduce the charging rate to reduce the peak demand or share power among more stations, or 2) shift the charging period away from peak grid times or to times that more renewable energy is available. However, most stations are not currently incorporating smart charging management strategies to change charging profiles.

Most EVs have an onboard charger that accepts 6.6–7.2 kW, which is the typical output of most public alternative current (AC) Level 2 (L2) stations.[1, 2] The L2 charging rate is also fairly consistent throughout the charging event, regardless of the battery's state of charge (SoC). There is much greater variability with direct current fast charging (DCFC): the EV's maximum charging rate can range from 50 to 350 kW,[3] the DCFC station outputs range from 25 to 350 kW, and the actual charging rate varies based on the vehicle's SoC (slowing down at low [<20%] and high [>80%] SoC).

1 Some older EV models restricted AC L2 charging to 3.3 kW, and a few higher-end EVs accept AC L2 rates of 9.6–19.2 kW.

2 https://energywisemnstore.com/content/Time-to-Charge-Chart-Clipper-Creek.pdf

3 https://blog.greenenergyconsumers.org/blog/a-buyers-guide-to-ev-charging-speeds

Energetics leads EV WATTS (Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions), a multi-sector project that facilitates the nation's move toward sustainable transportation. The project is collecting real-world use data from plug-in EVs and charging stations to address a growing need for practical information about vehicle electrification. The team analyzes these data to improve our understanding of driving and charging patterns. EV WATTS is helping to demonstrate how the latest advancements in EVs and charging station technology address barriers, improve the business case for electrification, and determine what behavioral changes electrification may require.

The project uses charging station data and vehicle usage data to build one of the largest datasets of its kind. The data collected for EV WATTS is aggregated and anonymized so that it can serve as a resource to researchers, policymakers, and other stakeholders. Using the data, the team has created interactive dashboards that display statistics and findings from EVs and charging stations. The dashboards allow users to explore this anonymized dataset, looking at energy demand, use patterns, charging details, and more. The most recent EV WATTS dashboards are available at EVWATTS.org.

EV WATTS is sponsored by the U.S. Department of Energy (DOE). Input and other assistance is provided by DOE national laboratories, Clean Cities Coalitions, fleets, state and local governments, vehicle manufacturers, utilities, EV drivers, and charging station providers.

All three of these factors (occupancy, charging duration, and charging rate) contribute to the peak electricity demand from a single charging station or multiple charging stations. This peak electricity demand can be important to a commercial facility or building that might incur higher electricity demand costs if the charging station demand adds to the existing facility or building demand. At a much higher level, utilities are interested in understanding how hundreds or thousands of charging stations in their territory might impact the grid.

Methodology

EV WATTS collected data from millions of charging events at stations across the United States. For this analysis, the EV WATTS team used these data to generate average demand curves for hundreds of stations. An hourly demand curve for each charging session was generated based on the timing of the charging (power flow) and the average power flow for that session.[4] For purposes of comparison, the average demand curves shown in this analysis are normalized by the number of active stations (across time, when the number of active charging stations could increase or decrease, and across different and varying sized groupings of charging stations).

This analysis focused on public charging stations, which have less predictable usage patterns than charging stations at single-family residences, multi-family dwellings, and fleet facilities. Fleet and residential chargers are typically used overnight by a consistent collection of EVs.

Findings

The average demand curves shown for groupings of charging stations varied daily across the duration of the EV WATTS project. The data analyzed in this paper represent the period from October 1, 2019, to September 30, 2023. The methodology used to calculate the utilization and demand curves can drastically impact the shape. Initially, our analysis investigated the potential difference between:

- Maximum average potential demand over all stations in the group,
- The highest single-day average demand,
- The average demand across the highest ten days, and
- The average demand across all days.

AC L2 stations were analyzed separately from DCFC stations, given the considerable difference in charging rates between the two types. It was further determined that the variability within DCFC station rates was significant enough to divide DCFC stations into two groups: <50 kW and ≥50 kW. **Table 1** provides some key high-level statistics, and **Figures 1**, **2**, and **3** show daily demand profile curves for the three station categories.

4 Charging interval data would have more accurately captured demand during each 15-minute interval and accounted for any variations in rate during the charging session. However, as noted above, AC L2 charging rates are relatively consistent, and DCFC sessions typically last less than an hour, so the present study's method is considered sufficiently accurate for this analysis.

Table 1: Public Stations by Charging Level				
	Maximum average potential demand	Highest single-day average peak demand and percent of potential	Average peak demand across highest ten days and percent of potential	Average peak demand across all days and percent of potential
L2	6.9 kW	1.3 kW (19%) @ 9:00 am	1.1 kW (16%) @ 9:00 am	0.4 kW (6%) @ 10:00 am
DCFC <50 kW	24.1 kW	19.2 kW (80%) @ 2:00 pm	5.4 kW (22%) @ 2:00 pm	0.8 kW (3%) @ 4:00 pm
DCFC >=50 kW	103.4 kW	13.4 kW (13%) @ 3:00 pm	9.4 kW (9%) @ 12:00 pm	2.5 kW (3%) @ 1:00 pm

Figure 1 below shows the daily demand curves for all public AC L2 stations. The shapes of these curves are exactly as one would expect—unsurprisingly, given the large sample size of 14,560 ports. Activity starts to increase at about 6:00 am, peaks at 9:00 am, and gradually declines until the next morning—mimicking vehicle usage during the typical U.S. workday. However, across all AC L2 stations, the actual demand is much lower than the potential demand.

| 3 |

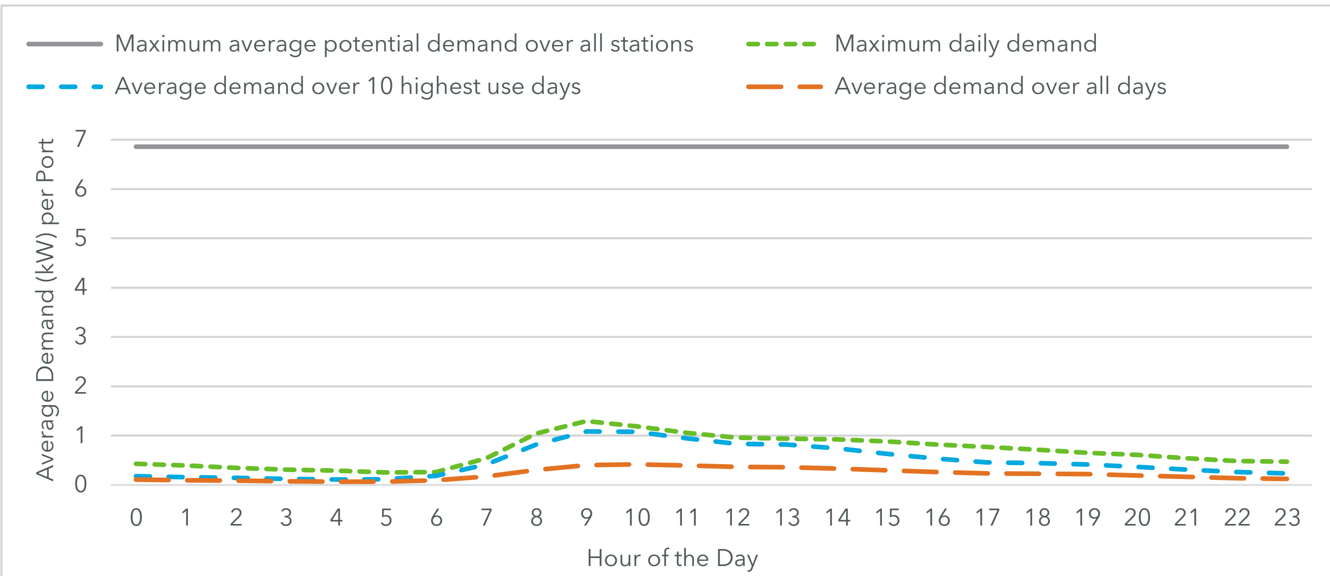


Figure 1: Daily Demand Curve for all L2 Stations

DCFC stations with max demand ≥50 kW have behavior relatively similar to L2 stations, with an increase in demand during daytime hours, except there is no clear peak during this more active period. The scale is about 15 times higher than the AC L2 plot, but similarly, only a small percentage of the total available charging power is being utilized.

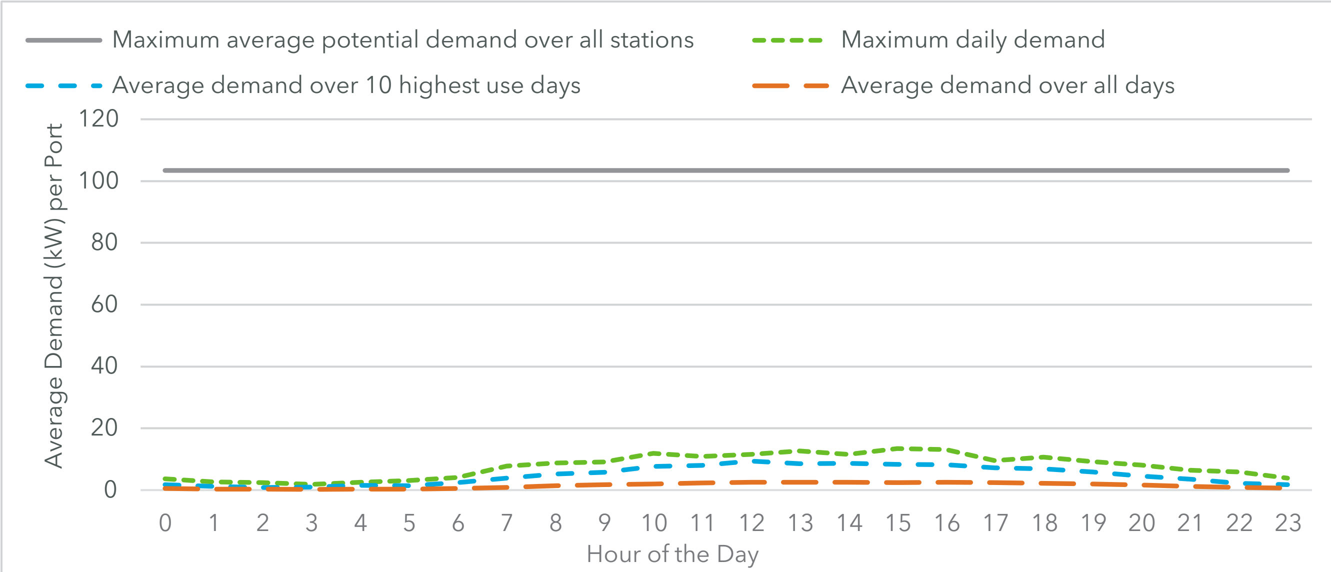


Figure 2: Daily Demand Curve for DCFC Stations ≥50 kW

The demand curves for DCFC <50 kW stand out because the maximum daily demand (in green) is so high; the largest maximum daily demand is almost 80% of the maximum charging potential across all stations. The large gaps between the green, blue, and orange lines suggest the existence of outlier days and hours when the stations were used 7 to 25 times more than average. This dataset is more sensitive to such outliers, as the number of total ports for DCFC <50 kW in the dataset is 893, compared to 2,216 total ports for DCFC ≥50 kW. Also, almost all EVs can draw 50 kW to maximize these lower-powered stations, whereas higher-powered stations are often limited to individual vehicle restrictions, which can vary. Demand also seems to stay consistently high from around 7:00 am to around 9:00 pm.

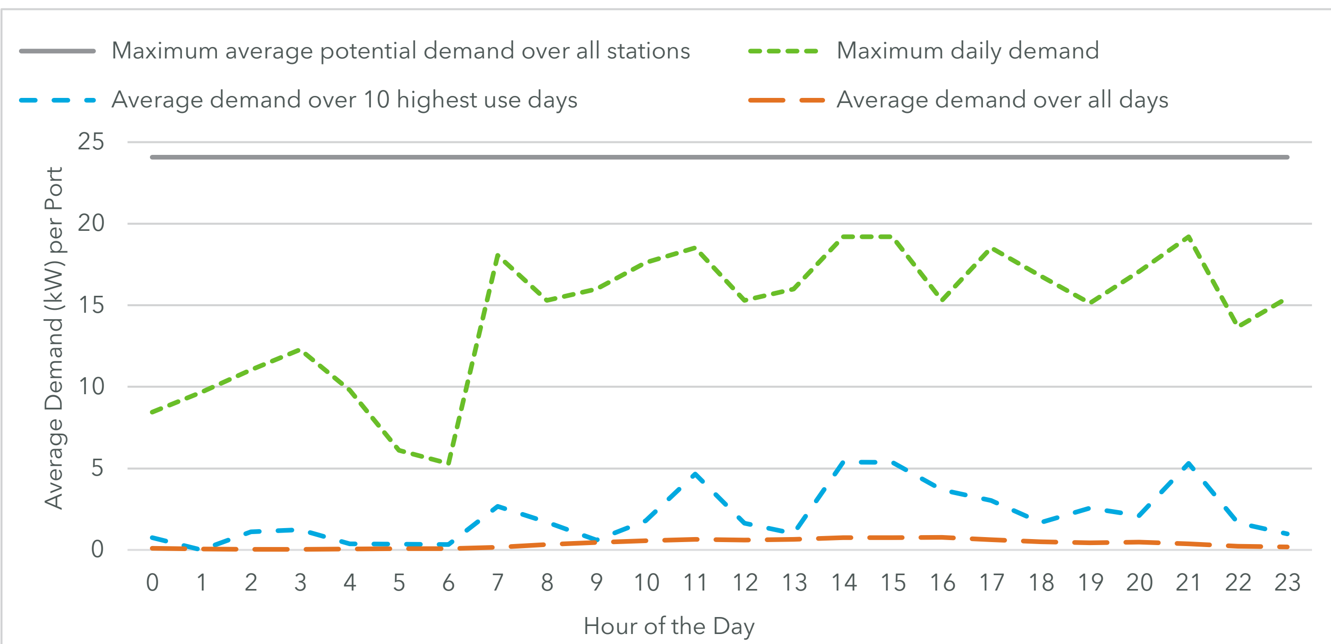


Figure 3: Daily Demand Curve for DCFC Stations <50 kW

Given the focus of this paper, the EV WATTS team made further comparisons among various characteristics—such as geographic location, venue, land use, and fee type—for the maximum daily demand curves for L2 stations.

Comparing the maximum daily demand curves across the nine geographic regions in the EV WATTS database, the curves are relatively similar across six regions. West North Central, Pacific, and South Atlantic regions are the exceptions. West North Central and Pacific show much higher maximum daily demand,[5] especially during the morning hours from 6:00 am to 12:00 pm, with West North Central demand remaining higher than most other regions throughout the day as well. South Atlantic stands out because of its higher demand in the afternoon hours, as well as some overnight peaks, whereas demand in other regions tends to wind down at those times.

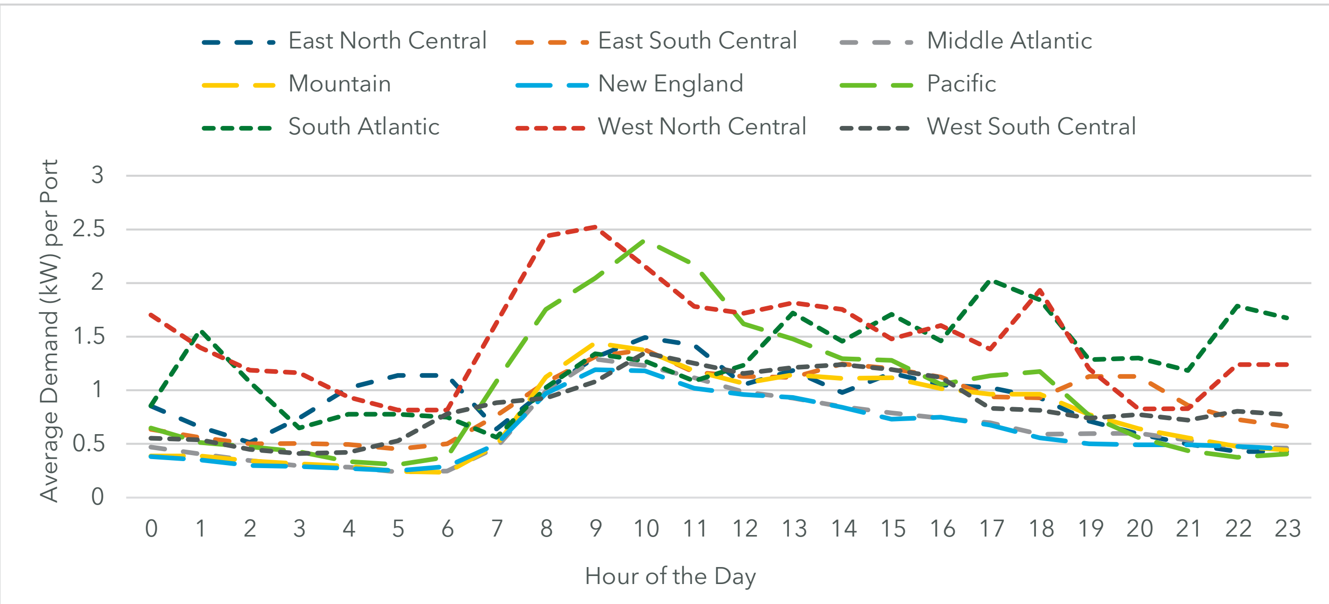


Figure 4: Daily Demand Curve for L2 Stations by Region

The EV WATTS team further investigated the data for the three regions with different demand curves (maximum, average for the ten highest use days, and overall average). For AC L2 stations in the South Atlantic region (**Figure 5**), the demand curve for the ten highest use days (in blue) trends slightly down after 9:00 am, whereas the maximum daily demand curve (in green) continues to slightly increase into the afternoon and evening and the average daily demand curve (in orange) is relatively flat throughout the day. This suggests that the maximum daily demand curve is not typical, but at some point the AC L2 stations in this region experienced this high usage during the afternoon. Note that the maximum average potential demand for AC L2 South Atlantic region stations is higher than other regions (and above the typical 6.6–7.2 kW) at 9.4 kW. Within the EV WATTS dataset, this region had more higher-powered AC L2 fleet chargers (potentially for medium- or heavy-duty vehicles) that influenced these demand curves.

5 https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf

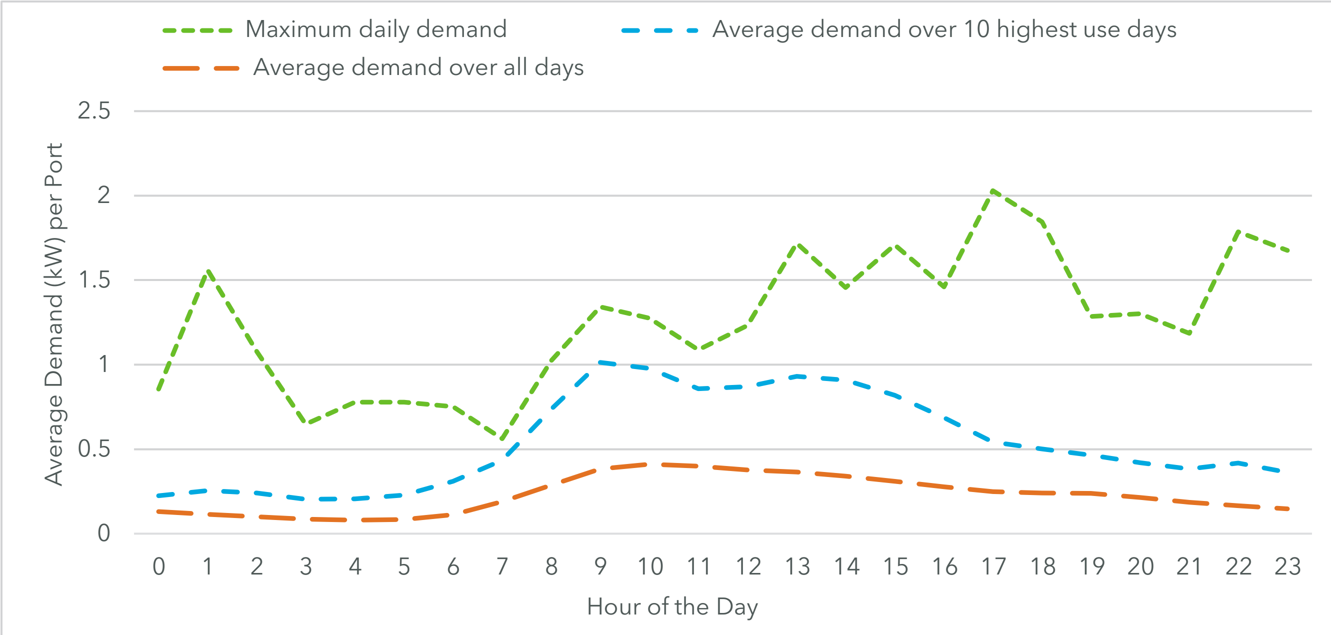


Figure 5: Daily Demand Curve for L2 Stations in the South Atlantic Region

The maximum daily demand curve for West North Central stations (**Figure 6**) also appears to be an outlier, while the maximum daily demand curve for Pacific stations (**Figure 7**) is much closer to that of the 10 highest use days. The peak demand points for all regions are shown in **Table 2**, with both the West North Central and Pacific region AC L2 stations reaching approximately one-third of their potential demand somewhat regularly.

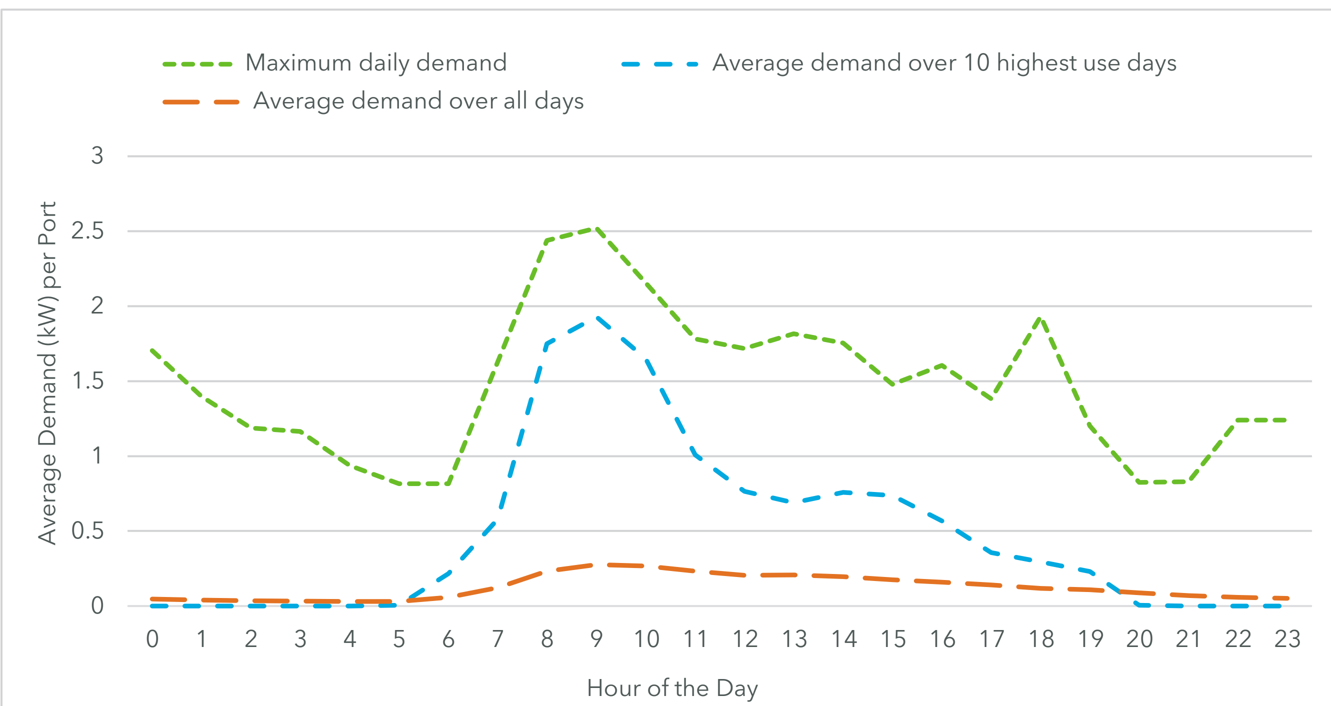


Figure 6: Daily Demand Curve for L2 Stations in the West North Central Region

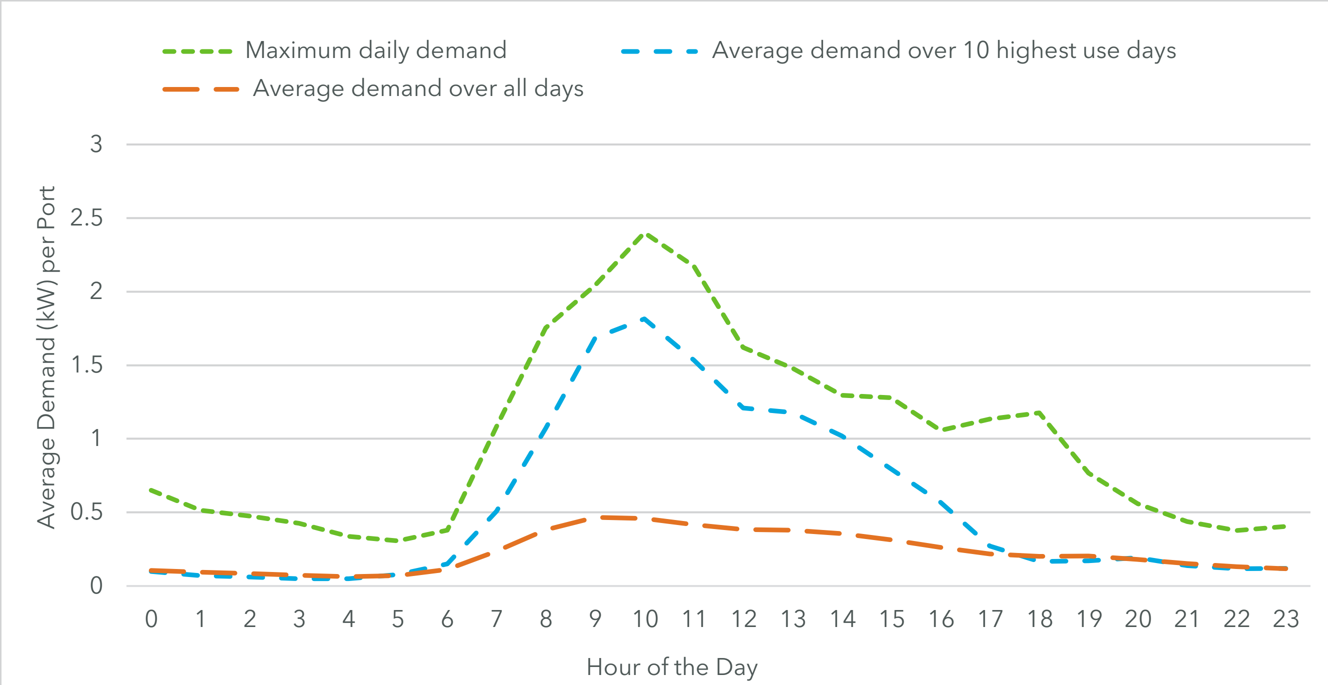


Figure 7: Daily Demand Curve for L2 Stations in the Pacific Region

Table 2: Public L2 Stations by Geographic Location

	Maximum average potential demand	Highest single-day average peak demand and percent of potential	Average peak demand across highest ten days and percent of potential	Average peak demand across all days and percent of potential
West North Central	6.7 kW	2.5 kW (38%) @ 9:00 am	1.9 kW (29%) @ 9:00 am	0.3 kW (4%) @ 9:00 am
Pacific	6.7 kW	2.4 kW (36%) @ 10:00 am	1.8 kW (27%) @ 10:00 am	0.5 kW (7%) @ 9:00 am
South Atlantic	9.4 kW	2.0 kW (22%) @ 5:00 pm	1.0 kW (11%) @ 9:00 am	0.4 kW (4%) @ 10:00 am
East North Central	6.9 kW	1.5 kW (22%) @ 10:00 am	1.0 kW (15%) @ 10:00 am	0.4 kW (6%) @ 10:00 am
East South Central	6.9 kW	1.4 kW (20%) @ 10:00 am	1.1 kW (16%) @ 9:00 am	0.4 kW (5%) @ 9:00 am
Middle Atlantic	7.1 kW	1.3 kW (18%) @ 9:00 am	1.1 kW (16%) @ 10:00 am	0.4 kW (6%) @ 10:00 am
Mountain	6.8 kW	1.4 kW (21%) @ 9:00 am	1.2 kW (18%) @ 9:00 am	0.5 kW (7%) @ 10:00 am
New England	6.6 kW	1.2 kW (18%) @ 9:00 am	1.1 kW (16%) @ 9:00 am	0.4 kW (6%) @ 10:00 am
West South Central	7.4 kW	1.4 kW (18%) @ 10:00 am	1.1 kW (14%) @ 10:00 am	0.3 kW (5%) @ 10:00 am

Next, the analysis compares maximum daily demand curves across different venues where charging stations are located (**Figure 8**). Stations located in transit facilities experienced the highest maximum daily demand overall, and those in retail, leisure destination, and hotel venues show more demand into the late afternoon. The venue types with stations that experienced the highest peak utilization are Transit Facility, Business Office, Medical or Educational Campus, and Multi-Use Parking Garage/Lot, reaching 20%–30% of their potential on their most utilized days (**Table 3**).

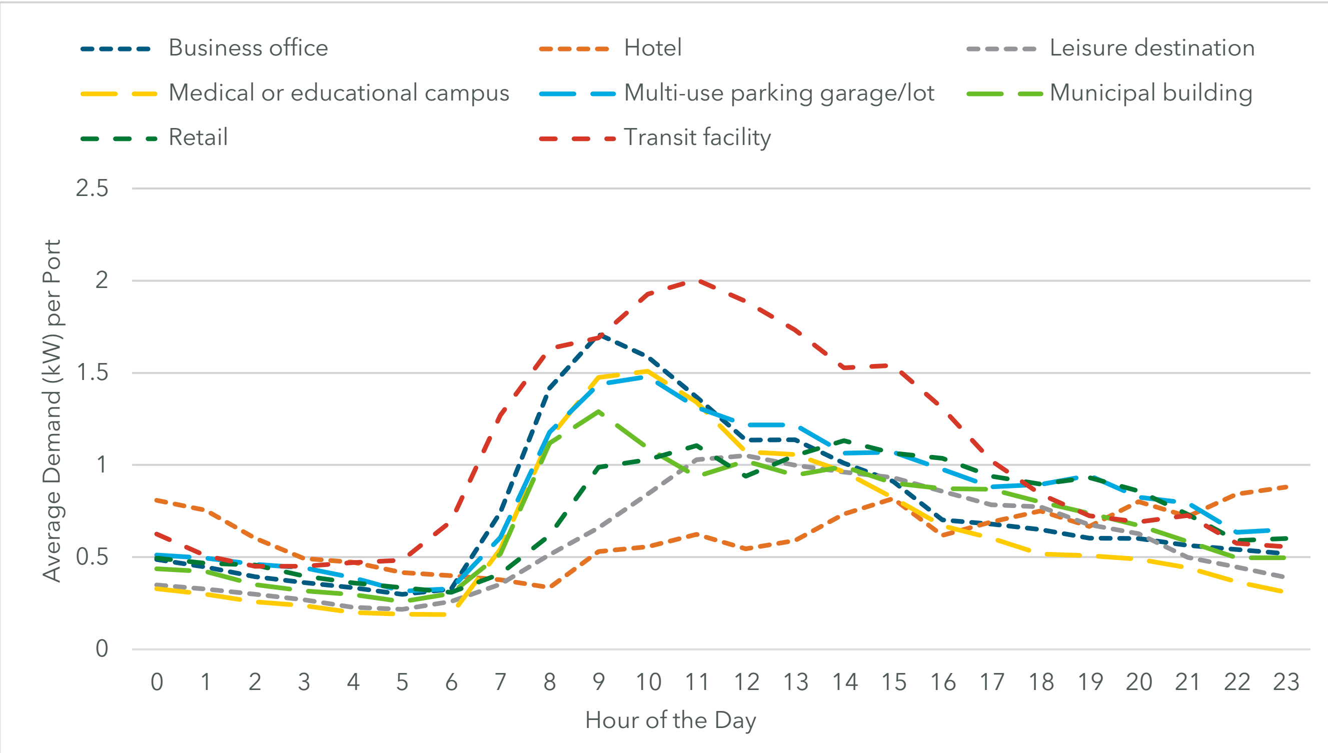


Figure 8: Daily Demand Curve for L2 Stations by Venue

Table 3: L2 Stations by Venue				
	Maximum average potential demand	**Highest single-day average peak demand and percent of potential**	**Average peak demand across highest ten days and percent of potential**	**Average peak demand across all days and percent of potential**
Transit Facility	6.9 kW	2.0 kW (29%) @ 11:00 am	1.6 kW (24%) @ 10:00 am	0.5 kW (7%) @ 10:00 am
Business Office	6.5 kW	1.7 kW (25%) @ 9:00 am	1.4 kW (21%) @ 9:00 am	0.4 kW (6%) @ 9:00 am
Hotel	7.1 kW	0.9 kW (12%) @ 11:00 pm	0.7 kW (9%) @ 10:00 pm	0.3 kW (4%) @ 9:00 pm
Leisure Destination	7.1 kW	1.1 kW (15%) @ 12:00 pm	0.8 kW (12%) @ 1:00 pm	0.4 kW (5%) @ 12:00 pm

Medical or Educational Campus	6.8 kW	1.5 kW (22%) @ 10:00 am	1.4 kW (20%) @ 9:00 am	0.6 kW (8%) @ 9:00 am
Multi-Use Parking Garage/Lot	6.9 kW	1.5 kW (21%) @ 10:00 am	1.3 kW (19%) @ 10:00 am	0.5 kW (7%) @10:00 am
Municipal Building	6.8 kW	1.3 kW (19%) @ 9:00 am	0.9 kW (14%) @ 9:00 am	0.4 kW (6%) @ 10:00 am
Retail	7.2 kW	1.1 kW (16%) @ 2:00 pm	0.9 kW (12%) @ 11:00 am	0.3 kW (4%) @ 12:00 pm

Unexpectedly, the maximum daily demand curve among various population densities or land use types occurred at stations in rural areas (**Figure 9**). This is partially attributed to the fact that the EV WATTS dataset includes fewer stations located in these areas, with the single-day maximum being slightly more of an outlier (the rural areas peak demand across the average of the top ten days, or the average across all days, is lower than the other land use types, as shown in **Table 4**). The timing of the peaks for each land use type is also quite different, as stations in less populated areas peaked later in the afternoon compared to stations in large cities. This may also be attributed to outlier days (although absent any charge management strategies, utilities and facilities still need to plan for such instances) since the average demand curves across all days are almost the same between these three land use types.

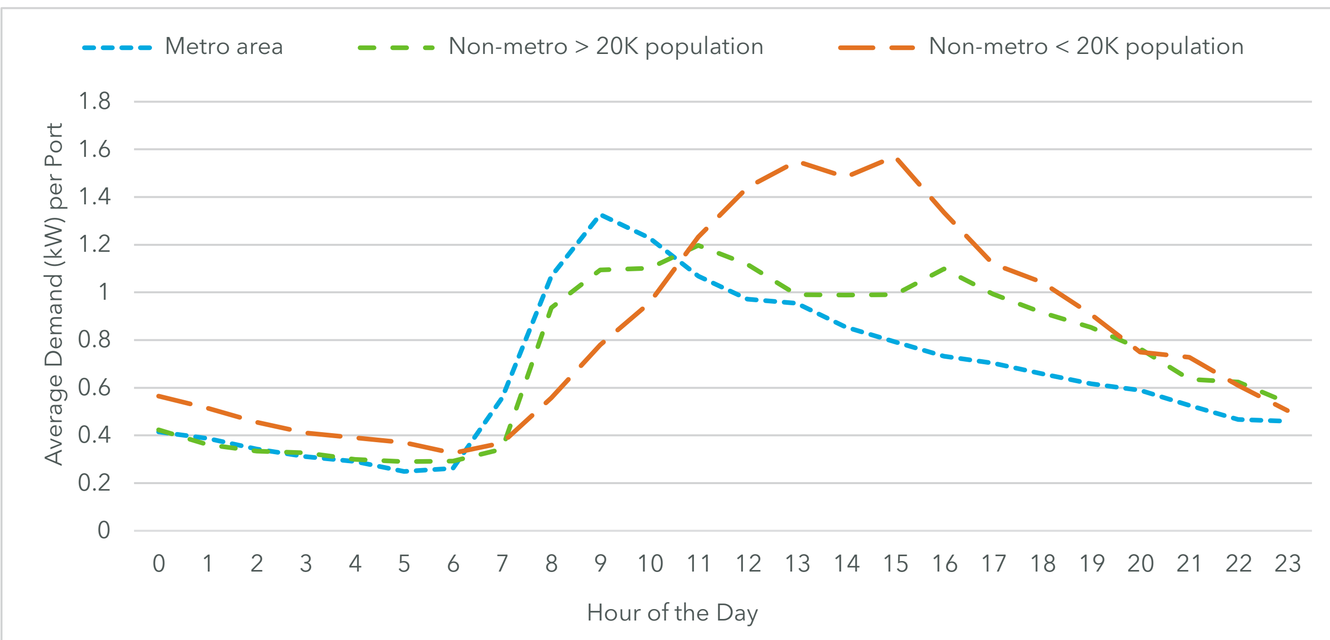


Figure 9: Daily Demand Curve for L2 Stations by Land Use

Table 4: Public L2 Stations by Land Use

	Maximum average potential demand	Highest single-day average peak demand and percent of potential	Average peak demand across highest ten days and percent of potential	Average peak demand across all days and percent of potential
Metro Area	6.9 kW	1.3 kW (19%) @ 9:00 am	1.1 kW (17%) @ 9:00 am	0.4 kW (6%) @ 10:00 am
Non-Metro > 20K	6.8 kW	1.1 kW (18%) @ 11:00 am	1.1 kW (16%) @ 11:00 am	0.5 kW (7%) @ 10:00 am
Non-Metro < 20K	6.9 kW	1.6 kW (23%) @ 3:00 pm	0.9 kW (13%) @ 1:00 pm	0.3 kW (5%) @ 11:00 am

Lastly, when comparing the maximum daily demand curves across stations that are either free to the user or have a fee for use (paid), the shapes of the two curves are essentially the same, but the demand is slightly higher for free stations. Note that peak demand is consistently lower for paid stations for the highest single-day average, average across the highest ten days, and average across all days, as shown in **Table 5**, which may indicate that pricing can help manage demand (although the paid stations don't specify which use flat pricing vs. time-of-use pricing).

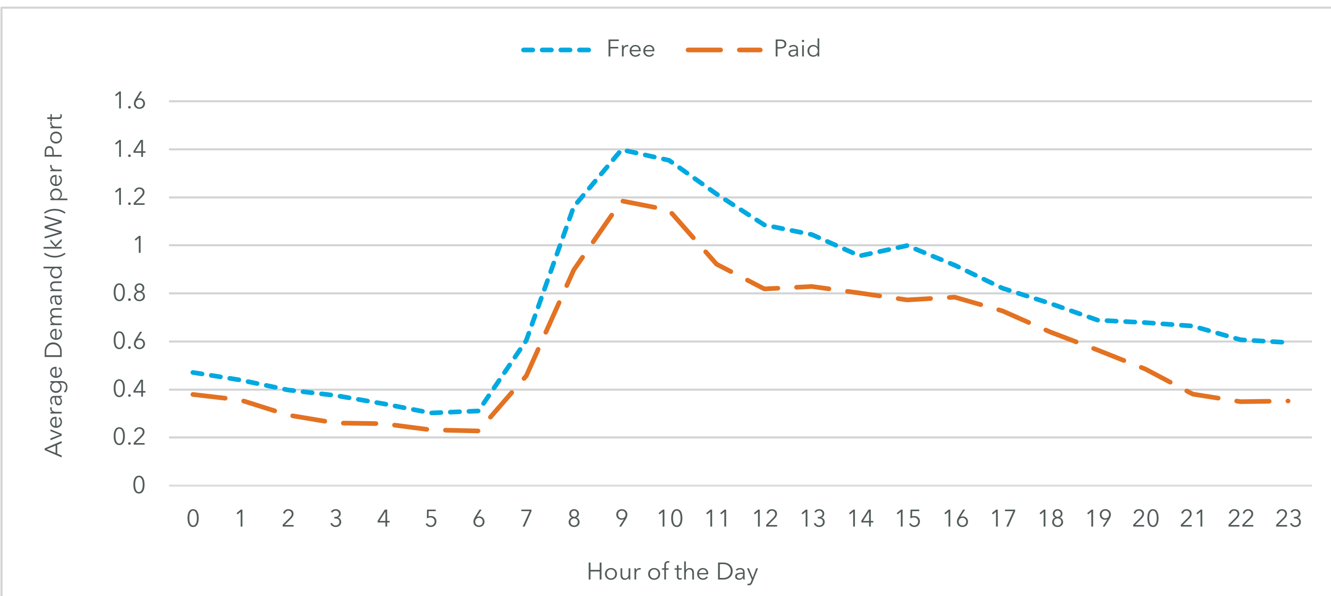


Figure 10: Daily Demand Curve for L2 Stations by Fee Type

Table 5: Public L2 Stations by Fee Type

	Maximum average potential demand	Highest single-day average peak demand and percent of potential	Average peak demand across highest ten days and percent of potential	Average peak demand across all days and percent of potential
Free	7.0 kW	1.4 kW (20%) @ 9:00 am	1.3 kW (18%) @ 10:00 am	0.5 kW (7%) @ 10:00 am
Paid	6.8 kW	1.2 kW (17%) @ 9:00 am	0.8 kW (12%) @ 10:00 am	0.3 kW (5%) @ 10:00 am

Conclusions

Large groups of public charging stations follow a daily demand curve with a sharp increase in demand from 6:00 am to 9:00 am that typically remains high through mid-day before declining throughout the afternoon and evening. The average peak demand is significantly lower than the potential peak demand if all stations were being used at their maximum power output (2%–7%). However, daily charging demand can vary greatly, especially among smaller subsets of data. Certain station characteristics tend to lead to more variability, resulting in less predictable impact on demand. A utility or facility must account for these exceptional days when anticipating how to accommodate such power use, regardless of charging level, location, or pricing structure. **Table 6** shows the station characteristics with the most variability, based on the ratio between the highest single-day average demand peak to the average demand peak across all days.

Table 6: Station Characteristics and Average Demand Peak Ratio

Station characteristic	Average demand peak ratio (highest single-day/all days)
DCFC <50 kW	24.9 (19.20 kW/0.77 kW)
L2 Region = West North Central	9.1 (2.52 kW/0.28 kW)
DCFC ≥50 kW	5.3 (13.44 kW/2.54 kW)
L2 Region = Pacific	5.2 (2.40 kW/0.47 kW)
L2 Region = South Atlantic	4.9 (2.03 kW/0.41 kW)
L2 Land Use = Non-Metro <20K	4.7 (1.57 kW/0.33 kW)
L2 Venue = Transit Facility	4.1 (2.01 kW/0.49 kW)

Contact

Billy Heidel, Data Analyst
WPHeidel@energetics.com

Bryan Roy, Program Director, Sustainable Transportation
BRoy@energetics.com

Wendy Lucht, Senior Transportation Program Analyst
WALucht@energetics.com

References

Clipper Creek. "Estimated Charge Time Chart for Electric Vehicles." Energy Wise MN. 2024. https://energywisemnstore.com/content/Time-to-Charge-Chart-Clipper-Creek.pdf.

Kelley Shin and Mal Skowron. "A Buyers' Guide to EV Charging Speeds." Green Energy Consumers Alliance. November 17, 2022. https://blog.greenenergyconsumers.org/blog/a-buyers-guide-to-ev-charging-speeds.

About Energetics

Energetics, CLEAResult Energy Sustainability Consulting, is is a technology and management consulting firm helping public and private entities integrate clean energy technologies and strategies into real-world applications. For over 40 years, we have worked with lead investors, innovators, and stakeholders to inform and expedite the development and market success of novel energy technologies, strategies, and practices that deliver a sustainable future. Our collaborative approach, expert analysis, and technology insights provide clients valuable perspectives and solid foundations for decisive action. Our knowledge of cutting-edge technology, trends, and stakeholders supports development of effective strategies and partnerships. For more information about Energetics, visit **www.clearesult.com/capabilities/energetics**.