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# Medium and Heavy Duty Fleet Electrification Planning and Assessment

Jennifer Kwong[1], Salsabil Salah[1], Jeremiah Deboever[1], Allan Zhao[1], Jamie Dunckley[1]

*[1] Electric Power Research Institute, Palo Alto, CA, jkwong@epri.com*

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## Executive Summary

The electrification of transportation is a key element of many corporate, state, and federal decarbonization plans. While the transition towards electrified transportation has already begun, there remain tremendous uncertainties with respect to when, where, and to what scale the necessary charging infrastructure will impact utility distribution systems. This is particularly true with regard to commercial vehicles and fleets, where freight and delivery companies, service stations, and other entities have the potential to transform their fleets in a rapid manner and are typically co-located, concentrating their impact on the grid. This paper discusses a project that is preparing electric distribution systems for the impacts of fleet vehicle electrification.

*Keywords: medium-duty, heavy-duty, truck, simulation, utility*

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## 1 Introduction

As fleets begin to electrify, it is pertinent to understand their behavior to be able to plan the charging infrastructure that will support them. Medium-duty and heavy-duty vehicles represent only 4% of U.S. vehicles but account for nearly 20% of the nation's transportation fuel consumption. The IEA predicts buses to electrify faster than light-duty vehicles (LDV) to over 5 million in 2030. Electric medium and heavy-duty (MDHD) trucks are expected to reach close to 4 million by 2030. Global electricity demand for EV fleets is expected to be over 800TWh and in the US ~200TWh by 2030, whereas in 2020 globally, it required only 80TWh of electricity [1]. This will result in a two-third reduction of GHG emissions compared to ICE vehicle fleets. According to McKinsey, by 2030, battery-electric trucks will be ~20% of the market share for medium-duty and ~5% of the market share for heavy-duty [2]. According to ICF, ~170 MDHD EV models are to hit the road in 2024, as shown in Figure 1 [3].

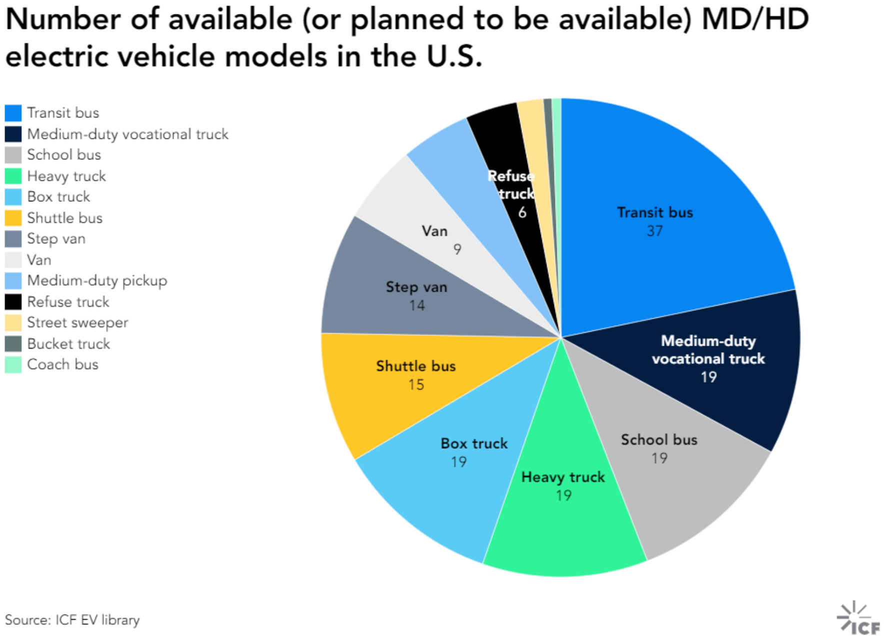

Figure 1 Number of available (or soon to be available) MDHD electric vehicle models in the US

There are currently around 13 million MDHD vehicles operating in the US which contribute to over a quarter of GHG emissions from the transportation sector [3]. Apart from the GHG emissions, MDHD vehicles also release nitrous oxide which contribute to air pollution especially in low-income areas. Figure 2 shows the NOx (nitrous oxide) emissions of Internal Combustion Engine (ICE) vehicles per year collected from the MOVES database. Currently, MDHD vehicles contribute to 43% of NOx emissions. Converting MDHD vehicles to electric will increase air quality significantly and thus also increase respiratory health outcomes in areas where these vehicles currently operate.

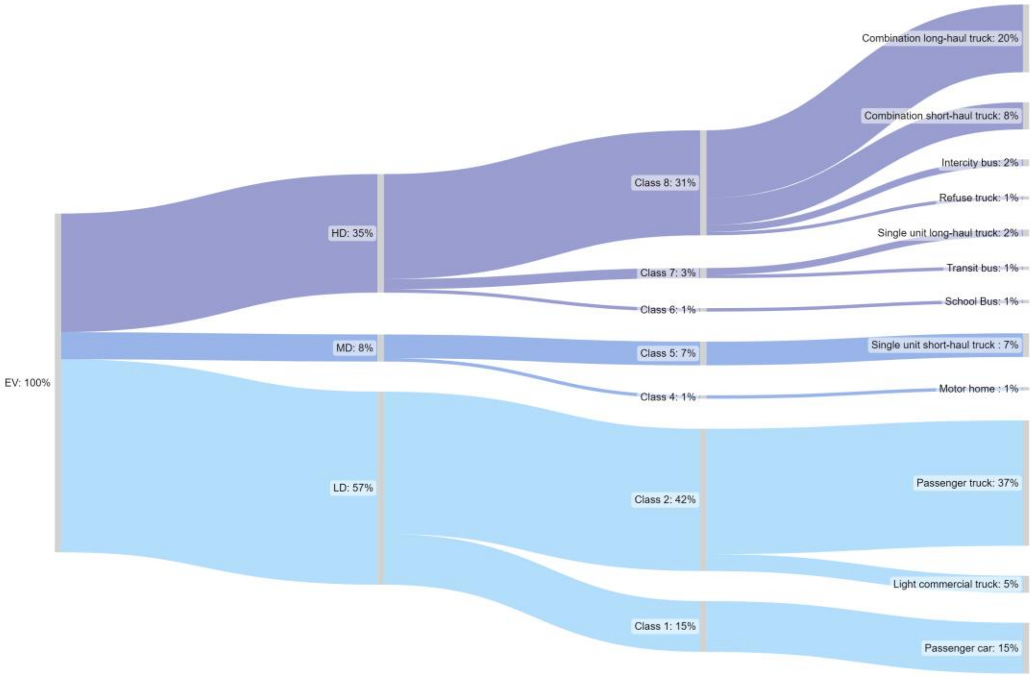

Figure 2 NOx emissions by current vehicle segments (created from data from the EPA MOVES 2021 database) [4]

Apart from increasing air quality compared to diesel buses, their battery-electric counterparts present immense advantages such as lower operating costs, zero tailpipe emissions, and lower noise levels [4]. According to the World Resources Institute, the US alone has over 13,000 committed battery-electric school buses [5]. These include currently operational buses as well as buses that will be purchased using current awards. According to the FTA, currently, ~2.5% of transit buses are electric in the U.S. as of 2021.

With numerous models of MDHD EVs hitting the road, the charging infrastructure remains a challenging issue. Out of the 114,000 public chargers, 22,000 are DC fast chargers (DCFCs) and Tesla superchargers. From these only a limited number of infrastructures may be used for overnight MD charging. According to ICF, an average Class 8 electric truck consumes about 2 kWh per mile, which is roughly equivalent to 660 kWh of electricity a day. Even with an overnight charge duration of 8 hours, the truck would likely require an overnightcharge power over 80 kW if it planned on traveling 300+ miles a day. With the 660-kWh battery capacity, the truck would need 80-100 hours to fully charge using a Level 2 charger and over six hours to charge using a DCFC [6].

This has implications on utility operations – as it means that since electric distribution companies need to be able to disperse much higher charging power for MDHD vehicles than light-duty vehicles. In addition, multiple MDHD vehicles tend to cluster together at depot locations, due to the nature of commercial fleet operations, while light-duty vehicles are dispersed across a residential neighborhood. This puts greater impetus on the utility to be able to anticipate the locations and peak hours of charging for these future vehicles, as the timeline for distribution upgrades to serve the power needed for fleets may be longer than three to five years, which is slower than fleets' ability to procure vehicles.

The electrification transition is a major opportunity and an immense challenge for electric distribution companies. To ensure a smoother transition, it is imperative for distribution companies to anticipate and proactively plan for this new demand, and by proactively and strategically planning for electrification, electric utilities will become a key enabler in achieving these broad electrification and sustainability targets.

## 2 Project Description

Major gaps have been identified in utilities' ability to strategically plan for electrification, specifically the uncertainty with pricing utility demand charges and upgrades to the grid to support further electrification [7].

This project seeks to help utilities evaluate medium-duty and heavy-duty vehicle behavior, including charging considerations, fleet travel patterns, and technology needs, as well as predict future fleet locations and sizes. It also assesses technology maturity to help inform utilities what might be arriving in terms of medium and heavy duty vehicles in ther near future. Jointly, this project will evaluate location-specific utility grid capacity that will enable fleet electrification while also identifying cost-effective integration solutions. By accomplishing these objectives, this project is expected to result in multiple new learnings, including fleet charging behavior and load shape data, how fleet vehicle and charging technology are expected to evolve, and how distribution planning tools can be used effectively for fleet segments that to date have not been represented in utility grid models. The learnings of this effort will lead to a fleet electrification infrastructure roadmap. The various portions of the project (technology maturity assessment, fleet characterization analysis, and the distribution grid analysis) are summarized in in greater detail later in their paper in their own subsequent sections

## 3 Technology Maturity Assessment

As part of existing research initiatives, EPRI has conducted a technology maturity assessment for medium- and heavy-duty zero-emission vehicles available today. This work has spawned two primary data sources: a vehicle market-oriented dataset and a vehicle demand-oriented dataset.

The vehicle market-oriented data tracks all commercially available medium- and heavy-duty zero-emission vehicles available for purchase. Logging a multitude of technical specifications – including battery capacity, range, power, and others – EPRI can draw conclusions about the state of technological maturity across different vehicle use cases and weight classes. This data informs larger analysis by providing contextual backing about the technical capabilities of larger zero-emission vehicles today.

The vehicle demand-oriented assessment tracks external, non-OEM forces affecting MDHD vehicle demand. This includes public policies that encourage or mandate ZEV adoption across different levels of government, publicly announced vehicle procurement figures from different entities, and projected vehicle adoption into the future. These data points ground assumptions about MHD zero-emission vehicle proliferation with real-world market limiters and accelerators.

# 4 Fleet Characterization Analysis

A major portion of this project is characterizing the travel behavior of medium and heavy-duty vehicles to use in the development of load profiles for vehicle charging. As there are not many electric medium-and heavy duty vehicles in operation currently, due to the nascent nature of the technology, telematics data from conventional ICE medium and heavy-duty vehicles procured from INRIX is used to make predictions about how much energy and power will be needed in the future. One of the assumptions that underlies the data analysis for this project is that medium and heavy duty vehicles will want to operate and travel similarly to as they currently do within the available data. While that is a consistent assumption, it is possible that the behavior of fleet vehicle operation will change in the future as electric medium-and-heavy duty vehicles begin to proliferate in the market, and the trucking industry itself changes.

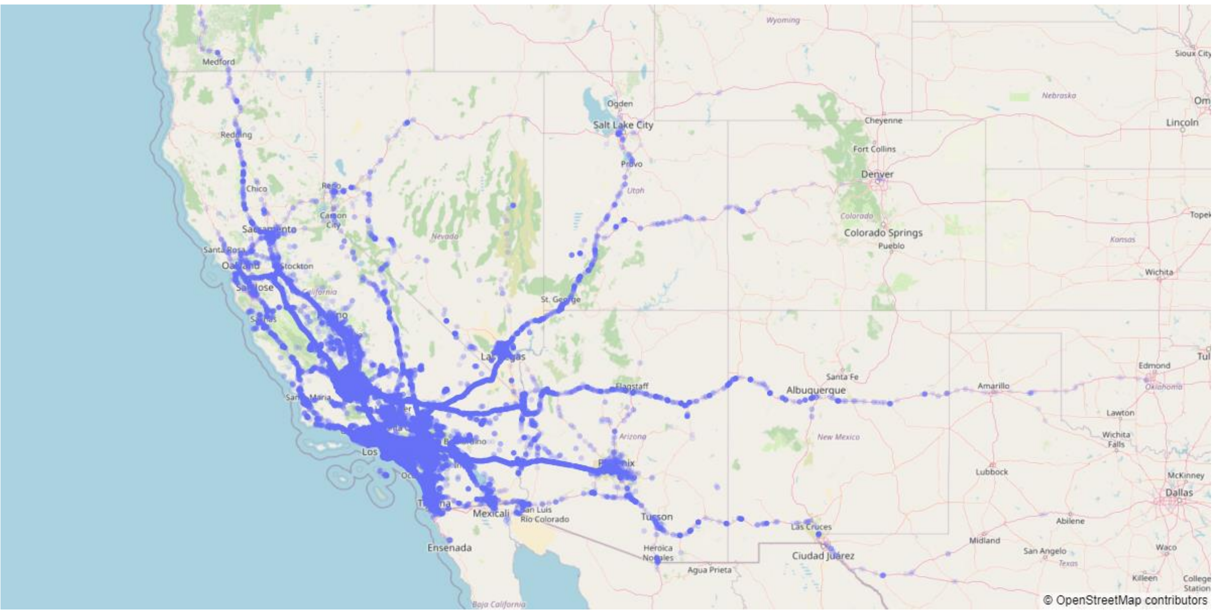

Figure 3 Vehicle trips within a single day for vehicles with at least one stop within Southern California

The telematics data was provided in the form of vehicle trips. The plot of energy needs in a geographic area in Figure 4 was created by analyzing the behavior of vehicles traveling through Southern California on a single day. The start locations of all trips made by all those vehicles are plotted in Figure 3. Attributes for each data row included a vehicle identifier, time and location of the start and end of the vehicle trips, and the distance driven within each vehicle trip. Using that data, each vehicle's trips were sequenced by day to determine the dwell time (stop duration) between multiple trips, which was assumed to be available charging time. Total energy needed to supply each vehicle's travel mileage was calculated, with assumed efficiencies of 2.0 kWh/mi for medium duty vehicles, and 3.0 kWh/mi for heavy-duty vehicles. An estimation of their charging power needed was done based on their distance driven and dwell time and at what time they were stopped.

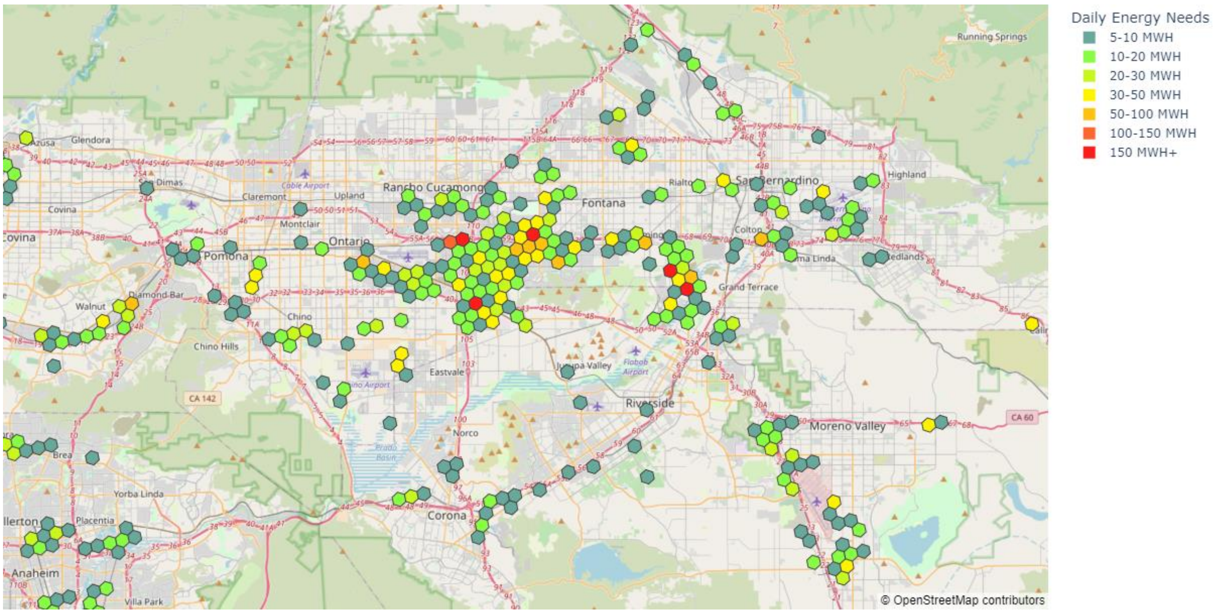

Figure 4 Energy needs within San Bernardino and Riverside counties for vehicles with trips in Figure 3

Figure 5 contains a sample load profile created from the INRIX data for another region. The load profile shows the amount of energy needed by the fleet vehicles throughout the hours of the day for every half-hour interval. The battery size is not considered and efficiencies are assumed for all vehicles. These plots take the relative number of vehicles created in the previous plots and multiply it against the power those vehicles would charge at (based on miles traveled) to get an estimated power required at that time interval. Fig 5 shows the sample load profile for the vehicles – with two different scenarios, charging immediately when the trip ends, and charging before the next trip starts. This can then be fed into the distribution analysis to see if the grid has capacity for medium and heavy duty vehicles at the peak hours identified.

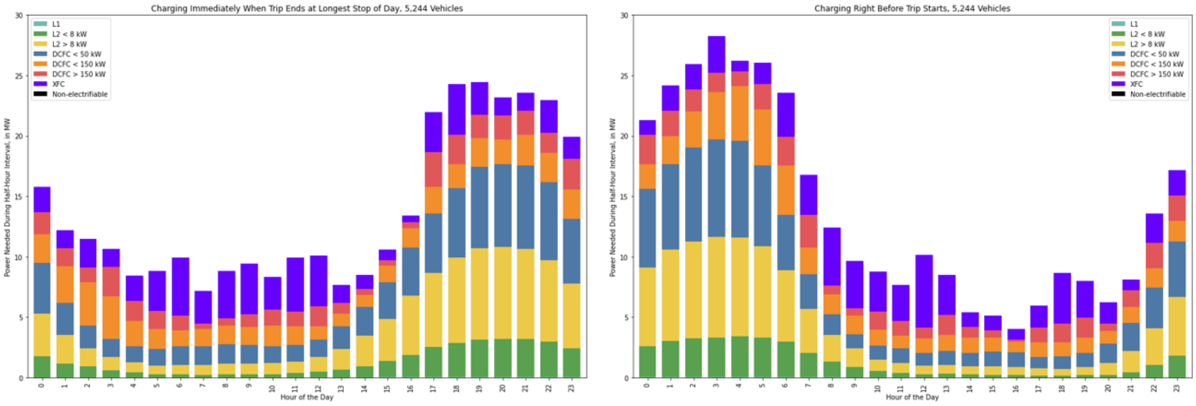

Figure 5 Load profile developed from approximately 5,250 vehicles, banded by potential charging power

## 5 Distribution Grid Analysis

In parallel with the fleet transportation behavior characterization efforts, an analysis of the distribution system for participating utilities is performed. In order to assess the impacts of fleets on the grid, a baseline understanding of the operating conditions of the electric feeders must be performed. Hosting capacity analysis can be applied to understand how much additional load can be accommodated at specific locations on the distribution system to accommodate fleet electrification [8].

It will be important to understand whether the increase on demand from MDHD vehicles will occur at the same time as current system peak, or if it will occur during off-peak hours. In addition, due to the magnitude of the power needs at certain sites, interconnection upgrade requests to the utilities will likely be needed. If power needs from MDHD vehicles concur with system peak, utilities may need to increase generation resources, upgrade their grid to match the demand, or also look at managed charging solutions for vehicles to shift demand to off-peak hours. Some fleet customers (e.g. school or transit buses) that have consistent schedules and limited hours of operation have flexibility in their charging schedule, which may help to lower upgrade costs for both customers and utilities if managed charging can be implemented. Utilities may also need to change their transformer replacement timelines if MDHD vehicles increase load during off-peak hours. The impact of the new demand from fleet electrification may be nuanced and enhancing planning practices may help distribution planners more effectively accommodate these new loads.

To assess electric distribution system impacts, the coincident load from all customers connected to the system being reviewed must be considered. Vehicle electrification power requirements can be far higher than what is currently on the distribution system for single sites – as illustrated by Figure 6, which was generated for a study by National Grid and RMI [9]. As discussed previously – multiple MDHD vehicles will likely charge at single sites, and the expectation is that they will add significant load to individual feeders, contributing to a sharp increase in demand on the distribution system.

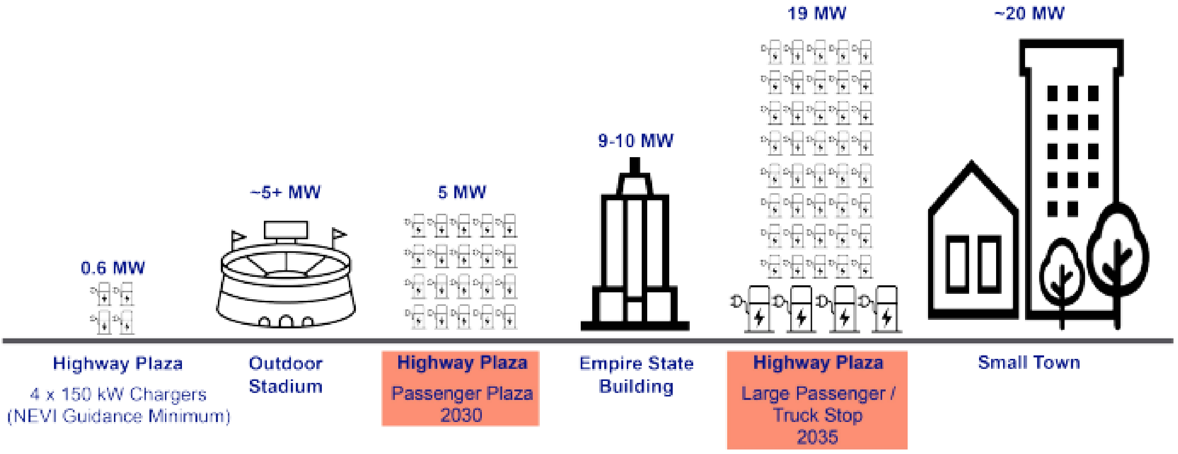

Figure 6 Comparative power needs for various existing structures and potential vehicle charging locations

Hosting capacity analysis can be used to understand how much additional load can be accommodated at specific locations on distribution system. The hosting capacity generally describes how much additional load a feeder can support before experiencing issues at any point in time during the year. For MDHD EV~~v~~s, depending on the territory, it is possible that peak demand for charging power for those vehicles could coincide with winter peak hours during the morning (due to heating needs) in colder regions, or summer peaking hours (due to cooling needs) in the afternoon/night. While the limiting conditions may not occur for more than a few days in the year, it can have outsize ramifications on fleet and utility operations if the conditions are exceeded [10].

Time-series hosting capacity (TSHC) analysis can provide an estimate of the available throughout the day / year capturing the daily and seasonal variability. This variability is caused by the varying load on the feeder and the available capacity at a specific location on a feeder will depend on how much downstream load there is. In Fig 6, the time-series hosting capacity of three nodes illustrates the differences in hosting capacity based on their locations on the feeder. Each node reported between 0.5 and 2MW of available capacity during the peak load hour (lowest value). However, depending on the location of the node, the capacity could vary greatly (2-8MW near the substation) or insignificantly (0.5-0.6MW on the red branch).

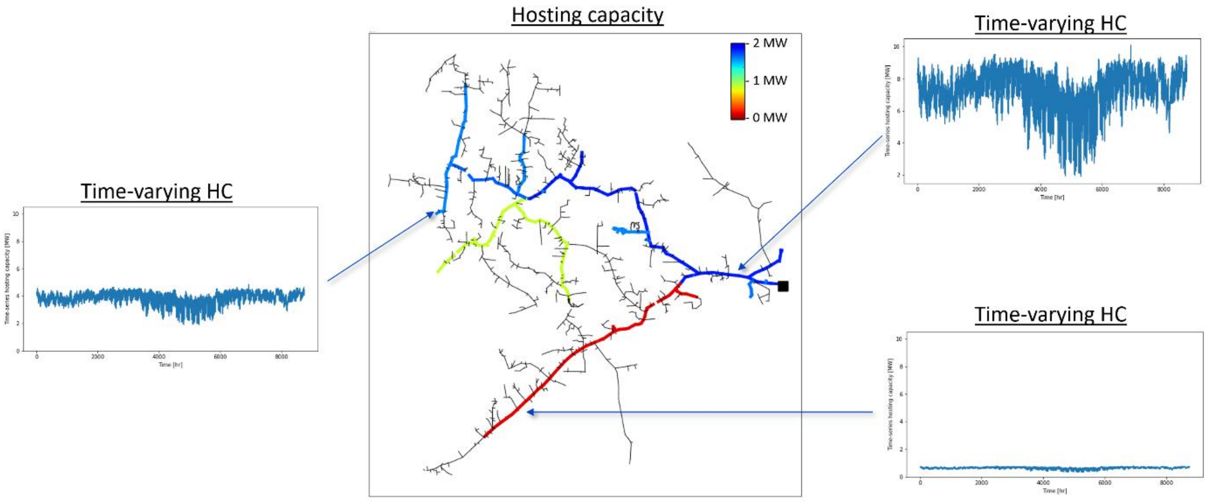

Figure 6 Hosting capacity analysis profile across different feeders

While distribution planners will always plan for the worst-case condition, it is important to recognize that a range of hosting capacities exists, and to capture the daily and seasonal variation in the capacity. More specifically, a box plot of the time-series hosting capacity can provide a better understanding of the available capacity overnight. For instance, Fig 7 shows a worst-case hosting capacity of 2 MW during the most limited hours of the year but also shows that 5 MW is available between 10pm and 7am regardless of the day of the year. Understanding the constraints within current system loads can help inform utilities on developing customer programs to help the system, for example, encouraging the use of charge management programs.

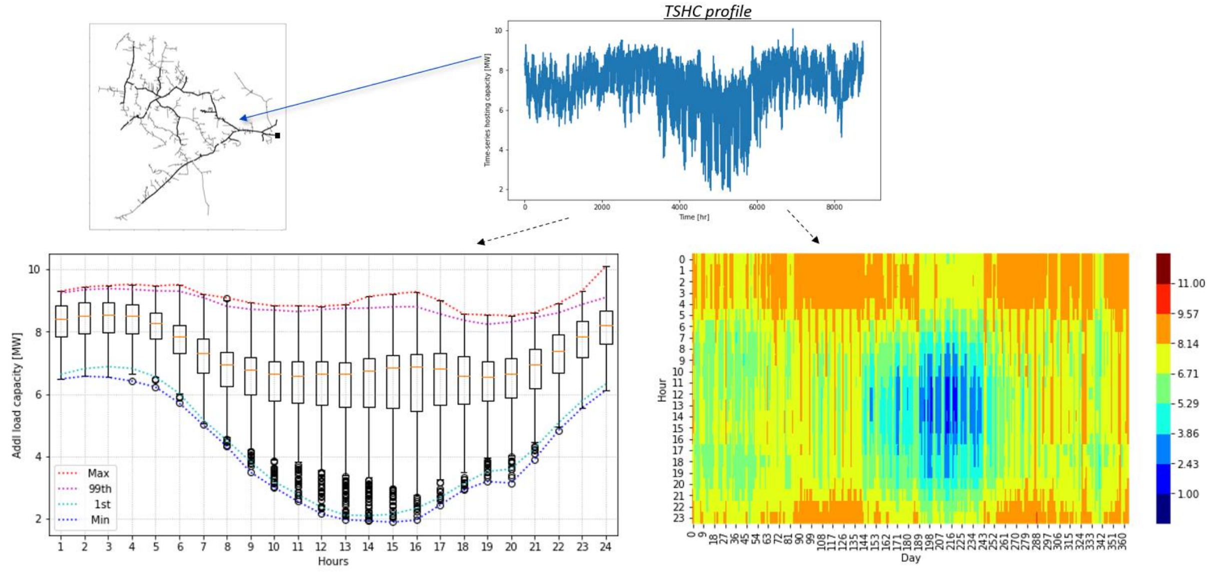

Figure 7 Time-series hosting capacity example

## 6 Conclusion and Fleet Electrification Impacts on the Distribution Grid

An important metric derived from time-series hosting capacity results is the energy deliverability at a location on a feeder. While utilities have traditionally thought of available capacity on the grid in terms of power, quantifying the energy available can provide valuable insights to summarize time-series hosting capacity results in a single metric, and in a language that is more understandable to fleet managers. Fleet managers will often be aware of the total number of miles driven by their fleet or their operational costs in terms of fuel consumed. These metrics can be translated into a kWh / day value to assess their energy demand from a site if they were to electrify. Thus, quantifying the energy deliverability could enable planners to compare the same metrics, both to assess if there is sufficient deliverable energy at a site during a day to support a customer's needs, and to respond to customers' inquiries about the difficulty of electrifying the site in order to support a fleet [10].

One of the next steps within the project is to combine the load shapes generated by the fleet characterization analysis for vehicles in a region with the hosting capacity analysis to determine the impact on the grid if 100% of MDHD vehicles within the region electrify on specific feeders. This will allow utilities to begin to prepare for the magnitude of impacts expected, and begin looking at how they could develop programs to encourage a shift in demand, such as managed charging or behind-the-meter charging solutions.

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## Presenter Biography

Jennifer Kwong is a technical leader on the transportation team at the Electric Power Research Institute (EPRI) in Palo Alto, California. She received her masters' in transportation system engineering and urban planning from the University of California, Irvine and her bachelors' in civil engineering and geography from the University of Maryland, College Park.

Her current work at EPRI focuses on translating passenger, medium, and heavy duty vehicle behavior into load shapes for utility planning purposes to help the electric grid prepare for transportation electrification.