

Town of Concord Electric Vehicle Charging Infrastructure Study

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ACRONYMS & DEFINITIONS

- **DC:** Direct current, typical of electrical current produced by solar modules prior to passing through an inverter which converts to AC, or alternating current. The electrical grid operates on AC, meaning that DC Fast Chargers require conversion.
- **DC Fast Charger (DCFC):** Electric vehicle charger using direct current and capable of charging vehicles faster than chargers using AC, generally with a rated power output of 25 kW or greater. Common in public charging or fleet use cases.
- **Demand Charges:** A monthly charge on an electricity bill based on the peak demand (kW) of a facility multiplied by a fixed \$/kW rate. The \$/kW of demand charges can vary by TOU periods. This mechanism is used by utilities to recover the fixed costs of the infrastructure required to deliver power.
- **EVI:** Electric vehicle infrastructure; referring to the charging station, required mounting, conduit, transformers and other balance of system equipment needed to supply electricity to electric vehicles
- **kW:** Kilowatt; a unit of power equal to 1,000 Watts; when used for DC Fast Charger, refers to the maximum instantaneous output of the unit.
- **kWh:** Kilowatt-hour; a unit of energy equal to 3,600 kilojoules, or equivalent to the product of 1 kW of constant power used or produced, over 1 hour.
- **Level II Charger:** Electric vehicle charger using alternating current, generally with a rated power output between ~6 kW and ~16 kW. Common in residential, workplace or fleet use cases.
- **Managed Charging:** The practice of adjusting an EV charging profile to optimize for cost and charge when electricity is cheaper or reduce coincident peak load.
- **Time-of-use (TOU):** A utility billing structure for electricity where the retail price of electricity varies depending on the time of day, time of year and/or day of the week in which the electricity is being used.
- **Unmanaged Charging:** The practice of allowing EV charging profiles to match natural driver/vehicle behavior, such that charging begins at the time of plug in and ends at the driver plug out time, or when the vehicle battery is fully charged (whichever occurs first).
- **VGI;** Vehicle Grid Integration; referring to the broad potential of electric vehicles to interact with the electric grid and customer facilities and provide benefits to the grid, vehicle owners and/or site hosts by providing services that support grid operation.

EXECUTIVE SUMMARY

This report identifies the electric vehicle infrastructure (EVI) recommended to support the Town of Concord’s transition on an all-electric fleet. The report addresses charging needs at all vehicle domicile sites in the Town, except for the Bus Depot. There are three (3) large sites that will support a majority of the vehicle electrification over the next twenty years. These sites are the Concord Public Works (CPW) Campus, the Concord Municipal Light Plant (CMLP), and Concord Fire and Police Station (Concord Station). **Figure 1** summarizes the final recommendations for EVI that minimize the cost of infrastructure build out while meeting vehicle needs. The 2030 and 2035 charging needs are incremental (not cumulative) to 2025 and 2030 needs, respectively, and cost estimates include both the estimate cost of electrical service upgrades and chargers. The charging needs identified in this analysis are based on the energy needs under the “Potential Electrification” scenario described in the Fleet Electrification report. The “Potential Electrification” scenario includes vehicles identified as good candidates for electrification, buses, and vehicles that are currently have potential replacements that are cost prohibited or not able to meet all of the operational needs of the current vehicle.

Analysis suggests that across all sites 36 Level 2 ports and 5 DC Fast Charging ports would be required by 2030 and an additional 9 Level 2 ports and 2 Level 3 ports by 2035. The 52 total ports are estimated to cost approximately \$1.7-1.9 million¹ through 2035 and can support the charging of 124 fleet vehicles located at 11 sites. Additional charging ports may be needed as EV technology progresses and more vehicles are able to be electrified.

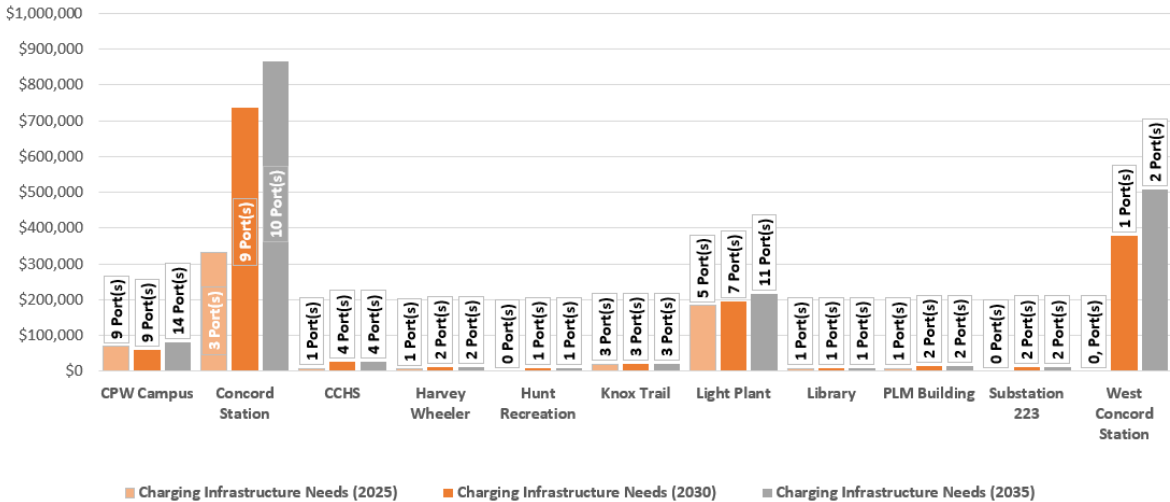
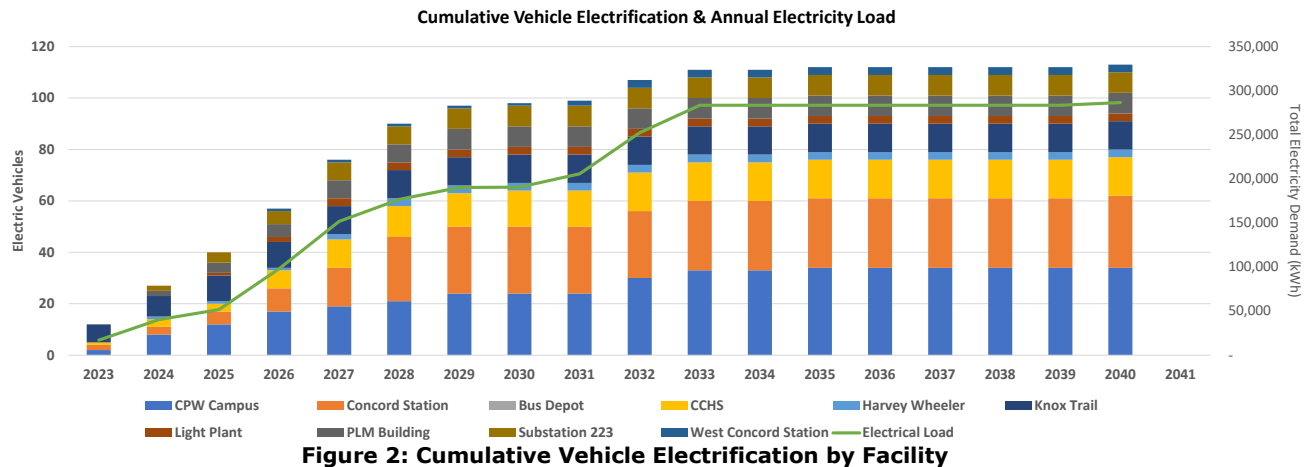


Figure 1: Estimated Charger & Installation Costs (excludes potential emergency charging needs)

¹ Inclusive of estimated costs for new electrical services where necessary, but excluding potential emergency charging needs.

BACKGROUND

The report provides an analysis of the future electric vehicle infrastructure (EVI) needs across all of the Town of Concord’s fleet domicile facilities. The report builds directly on previous analysis by the Project Team that identified vehicle electrification opportunities and a vehicle electrification timeline for the Town’s fleet. **Figure 2** summarizes the vehicle electrification timeline and growth in annual electricity load for the Town’s domicile facilities. The infrastructure needs identified for each site are based on the timeline below and focused on the near-term (2025), mid-term (2030) and long-term (2035).



APPROACH SUMMARY

Figure 3, below, outlines the general approach used in the detailed EVI analysis. Each step in this approach is further discussed in the following sections.

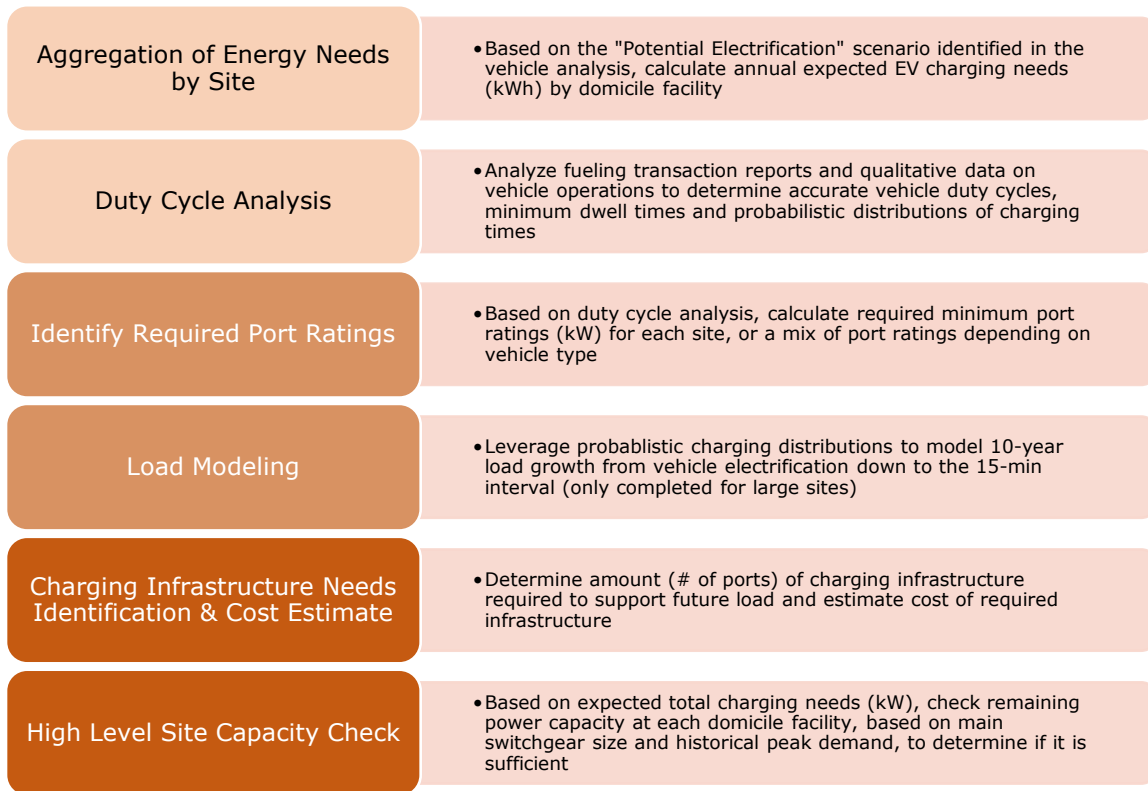


Figure 3: EVI Analysis Approach

METHODOLOGY

When determining required charging infrastructure to support fleet electrification, there are two primary constraints that must be addressed. First, charging ports must have high enough power to charge vehicles during their dwell time. Appropriate port ratings (kW) may vary by vehicle type or use case. Second, there must be enough charging ports to provide sufficient energy to every vehicle parked at each domicile facility. Solving for both constraints enable site-specific recommendations of charging infrastructure needs to be made for every domicile facility based on the energy needs and operating patterns of the vehicles at a given site, enabling a fleet to cost-effectively plan for implementation.

Since the purpose of long-term charging infrastructure planning is to enable Concord to cost-effectively phase implementation of charging infrastructure with future needs in mind, this analysis relies on the "Potential Electrification" scenario for vehicle electrification identified in during the vehicle analysis. Due to the rapidly changing medium- and heavy-duty electric vehicle options available in the market, it is likely that Concord will not purchase the exact electric models identified during the vehicle analysis. Despite the possibility of the Town not purchasing the exact models identified in this study, the battery capacity and duty cycles, and thus the required energy needs, are expected to remain similar. As such, the energy needs used in this analysis are reflective of future needs even if vehicle purchases shift. Thus, leveraging an aggressive vehicle electrification scenario ensures that charging infrastructure recommendations are sufficient to support all possible vehicle electrification and minimize the need for expensive retrofits.

Due to a lack of vehicle data, this study does not include detailed modeling of charging infrastructure that may be needed as the Town begins to electrify vehicles that do not have a suitable option currently available (vehicles in the “No Electric Option” category). Many of these heavy-duty vehicles operated by CMLP and CPW also have emergency response needs. Given the long-term outlook of this study and importance of future proofing charging needs, potential charging needs to serve these vehicles are discussed further in the **Emergency Charging Needs – Public Works & CMLP**. Concord can use the information provided to inform strategic oversizing of any new electrical service or panel to serve charging at the Public Works campus.

Data Sources

Three primary data sources were used to assess the dwell times, identify required port ratings and calculate charging probabilities for Concord’s fleet.

- **Fueling Transactions:** A record of every fueling transaction completed by existing ICE vehicles in 2019 was analyzed to inform required port ratings and provide insight into when vehicles currently fuel. Based on the best fit EV for each existing vehicle, existing fueling events were converted to charging events to assess minimum, maximum, and average charging times that could be expected if each existing vehicle were converted to electric and continued to fuel as it does today. Additionally, the time distribution and length of these synthetic charging events were used to create charging probabilities (discussed further below).
- **Staff Interviews:** Interviews with department staff were used to gather qualitative information on how vehicles operate. Interviews focused on regular vehicle operating hours, emergency operations of CPW and CMLP vehicles and shift patterns of Police patrol vehicles.
- **Proxy Data:** A Town Fleet database was compiled by the Project Team during this project. The Town-wide equipment ID system was created to enable simple tracking of vehicles across departments once the data was aggregated into a central database. Working with Town staff, the Project Team assigned prefixes to existing vehicle numbers to create a set of equipment IDs that delineated vehicles from different departments while keeping the existing numbers intact. For example, vehicle 1 in the Police Department was assigned CPD1. Due to the limited amount of data that the Town collected historically, several data fields were completed or estimated by Longobart & Ross with Optony's support. Estimates were informed by industry best practices from the American Public Works Association (APWA), data from similar fleets and the expertise of the Longobart & Ross team.

Concord did not have any telematic (GPS) data available to provide quantitative data on when and how long vehicles are parked. To supplement the data collected above, anonymized telematic data from other similar municipal fleets was used as a reference for the operations of vehicles in Concord’s various departments, most notably CPW vehicles. For example, this data was used to add insight into how long CPW vehicles would have to charge if they were EVs. The qualitative data shared by Concord staff on non-emergency operations did not differ

materially from the operations of similar fleets, adding confidence that proxy data was relevant.

Dwell Time Analysis & Port Power Ratings

General Dwell Time Analysis

Fueling transaction data and staff interviews were leveraged in different ways to analyze vehicle duty cycles and identify dwell times. Since Concord did not have telematic (GPS) data available to provide a quantitative record of when vehicles were parked, qualitative data from interviews was used to determine average dwell time for most vehicles in the Town's fleet. For most vehicles in the Town's fleet that operate on standard business hours, dwell times are expected to be a minimum 12 hours (e.g., 6pm – 6am). Dwell times were compared with vehicle energy needs to identify a common port power rating needed to provide the required daily energy during an average dwell time.

Power Port Ratings

Dwell time was combined with expected per vehicle energy needs to identify required port ratings for each facility. In some cases, multiple port ratings were identified for a single facility due to differences in the operations of subsets of vehicles located at a particular facility.

Public Works Campus Dwell Time Analysis

For the Public Works Campus, a facility with many medium- and heavy-duty vehicles, the general recommendations were refined based on vehicle type. Fueling transactions converted to charging events were analyzed to filter out vehicles that may require charge times longer than the average dwell time in certain instances when the battery is fully depleted. Vehicles that are filtered out are usually those with large battery capacities. This resulted in two subsets of vehicles that required ports with higher power than the default 6.6 kW recommendation.

Police Department's Dwell Time Analysis

Due to their unique duty cycles and operational demands, vehicles in the Police Department were analyzed separately. These vehicles were split into three categories reflecting different duty cycles: admin, special unit and patrol. Admin units are assumed to follow similar duty cycles as a standard vehicle in the Town's fleet, with daily driving and long overnight dwell time. Special units were assumed to require charge times as short as possible. An analysis of the daily energy needs for special units indicated that 150 kW ports would be sufficient to provide every vehicle's average daily energy requirement in about five minutes. Since special units do not follow predictable shift schedules and may not be charged as consistently as patrol vehicles, the analysis of existing vehicle fueling records was also reviewed, indicating that, if vehicles were to fuel following the same pattern as current ICE vehicles, the average charging time at 150 kW is 25-30 minutes, with the maximum being 45 minutes.

Finally, the dwell times of patrol vehicles were determined by an analysis of the Police Department's shift schedule. **Figure 4**, below, provides an example of the shift visualization completed and illustrates that vehicles are likely to have seven hours to charge in between shifts.

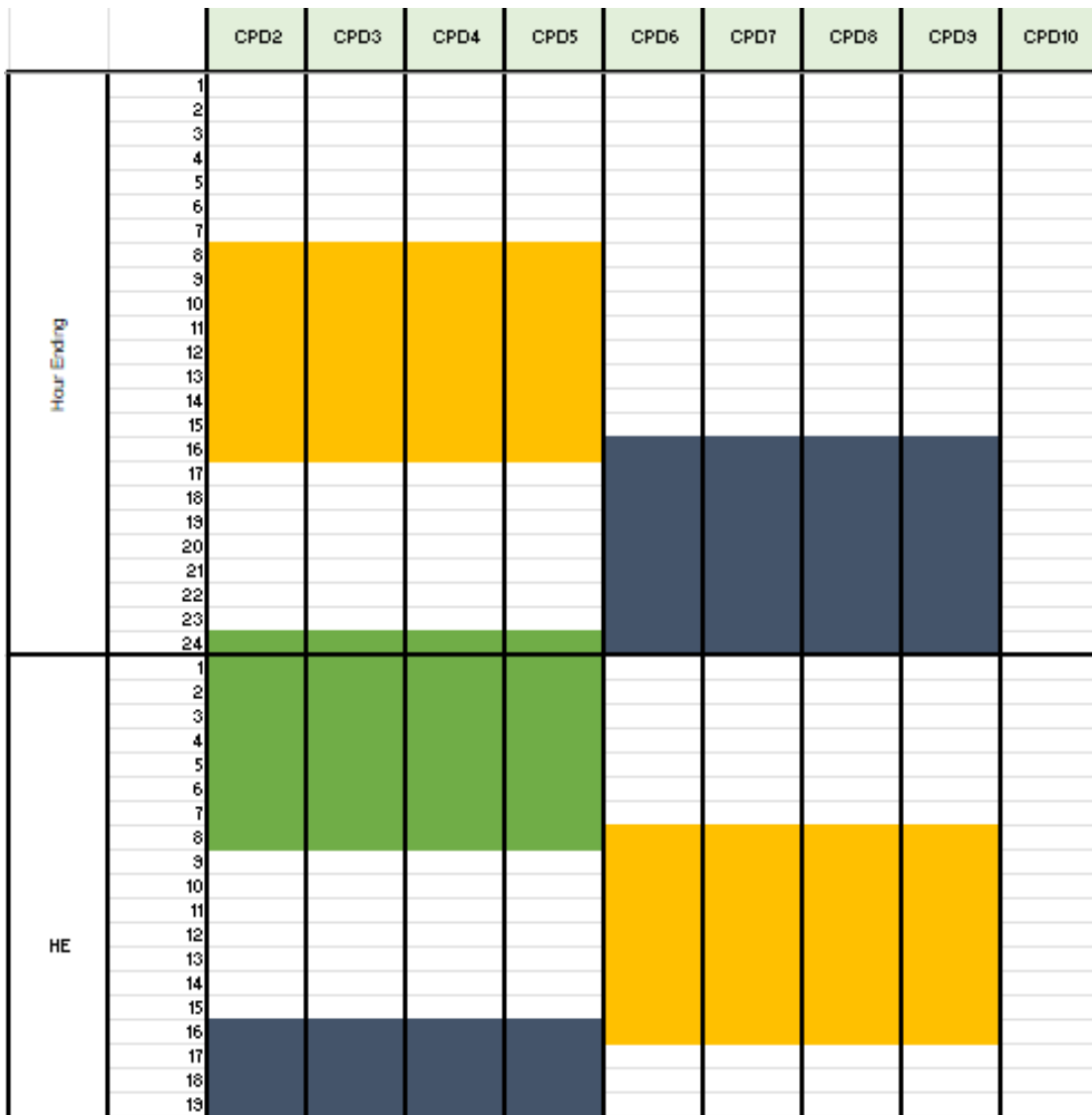


Figure 4: Sample of Police Patrol Duty Cycle Analysis

A summary of the vehicle dwell times identified by facility is provided in **Table 1**.

Table 1: Vehicle Dwell Time by Site

| Site | Dwell Time |
|-----------------|--|
| CPW Campus | 11-13 hours overnight, periodic emergency responses |
| Concord Station | Special Unit: Immediate turnaround Patrol: 2 hours or Admin: 11-13 hours |
| CMLP | 11-13 hours overnight, periodic emergency responses |
| Harvey Wheeler | 11-13 hours overnight |
| Hunt Recreation | |
| Knox Trail | |
| Main Library | |
| PLM Building | |
| Substation 223 | |
| West Concord | |

Managed Charging Potential

For many fleets, employing managed charging strategies that use charging station or 3rd-party software to limit the hours in the day when vehicles can charge are effective for reducing the cost of charging. In the case of Concord, however, none of the Town's domicile locations are on an electrical rate that has time-of-use (TOU) electrical rates. The cost of electricity does not vary by time of day.² As such, assuming vehicles are charged on the same utility rate as the domicile facility, there is no potential to reduce charging costs by shifting charging to specific times (e.g. overnight). However, CMLP will be offering a new commercial EV charging rate which features TOU charges. Under the new rate, the difference between on-peak and off-peak energy rates is approximately 0.21 \$/kWh. This significant delta creates an opportunity to reduce the cost of charging if there is flexibility to when vehicles are charged. It is likely that, at most sites, the dwell times of Concord's fleet provide the potential to employ managed charging strategies to maximize charging during off-peak hours and minimize charging when vehicles return in the early evening during peak hours.

Telematic data providing detailed information on when vehicles are in use versus when they are parked for fleets similar to Concord reveals that vehicles often have significantly longer to charge than is needed to provide the required energy. As an example, **Figure 5**, below, charts the percent of vehicles domiciled at an example Corporation Yard, using anonymized data from a municipal fleet like Concord's, over the course of an average week. During weekdays most vehicles are parked for 12 or 13 hours overnight, and longer on the weekends.³ Thus, there is potential to employ managed charging strategies should CMLP deem it beneficial for the local grid or a decision is made to separately meter new charging stations and take advantage of the commercial EV charging rate CMLP is planning to launch during 2022.

² Electrical rates do include demand charges. However, it was concluded that charging peak load was unlikely to coincide with building peak load and incur a higher demand charge if building peak load and charging peak load were coincident. This is discussed in more detail under the TCO Methodology section in the Fleet Report.

³ Since this graph is depicting an average, it may obscure instances where all vehicles are not parked. However, the purpose of this graphic is to observe the periods of time where the average equals the maximum possible percentage of vehicles parked, which is an indication of dwell time.

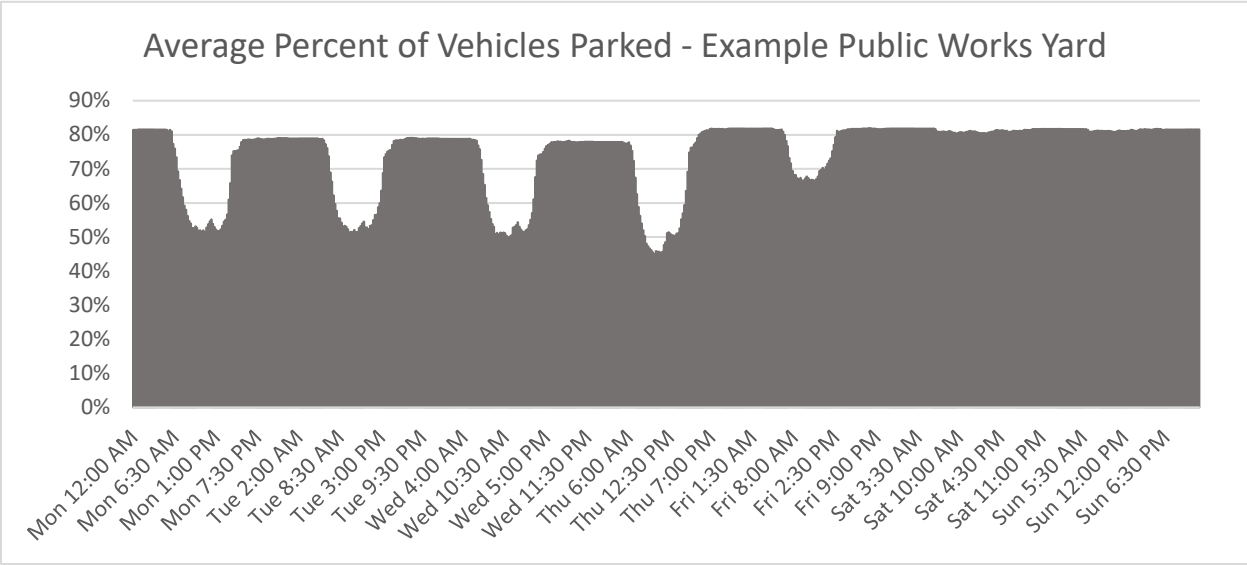


Figure 5: Percent of Vehicles Parked⁴

Load Modeling & Overall Infrastructure Needs

After determining port ratings, the number of ports required must be calculated. On facilities with a small number of vehicles this was determined by adding charging ports and manually calculating the minimum number of ports that could provide the required daily energy in the expected dwell time and which ports could be shared amongst multiple vehicles. For larger sites, a sophisticated probabilistic load modeling technique was used, as described below.

Charging Probabilities

To enable accurate modeling of load growth over time and identification of total charging infrastructure needs in 2025, 2030 and 2035, a site-specific, annual, probabilistic method was used. Depending on the characteristics of the vehicles domiciled at each site, the distribution of fueling transactions and the expected times when vehicles are parked were converted to a probability distribution that indicated the chance that a vehicle was charging in each 15-min interval of a given week. For emergency vehicles, such as those in the Police Department, there is limited flexibility available in vehicle fueling patterns. Given operational requirements, vehicles, even after conversion to electric, must charge in the same way that they are fueling today. Emergency vehicles may not have 12 hours overnight to charge. As such, the distribution of current fueling transactions is the most appropriate data source to determine when those vehicles will be charging once they are converted to electric. In contrast, vehicles with standard operating hours, such as those parked at the Harvey Wheeler Building, have significant flexibility to change existing fueling patterns once they are electrified. For these vehicles, qualitative data of when vehicles are parked is the most appropriate data source to determine when those vehicles will be charging once they are converted to electric. **Table 2**

⁴ The percentage of vehicles parked never equals 100% due to gaps in the sample telematic data wherein data is not available for all vehicles with telematics over the entire analysis period. Data gaps appear as a vehicle not being parked. This is not a function of vehicles being used overnight.

summarizes the data source used for load modeling and infrastructure needs determination at each site where probabilistic modeling was used.

| Site | Available Data |
|-----------------|-------------------------------------|
| CPW Campus | Qualitative data on operating hours |
| CMLP | Qualitative data on operating hours |
| Concord Station | Fueling transactions |

The weekly charging probability profile represents an average expectation for which time intervals are most and least likely to be used for charging by a vehicle during a work week. Since probability distributions differ depending on the number of EVs at a site, and that number is expected to increase each year, different distributions were created for each year at each site.

Figure 6 shows the probability distribution of an average week used for modeling charging needs at the CPW Campus in 2030. Based on parking data, vehicles have a higher chance of charging starting at the end of the workday into the evening and a lower chance during the day, with a small peak around lunchtime.

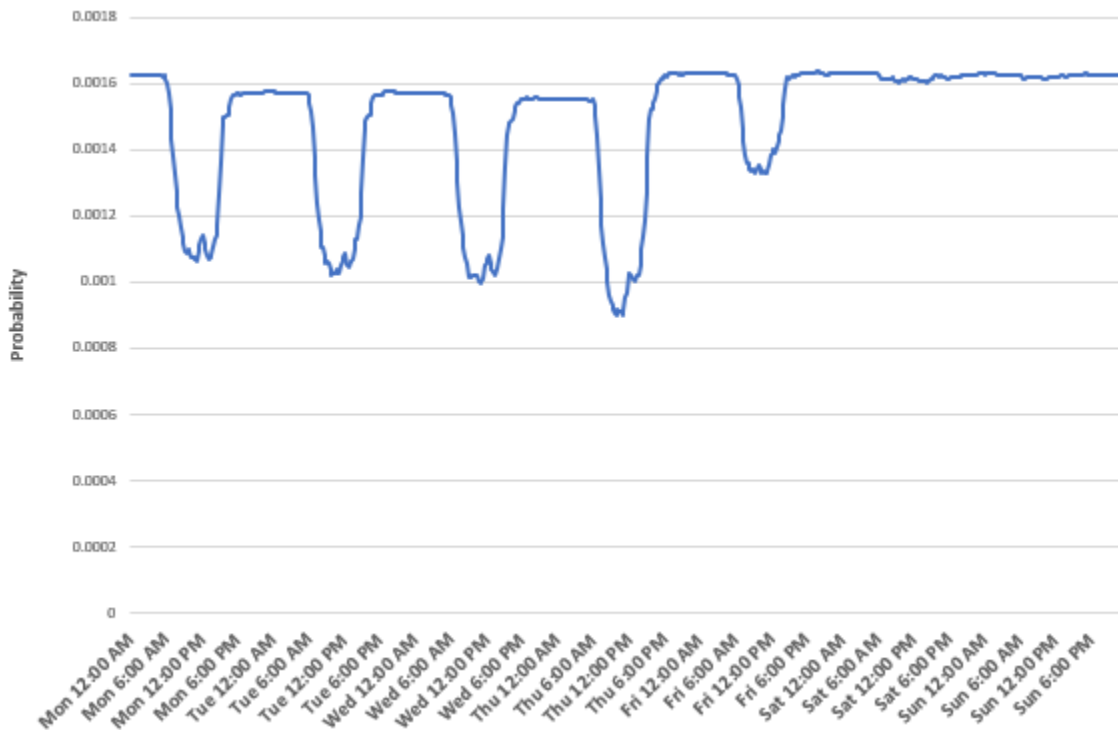


Figure 6: Example of Weekly Charging Probabilities

Multiple probability profiles were created at sites with distinct vehicle types that operated in different ways. **Figure 7** shows the probability distribution of an average week for the Police Department vehicles located at Concord Station. Probabilities are demarked by vehicle type due to the different duty cycles of patrol vehicles and admin vehicles.

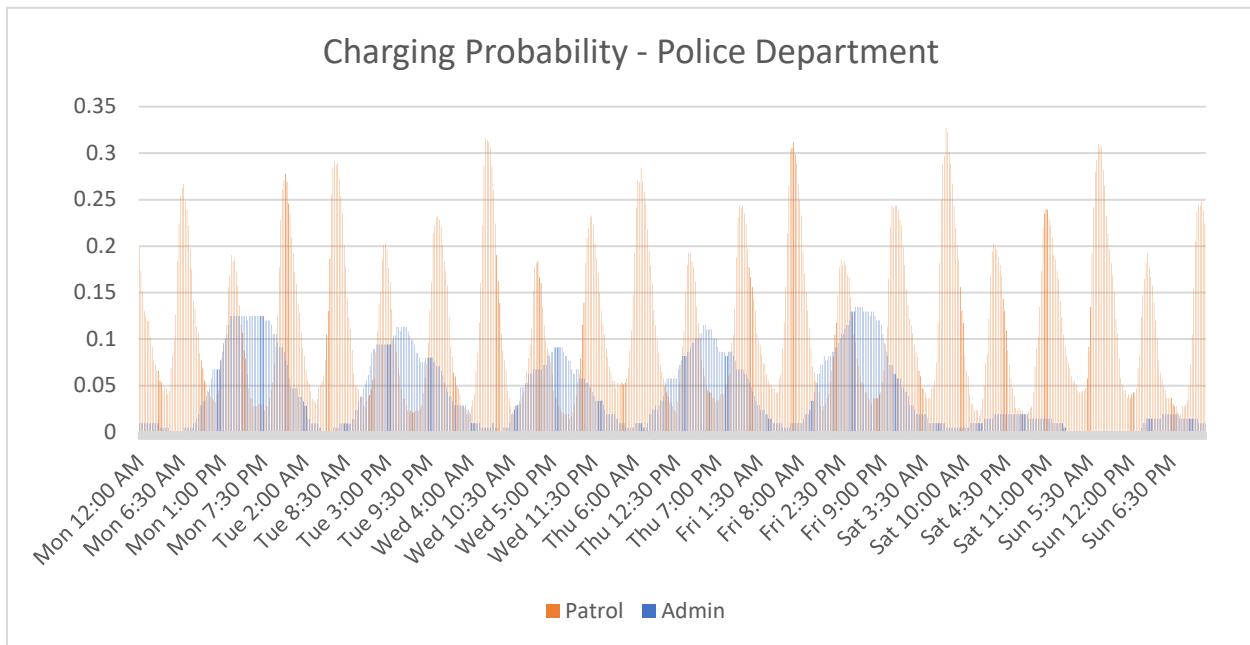


Figure 7: Weekly Charging Probabilities (Concord Station, 2030)

Once probability profiles were established, projected EV load profiles were constructed by site and by year based on the total number of vehicles, required port ratings and annual energy requirements of those vehicles.⁵

Load Profile Builder

In order to simulate the electric load profiles from charging of a future electric vehicle fleet, the Project Team utilized an internal modeling tool to build time dependent load profiles. The load profile builder leverages the weekly probability profiles discussed above to take an index of 672 numbers (the number of 15-minute intervals in a week), where each number represents the likelihood that a random charging interval will occur on that day and time. Once the charging probability indices are determined, the user provides additional inputs to the load profile builder. The load profile builder was given these fixed inputs for each department site in each year studied:

- Number of EVs at each facility⁶
- The total annual amount of electrical energy needed to fuel all EVs domiciled at each facility from 2023 to 2040
- Maximum number of ports available
- The power rating of each port, as determined for each site, with different port ratings for different sub-classes of fleet vehicles, as appropriate⁷
- The site’s time-of-use structure, if applicable⁸

⁵ Daily energy requirements were calculated in Phase 1 of the project.

⁶ This determines the maximum number of vehicles charging at any given time, since the number of ports active is assumed to be less than or equal to the number of vehicles

⁷ Example: Police patrol vehicles have a different dwell times and behavior from Police administrative vehicles and required higher powered ports

⁸ Town of Concord electrical accounts are not on time-of-use structures.

- Whether the port power rating is fixed, or how it varies by time-of-use periods (peak, off-peak, etc.)
- Whether the load profile should be built to allow unrestricted charging according to driver behavior and ignore TOU pricing impacts; or manage charging to avoid highest TOU cost impacts
- The time at which overnight and weekend charging treatment should be assumed for vehicles which are exclusively used during normal business hours, and parked during nights and weekends

These choices are given to the load profile builder as inputs in a control panel of a spreadsheet-based simulator. Over the course of a non-leap year, there are 35,040 charging intervals.⁹ For each charging port (as based on inputs given above) the load profile builder creates a vector of 35,040 intervals and repeatedly generates a signal of whether that port should be active or inactive based on the probabilities given at the outset. The load profile builder then takes the sum of all charging in all intervals across all ports. The user is given this annual total along with an error signal which compares the total delivered energy to the required annual energy as determined in the fixed inputs. If the total amount of energy delivered is below the amount needed, an adjustment factor is increased to boost the utilization of each port in proportion to its probability profile. This boost forces more charging events into the most preferred charging intervals as determined by vehicle behavior from the data sources described above. However, if the total energy allotted by the load profile builder exceeds the amount of energy needed the user can decrease the number of ports or manage charging by restricting charging only to certain intervals (e.g. overnight and weekends).

Total Port Needs

From the simulations of annual charging completed for each site, the total port needs for each power rating can be identified by analyzing the maximum number of coincident ports in use. To account for variations in vehicle charging needs, a safety factor of 20% is applied to the maximum coincident port number to determine the final recommended port counts. These port counts can be found later in the report in Tables 4 – 6.

Infrastructure Cost Assumptions

Given the rapid expansion and evolving nature of the electric vehicle industry, charging infrastructure costs are widely variable and come with a significant amount of uncertainty. Recent research has indicated that the industry is following a pattern similar to the solar industry, where the cost of materials falls according to a standard “experience curve” but soft costs (site assessment, utility interconnection and permitting) remain high, unpredictable and site-specific.¹⁰

The cost assumptions for charging hardware and installation costs in this study are primarily drawn from a 2019 study by the International Council on Clean Transportation and

⁹ 365 days per year x 24 hours per day x 4 intervals per hour (with each interval at 15 minutes)

¹⁰ Chris Nelder and Emily Rogers, Reducing EV Charging Infrastructure Costs, Rocky Mountain Institute, 2019, <https://rmi.org/ev-charging-costs>

supplemented by primary research and outreach to charging station providers.¹¹ This study aggregated data from past studies, as well as costs reported to public utility commissions via utility programs. Data on charger component costs aggregated through industry interviews by the Rocky Mountain Institute confirmed that the costs in the ICCT study were in an accurate range. Representative of the limited data available, both the ICCT and RMI studies built significantly on data from a 2013 Electric Power Research Institute study.¹² Given the age of the EPRI data, costs figures may have fallen in the intervening years. However, the cost range remains sufficiently broad to warrant a conservative approach.¹³ **Table 3** includes a summary of the cost figures used to calculate total cost.

Table 3: Summary of EVI Cost Assumptions

| Charger Hardware Costs (per port) | | Installation Costs | | | | |
|-----------------------------------|-------------------|---------------------------|----------------------------|------------------------------|-----------------------------|-----------------------------|
| Charger Type | Cost (\$) | Number of Ports Installed | Level 2 Cost per Port (\$) | DCFC Cost per Port (62.5 kW) | DCFC Cost per Port (150 kW) | DCFC Cost per Port (350 kW) |
| Level 2 (6.6 – 11.5 kW) | \$1,550 - \$2,793 | 1 | \$2,836 | \$45,406 | \$47,781 | \$65,984 |
| DC Fast (50 kW) | \$28,401 | 2 | \$3,020 | \$36,235 | \$38,047 | \$52,541 |
| DC Fast (150 kW) | \$75,000 | 3-5 | \$3,090 | \$26,964 | \$28,312 | \$39,097 |
| DC Fast (350 kW) | \$140,000 | >6 | \$2,305 | \$17,692 | \$18,577 | \$25,654 |

The hardware costs used are per port and assume networked capability. The Charger Hardware Cost figures above include only the charging unit, wiring, conduit and service panel costs. Trenching costs for installation are *not* considered in the cost estimates calculated for this study because site layouts have not been determined. Installation Costs include labor, permits, taxes and the cost of make-ready electric infrastructure on the customer side of the meter. Make-ready electric infrastructure on the customer side of the meter generally includes wiring, conduits, trenching, service panels and switchgear upgrades (if needed) and can vary significantly from site to site.¹⁴

Cost assumptions are used to provide a starting point in estimating infrastructure costs. Town staff can adjust cost assumptions for key sites in the Fleet Electrification Pro-Formas accompanying this report.

Electric Vehicle Infrastructure Incentives & Financing

While the infrastructure costs presented in this report do not include incentives, both the State of Massachusetts and CMLP offer incentives that could be used to reduce infrastructure

¹¹ Michael Nicholas, Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas, International Council on Clean Transportation, August 2019, https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf

¹² Electric Power Research Institute, Electric Vehicle Supply Equipment Installed Cost Analysis, 2013, <https://www.epri.com/research/products/000000003002000577>

¹³ Initial data reported to the California Energy Commission via the CALeVIP project shows even higher installation costs than assumed in this report. However, these costs result from a small sample size that CEC indicates may have been skewed by a few high cost sites. As a result, these costs have not been included in this study. The data is available here: <https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/california-electric-vehicle/calevip-level>.

¹⁴ Reducing EV Charging Infrastructure Costs, Rocky Mountain Institute, 2019

costs. Under the MassEVIP Workplace & Fleet Charging Program, MassDEP provides incentives for up to 60% of EV charging equipment and installation for Level I or Level II charging stations.¹⁵ Projects are limited to \$50,000 per address and applications are assessed on a first-come, first-served basis. To compliment this funding, CMLP has designed a Commercial EV Charging Station Rebate program. Participants can receive up to \$3,000 dollars for both eligible hardware and installation costs (\$6,000 total) for dual-port, or two single port, Level II charging stations. Importantly, all chargers funded under this program must be installed on a dedicated meter and billed under CMLP's new EV rate tariff or forthcoming rate structure.

For many of the Town's sites, the combination of CMLP and state incentives is likely to be effective in reducing costs. However, neither of these programs are designed to fund DC fast chargers, making their applicability limited on the Town's larger sites.

In addition to incentives, increasingly available 3rd-party financing options for fleets may be useful for Concord to address capital costs required for charging infrastructure. Some charging infrastructure developers and vendors offer "charging as a service" options that enable a fleet to defer capital costs of infrastructure in favor of shifting those costs to the operating budget and paying them off on a per kWh basis over time. Charging as a service can be examined further as the Town explores procurement options.

INFRASTRUCTURE NEEDS & CAPITAL COST ESTIMATES

Unlike vehicle electrification, which has the potential for total cost of ownership savings, the infrastructure required to charge electric vehicles is a cost that the Town of Concord is required to bear in support of their fleet electrification goals. A primary challenge when identifying charging infrastructure needs is identifying the minimum number of charging ports at each location required to satisfy the fleet's daily energy needs while balancing operational considerations such as dwell time. One way to minimize the total cost of EVI is to minimize installation costs through futureproofing. Instead of installing a handful of charging stations to meet immediate need and then having to remove those, expand power capacity and re-install more chargers as fleet electrification continues, total costs can be minimized by installing make-ready electrical infrastructure to support future charging needs at the time of initial installation. Long-term planning of charging infrastructure allows fleets to futureproof effectively.

Operational Considerations of Vehicle to Port Ratios

For every domicile facility considered, the recommendations indicate a vehicle to port ratio greater than 1:1. Implementing vehicle to charger ratios higher than 1:1 minimizes EVI hardware and installation costs but has operational considerations, as not every vehicle can be plugged in at the same time. This challenge can be managed in a variety of ways ranging from staff training to software solutions. A first solution is to recognize that during standard operations vehicles do not need to be charged every night. It is important to recognize that, especially as electric vehicle range increases, the common perception that EVs need to charge every night is a misconception. Across the sites analyzed in this report, the modeled average daily energy needs per vehicle ranges from under 1 – 86 kWh per day, with a maximum of

¹⁵ <https://www.mass.gov/doc/matrix-of-massevip-grant-programs/download>

114 kWh per day from a potential electric fire engine at the West Concord Station. In contrast, the vehicle types modeled have between 60 – 400 kWh battery capacities. This is a clear indication that the majority of vehicles in the Town’s fleet will not be required to charge every night.

A second option that may be appropriate for large sites such as the CPW Campus that require more complex management is to have additional staff on hand that rotate the vehicles overnight.

Finally, in some cases, it may be advantageous for the Town to add additional charging ports, without taking the capital-intensive step of expanding the recommended power capacity, to enable more vehicles to be plugged in at once and leverage software to balance charging across ports. The recommendations provided below are for “fully powered” ports, meaning charging ports that have sufficient circuit capacity to provide a power output at their nameplate capacity. However, additional ports could be added to enable more vehicles to connect to a given circuit.

Projected Infrastructure Needs by Site

This section summarizes infrastructure needs for 2025, 2030 and 2035 across all domicile facilities. The majority of Concord’s charging day-to-day charging can be completed on Level II charging stations of varying kW output. A mix of 6.6 kW and 11.5 kW is recommended at most sites depending on the exact duty cycles and battery sizes of the vehicles domiciled at the given site. Vehicles with larger battery sizes, such as medium-duty electric vans, may require 11.5 kW chargers to ensure that vehicles can achieve a complete charge overnight.

On the following pages, **Table 4** includes 2025 infrastructure needs, **Table 5** includes 2030 infrastructure needs and **Table 6** includes 2035 infrastructure needs.

Table 4: Summary of Infrastructure Needs by Site (2025)

| Site | # of Electric Vehicles by Scenario (% of Total) | | | # of Ports (Fully Powered) & Type | Vehicle to Port Ratio ("Potential Electrification") | Notes |
|-------------------------|---|-----------------------------|----------------|-----------------------------------|---|---|
| | "Best Fit" | "Potentially Electrifiable" | "All Vehicles" | | | |
| CPW Campus | 4 (8%) | 12 (24%) | 14 (27%) | 4 x 11.5 kW 4 x 6.6 kW | 1.5 | 2 existing L2 ports |
| Concord Station (Total) | 2 (6%) | 5 (15%) | 5 (15%) | 2 x 11.5 kW 1 x 6.6 kW | 1.66 | |
| Police | 2 (3%) | 3 (11%) | 3 (13%) | 1 x 11.5 kW | 3 | 150 kW for Special Unit, 11.5 kW for Patrol, 6.6 kW for Admin |
| Fire | 0 (40%) | 2 (38%) | 2 (51%) | 1 x 11.5 kW 1 x 6.6 kW | 1 | |
| CCHS | 3 (20%) | 3 (20%) | 3 (20%) | 1 x 6.6 kW | 3 | |
| Harvey Wheeler | 0 (0%) | 1 (33%) | 1 (33%) | 1 x 11.5 kW | 1 | |
| Hunt Recreation | 0 (0%) | | | N/A | N/A | |
| Knox Trail | 6 (50%) | 10 (83%) | 11 (92%) | 1 x 11.5 kW 2 x 6.6 kW | 3.33 | |
| Light Plant | 4 (15%) | 13 (52%) | 16 (64%) | 1 x 150 kW 4 x 6.6 kW | 2.6 | 150 kW for Heavy Duty vehicle(s) |
| Library | 1 (100%) | | | 1 x 6.6 kW | 1 | Level I charger would viable |
| PLM | 4 (50%) | 4 (50%) | 4 (50%) | 1 x 6.6 kW | 4 | |
| Substation 223 | 0 (0%) | | | N/A | N/A | |
| West Concord Station | 0 (0%) | | | | N/A | |

Table 5: Summary of Infrastructure Needs by Site (2030)

| Site | # of Electric Vehicles by Scenario (% of Total) | | | # of Ports (Fully Powered) & Type | Vehicle to Port Ratio ("Potential Electrification") | Notes |
|-------------------------|---|-----------------------------|----------------|---|---|---|
| | "Best Fit" | "Potentially Electrifiable" | "All Vehicles" | | | |
| CPW Campus | 5 (10%) | 24 (47%) | 32 (63%) | 4 x 11.5 kW 5 x 6.6 kW | 2.66 | 2 existing L2 ports |
| Concord Station (Total) | 19 (58%) | 26 (79%) | 26 (79%) | 3 x 150 kW 5 x 11.5 kW 1 x 6.6 kW | 2.88 | 150 kW will be used for fire engines, Police Special Unit vehicles & redundancy 11.5 kW for Patrol |
| <i>Police</i> | 18 (95%) | 19 (100%) | 19 (100%) | 2 x 150 kW 4 x 11.5 kW | 3.16 | |
| <i>Fire</i> | 1 (11%) | 7 (78%) | 7 (78%) | 1 x 150 kW 1 x 11.5 kW 1 x 6.6 kW | 2.33 | |
| CCHS | 10 (67%) | 14 (93%) | 14 (93%) | 1 x 11.5 kW 3 x 6.6 kW | 3.5 | |
| Harvey Wheeler | 0 (0%) | 3 (100%) | 3 (100%) | 2 x 11.5 kW | 1.5 | |
| Hunt Recreation | 1 (100%) | 1 (100%) | 1 (100%) | 1 x 6.6 kW | 1 | |
| Knox Trail | 7 (58%) | 11 (92%) | 12 (100%) | 1 x 11.5 kW 2 x 6.6 kW | 3.66 | |
| CMLP | 4 (15%) | 16 (64%) | 21 (84%) | 1 x 150 kW 2 x 11.5 kW 4 x 6.6 kW | 2.28 | 150 kW for Bucket Trucks |
| Library | | 1 (100%) | | 1 x 6.6 kW | 1 | Level 1 viable |
| PLM | | 8 (100%) | | 2 x 6.6 kW | 4 | |
| Substation 223 | 3 (60%) | 5 (100%) | 5 (100%) | 1 x 11.5 kW 1 x 6.6 kW | 2.5 | |
| West Station Concord | 0 (0%) | 0 (0%) | 1 (33%) | N/A | N/A | |

Table 6: Summary of Infrastructure Needs by Site (2035)

| Site | # of Electric Vehicles by Scenario (% of Total) | | | # of Ports (Fully Powered) & Type | Vehicle to Port Ratio ("Potential Electrification") | Notes |
|-------------------------|---|-----------------------------|----------------|---|---|--|
| | "Best Fit" | "Potentially Electrifiable" | "All Vehicles" | | | |
| CPW Campus | 9 (18%) | 34 (67%) | 48 (94%) | 6 x 11.5 kW 8 x 6.6 kW | 2.42 | 2 existing L2 ports |
| Concord Station (Total) | 19 (58%) | 27 (82%) | 27 (82%) | 4 x 150 kW 5 x 11.5 kW 1 x 6.6 kW | 2.7 | 150 kW for, Engines, SU & redundancy 11.5 kW for Patrol |
| <i>Police</i> | 18 (95%) | 19 (100%) | 19 (100%) | 2 x 150 kW 4 x 11.5 kW | 3.16 | |
| <i>Fire</i> | 1 (11%) | 8 (89%) | 8 (89%) | 2 x 150 kW 1 x 11.5 kW 1 x 6.6 kW | 2 | |
| CCHS | 11 (73%) | 15 (100%) | 15 (100%) | 1 x 11.5 kW 3 x 6.6 kW | 3.75 | |
| Harvey Wheeler | 0 (0%) | 3 (100%) | 3 (100%) | 2 x 11.5 kW | 1.5 | |
| Hunt Recreation | Same as 2030 | | | | | |
| Knox Trail | Same as 2030 | | | | | |
| Light Plant | 4 (15%) | 17 (65%) | 24 (96%) | 1 x 150 kW 4 x 11.5 kW 6 x 6.6 kW | 1.54 | 150 kW for Bucket Trucks |
| Library | Same as 2030 | | | | | |
| PLM | Same as 2030 | | | | | |
| Substation 223 | Same as 2030 | | | | | |
| West Concord Station | 0 (0%) | 2 (67%) | 3 (100%) | 2 x 150 kW | 1 | |

Sites requiring further explanation are discussed below.

CPW Campus

The recommended charger mix at the CPW Campus in 2035 consists of eight 6.6 kW ports and six 11.5 kW ports. These chargers will be sufficient to serve all vehicles for which an electric option was modeled. However, many of the heavy-duty vehicles in the Public Work's department did not have suitable electric options and were not analyzed. Under the expectation that a portion of these vehicles will be electrified as the market advances, the Town should expect that some level of fast charging will be required at the site to serve heavy-duty vehicles and provide redundancy to the fleet at large. Based on the ratio of fast chargers to heavy-duty vehicles being considered by similar fleets, Concord should expect approximately six 25 kW chargers or 2 150 kW chargers, in addition to the Level II charging recommended in Tables 4-6, will be needed to serve larger vehicles.

The needs discussed here and in the previous tables **do not** include emergency operations, which are discussed below.

Concord Station

Three different port types were recommended for the Concord Station, in addition to the stations already installed. Based on the schedule analysis of the Town's patrol vehicles, 11.5-kW charges were deemed the most cost-effective port type to use for daily operations. By 2035, four of these ports are recommended for the Police Department to enable concurrent charging of the maximum number of patrol vehicles that would need to charge during the same break between shifts. Additionally, four 150-kW DC fast chargers were recommended to serve a mix of vehicles. Two for the Police Department to serve detective or admin vehicles that need a quick turnaround and to provide redundancy for patrol vehicles. The other two fast chargers will be required to serve fire engines should the Town decide to electrify those vehicles in the future. Finally, a 6.6 kW port is recommended to serve the administrative vehicles in the Fire Department.

Light Plant

A mix of three different port types is also recommended for the Light Plant given the diversity of vehicle types domiciled at the facility. The majority of the daily charging needs can be served by a mix of 6.6 kW and 11.5 kW ports, with a 150-kW charger being recommended to serve bucket trucks should those be electrified in the future. A 150-kW charger can charge electric bucket trucks in approximately 2 - 2.5 hours. Given the low daily mileage of the bucket trucks, our analysis indicated that the bucket trucks would likely only have to charge every 4-6 days during normal operations, meaning that sharing a fast charger is operationally feasible and reduces the total infrastructure build required. The needs discussed here and in the previous tables **do not** include emergency operations, which are discussed below.

Emergency Charging Needs – Public Works & CMLP

As the Town of Concord continues to explore electrification of its heavy-duty vehicles, additional charging infrastructure is expected to be needed for emergency scenarios. Beyond the Police and Fire Departments that provide emergency services daily, and for which

emergency requirements were factored into the charger recommendations in this report, many Public Works and CMLP vehicles are used to respond to emergencies such as large snowstorms or blackouts. Under these circumstances, vehicles will experience significantly different duty cycles than an average day. Accordingly, vehicles that can usually rely on a Level II charger to provide overnight charging may need to re-charge at a DC Fast charger during emergency response periods.

Due to the small size of Concord's fleet, the Town faces a particular challenge because there are not enough vehicles to stagger deployment during emergencies. For example, CMLP staff indicated that during a large power outage all bucket trucks might be in use at one time. Both Public Works and CMLP are likely to need 3 to 5 150- or 350-kW chargers, or larger, to support emergency operations as the Town adopts heavy-duty electric vehicles.¹⁶ Since CMLP and Public Works already collaborate on emergency response (e.g. tree work), a shared bank of DC fast chargers may make sense to support emergency charging in the long run.

Exact emergency infrastructure needs were not modeled in this study because most of the vehicles included in the emergency response did not have electric alternatives. More information on the emergency operation constraints for each department, gathered from staff interviews, is provided below.

Public Works

The Public Works Department provides a range of emergency services 365 days a year. These services include water main breaks and tree clearance, but the largest emergencies dealt with by the department are snow and ice storms. During storms, trucks providing plowing will commonly be on the road for 20 out of 24 hours, sometimes longer in extreme scenarios. Maximum plow routes are 15-20 miles, and a truck might complete a route four times between breaks, meaning trucks are likely to travel 60-80 miles in between charges. While no heavy-duty trucks that provide plowing had appropriate EV alternatives assessed in this study, battery sizes of Class 8 trucks meeting the operational requirements of plow trucks range from 300 – 450 kWh. Based on this, a 350-kW charger would be sufficient to recharge in 1-2 hours. If a vehicle is on a route shorter than 15-20 miles, then the same charger would be able to complete charging in less time while a truck is parked, and the driver is resting. Fast chargers are capable of operating outside in cold temperatures, meaning that trucks would not necessarily be required to be in a garage during charging. Additionally, while CPW would need to confirm exact specifications from manufacturers when vehicles are available, electric vehicles available today can generally operate heat and other auxiliary functions while a vehicle charges.

As a wider range of electric vehicles become available and CPW requires high powered charging to support heavy-duty electric vehicles, new, or significantly upgraded, electric service at the site will be needed. The estimated

CMLP

Interviews with CMLP staff indicated that a large-scale outage could require a 16 to 36-hour response. For the first 24 hours of a response, CMLP crews work straight through with no breaks. Given the size of the Town, miles driven during emergencies is not the best metric to determine EV suitability. Rather, vehicles drive relatively short distances to work sites and need to be able to power equipment on site through a 24-hour period. Before CMLP adopts

¹⁶ It is important to note that most electric vehicles on the road in 2021 are not capable of charging at rates above 100 kW and only a select number of models are capable of charging at or above 250 kW. However, the EV industry, particularly medium- and heavy-duty vehicle manufacturers, have developed a charging protocol designed to support charging up to 3 MW. It is expected that the vehicle-side charging constraint will expand significantly in the coming years.

multiple electric bucket trucks, it will need to pilot, or otherwise determine, that these trucks can meet this emergency need. From a charging perspective, solutions providing mobile power (such as the DANNAR Mobile Power Station) may be just as important to providing emergency response as rapid charging. Given the expected battery capacity of the Class 8 electric bucket trucks considered in this project (336 kWh), 350 kW stations are expected to be able to recharge vehicles in less than hour. If faster charging is need, Concord may need to wait until vehicle charging capabilities reach 1 MW or above.

Projected Infrastructure Needs: Costs

The section presents projected electric vehicle infrastructure costs for each site based on build out to meet 2040 needs. The costs listed are total costs for a given site and are not reflective of project-specific costs if Concord pursues phased implementation of the required charging infrastructure.

Figure 8 summarizes the estimated costs by component across all sites for base infrastructure needs in 2035. Costs include all charging station hardware and installation costs, as well as costs for procurement management (as applicable) and estimated in house overhead for Public Works staff.

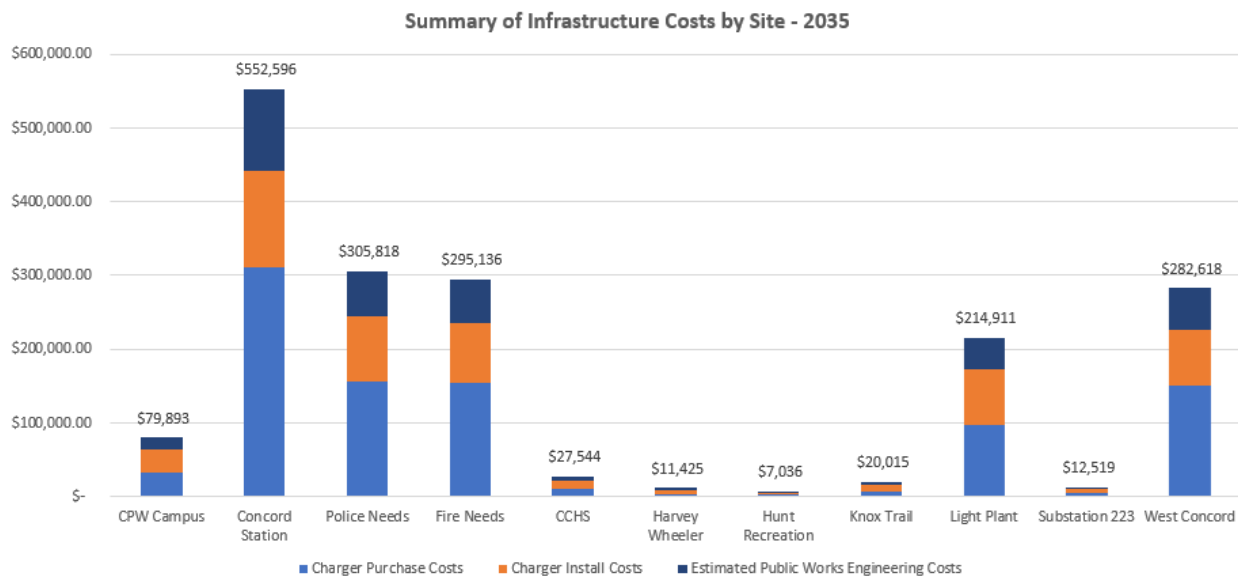


Figure 8: Estimated Electric Vehicle Infrastructure Costs – 2035 – Base Needs

Beyond costs for charging hardware, conduit, wiring and trenching, additional electrical infrastructure upgrades to building equipment can add cost if charging infrastructure is connected to the building meter, or a new service is needed. **Table 8** summarizes the remaining power capacity on each facility’s main switchgear compared to the additional power needed in the recommended charging scenario. **A detailed review of subpanel capacity was not completed.** Such a review will need to be completed prior to any charging infrastructure installation in order to determine the exact electrical design.

This review of Concord’s domicile facilities indicated that current power capacity at both Concord and West Concord stations is not sufficient to support all future charging. This means that switchgear upgrades, a new service or a software solution such as adaptive load

management will be required, depending on the needs of the site. Adaptive load management is a solution that leverages software to balance the power a set of charging stations is drawing to ensure that the total draw never exceeds the building capacity. This can be a less capital-intensive solution but requires the ability to curtail charging ports, which is not recommended for the Police Department.

Table 7: Remaining Power Capacity vs Power Needed

| Site Name | Estimated Capacity Available (kW) ¹⁷ | 2040 Charging Needs (kW) | Sufficient Capacity? |
|----------------------|---|--------------------------|----------------------|
| CPW Campus | 519.22 | 121.8 | Yes |
| Concord Station | 230 | 664.1 | No |
| CCHS | 133 | 31.3 | Yes |
| Harvey Wheeler | 356.33 | 23 | Yes |
| Hunt Recreation | 155.30 | 6.6 | Yes |
| Knox Trail | 212.83 | 24.7 | Yes |
| Light Plant | 336.4 | 235.6 | Yes |
| Library | 568.42 | 6.6 | Yes |
| PLM | 65.6 | 13.2 | Yes |
| Substation 223 | 33.24 | 18.1 | Yes |
| West Concord Station | 48.43 | 300 | No |

While this analysis indicated that the CPW Campus has sufficient capacity on its current electrical service to provide charging for vehicles that were identified as having appropriate, or potentially appropriate, electric options, additional capacity is expected to be needed as CPW explores electrification of its heavy-duty vehicles. This is particularly important when considering emergency operations (see **Emergency Charging Needs – Public Works & CMLP**).

Figure 9 summarizes the estimated costs by component across all sites for base infrastructure needs in 2035, with the addition of estimated electrical capacity upgrades on the customer side of the meter. Given the age of West Concord Station and existence of a back-up generator at Concord Station, it is assumed that a new service dedicated to EV charging would be the simplest solution. As such, additional costs are based on adding a new service. Costs should be refined based on conversations with CMLP.

¹⁷ Remaining power capacity was calculated based on the main panel capacity at each site less the existing peak demand at the facility.

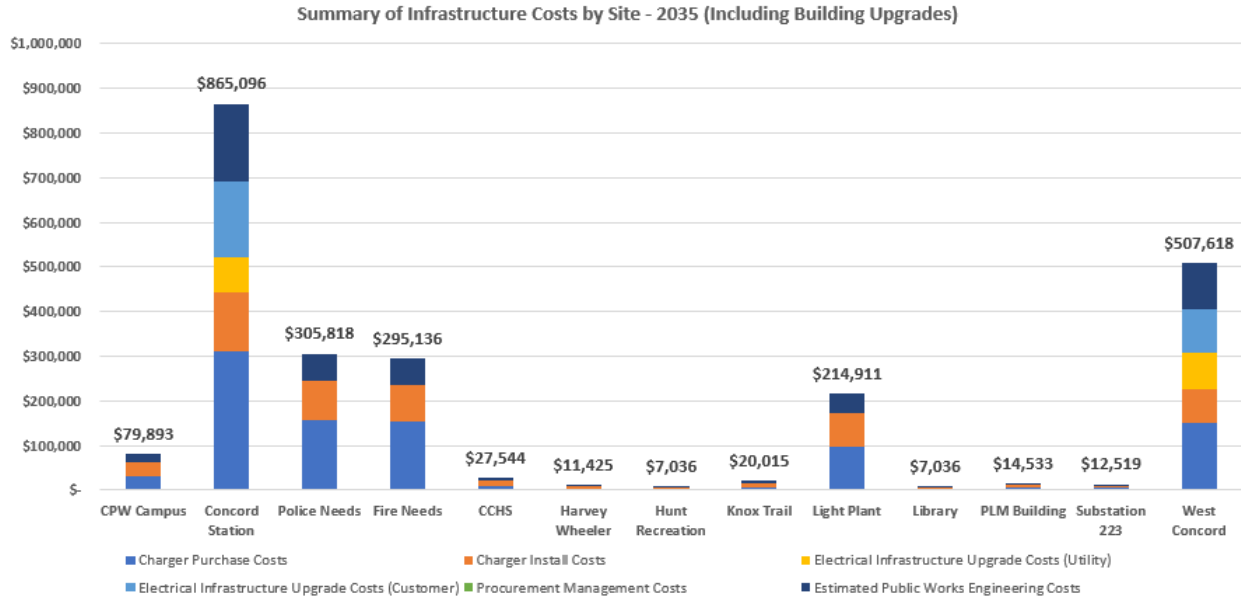


Figure 9: Estimated Electric Vehicle Infrastructure Costs – 2035 – Base Needs with Building Upgrades

Layering on rough cost estimates for the theoretical infrastructure needs for emergency charging increases costs further. **Figure 10** summarizes the estimated costs by component across all sites for base and emergency infrastructure needs in 2035, inclusive of building electrical capacity upgrades. **Since emergency charging needs were not modeled in detail, the estimates below are only intended to provide the Town with information on the order of magnitude for costs related to an additional 3-5 350 kW chargers at the CPW Campus and Light Plant.**

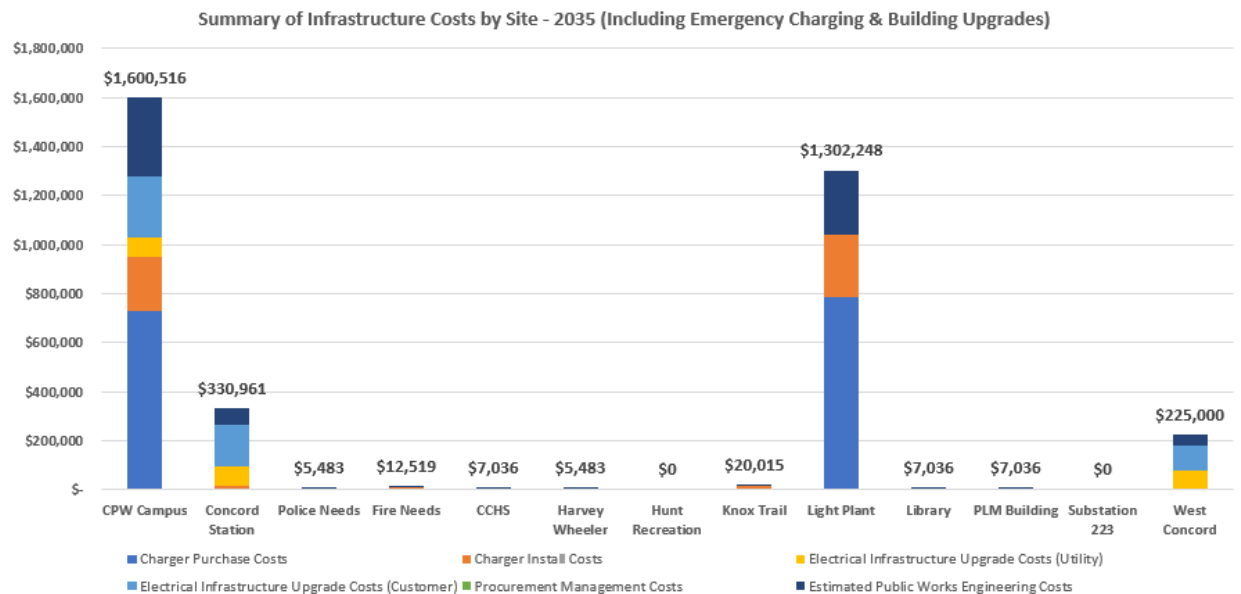


Figure 10: Estimated Electric Vehicle Infrastructure Costs – 2035 – Emergency Needs with Building Upgrades

Utility Upgrade Costs

If the required charging infrastructure exceeds the capacity of the nearest transformer on the distribution system, make-ready costs on the utility side of the meter have the potential to exceed costs on the customer side of the meter. All site needs should be reviewed by CMLP to determine if additional upgrades may be needed to support charging.

INFRASTRUCTURE IMPLEMENTATION & NEXT STEPS

Determining the exact phasing of infrastructure implementation, as well as the supporting procurement and funding or financing strategy, is the next step for the Town to enable vehicle electrification beyond initial pilot projects. A primary goal of this project was to identify the long-term EV infrastructure needs for the Town of Concord’s fleet to ensure that the Town can cost-effectively implement said infrastructure prior to vehicle adoption. Identifying long-term needs enables the Town to avoid underbuilding EV charging infrastructure, resulting in costly expansions and site upgrades, as the Town’s fleet assets come up for replacement and the EV market continues to expand. When determining its implementation strategy, it is important for the Town to understand lead times required for a successful project.

While permitting and installing a handful of charging stations may take 3-6 months, the sitewide projects considered at the CPW Campus and Concord Station are expected to take 1-2 years from procurement through construction completion. Depending on any distribution system upgrades required by CMLP, this timeline could extend further for certain sites. The RFP and Design steps could be swapped, depending on whether the Town takes a design-build approach or whether design is completed by a 3rd-party engineering firm prior to a solicitation for hardware and installation.

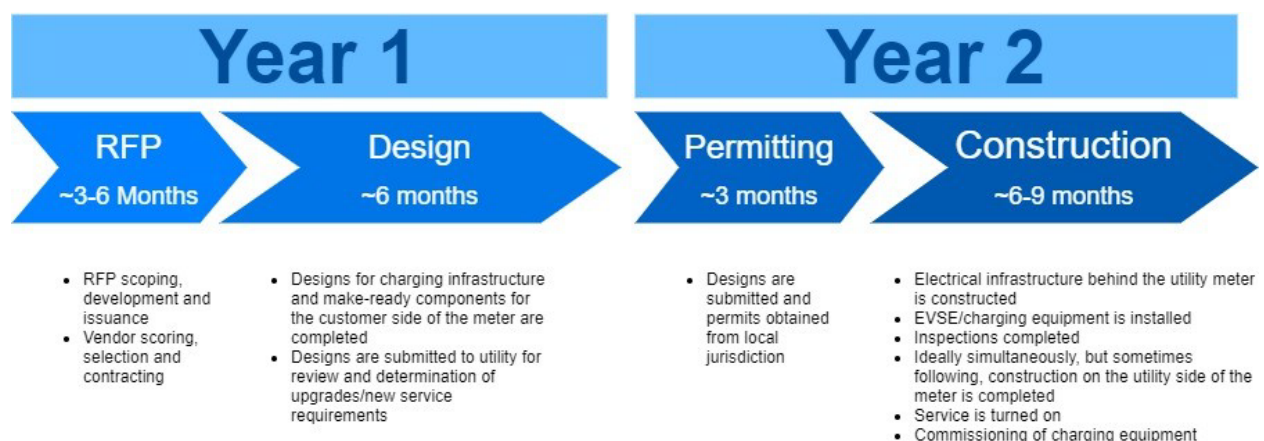


Figure 11: Timeline of Electric Vehicle Charging Infrastructure Installation

One best practice for the Town to consider when approaching infrastructure implementation is to treat major electric vehicle infrastructure projects (e.g., Concord Station) as a capital project. The project scale required is beyond the maintenance staff’s purview and is best framed as a capital improvement. Additionally, the budget required is in line with other large capital projects. Just as installing new fossil fueling infrastructure is considered a long-term investment handled through the Town’s capital improvement plan, electric vehicle infrastructure is the same.

Another best practice for the Town to consider while determining a strategy for charging infrastructure procurement and implementation is future-proofing of make-ready infrastructure. Make-ready infrastructure refers broadly to the electric infrastructure (transformers, panels, conduit) required to support charging stations. Lifetime costs of installing EV infrastructure at a site can be reduced by oversizing the make-ready infrastructure during the initial project. For example, if the Town is targeting a certain number of charging stations for installation at a given site in 2025, future-proofing the supporting infrastructure with 2035 needs in mind, while only purchasing the number of charging stations needed for number of EVs in 2025, will reduce the total cost of the infrastructure build-out.

Finally, additional planning is recommended to further address emergency charging needs and consider on-site power to support charging during blackouts as the Town's efforts to electrify heavy-duty vehicles crystalize. A mix of solar PV, battery storage and a generator supporting a select number of charging stations can provide charging to mission critical vehicles. Expected load profiles of charging during these scenarios will need to be created and modeled with a mix of distributed energy resources to determine the expected duration of off-grid charging that can be provided.