Impacts of Increasing Electrification on State Fleet Operations and Charging Demand

Sarah Booth,[1] Jesse Bennett,[2] Matthew Helm,[1] Devin Arnold,[1] Bridget Baker,[1] Remmy Clay,[1] Mary Till,[1] and Ted Sears[2]

1 Sawatch Labs
2 National Renewable Energy Laboratory

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Technical Report
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List of Acronyms

EPAct	Energy Policy Act of 1992
EV	electric vehicle
EVSE	electric vehicle supply equipment
GHG	greenhouse gas
ICE	internal combustion engine
kW	kilowatt
NREL	National Renewable Energy Laboratory
TCO	total cost of ownership

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Introduction

The National Renewable Energy Laboratory (NREL) provides technical and analytical support to the U.S. Department of Energy's alternative fuel programs, including the State and Alternative Fuel Provider Fleet Program. Through the program, the U.S. Department of Energy implements regulations pursuant to the Energy Policy Act of 1992 (EPAct), as amended, which requires alternative fuel providers to use alternative fuels in those vehicles where the fuel is available. These fleets continue to be a subject of broad interest as a test bed for implementing and evaluating new vehicle and fuel technologies, and are the subject of compliance options set forth in EPAct and associated regulations. The work in the alternative fuel arena that these fleets pursue inevitably generates case studies and lessons learned that other EPAct fleets, and indeed other non-EPAct fleets as well, can use to their advantage as they begin to deploy new and advanced vehicle technologies.

State fleets represent an enticing opportunity to explore the near-term feasibility of fleet electrification. In many instances, state fleet operations encompass a wide geographic area with fleet locations for many vehicles. Serving these wide areas will require a significant amount of energy and, in the case of electric vehicles (EVs), a significant level of charging power. The peak demand as a result of this charging demand is of interest for fleets, with impacts on both utility bills and installation costs ranking among some of the greatest concerns. The combination of a wide operational area and multiple fleet locations positions state fleets as ideal candidates to understand the impacts of vehicle charging on fleet operations.

As the availability of electric drivetrains expands beyond light-duty sedans, fleets need to understand when it will be appropriate operationally and financially to start adding electric drivetrains to their fleets. Throughout this process, it will also be important to understand the charging implications of fleet electrification and the resulting impacts to facility electrical systems. To better understand these considerations, NREL contracted Sawatch Labs to analyze the role that increasing state fleet electrification may have on the charging demand at fleet parking facilities. As states move from initial EV adoption to increased deployment of EVs, the implications that fueling these vehicles will have on facility electricity demand will only grow. This analysis project includes the assessment of fleet data from three states in different regions in the United States to:

1. Identify state vehicles for which an EV is a good operational and economic fit.
2. Identify where charging infrastructure will be needed to support broad state fleet electrification.
3. Project charging demand curves to highlight where charging may have impacts on facility peak demand.

Each of these is expected to facilitate efforts by states to operate EVs in their fleets efficiently and cost-effectively.

To accurately understand fleet electrification opportunities and challenges, fleet partners provided the research team with telematics data for their vehicles. Telematics data, such as vehicle speed and location, enable a detailed understanding of vehicle travel patterns to determine both energy needs based on driving behaviors and charging opportunities based on parking habits. The analysis methodology outlined in the next section provided fleets with vehicle electrification opportunities and charging demand analyses to support fleet electrification planning efforts. Each participating fleet was provided with access, via Sawatch Labs' online dashboard, to the detailed analysis for its vehicles and parking facilities. This report provides an overview of the analysis across the three state fleets and identifies lessons learned that can help other EPAct-covered state fleets—and others—as they increase their fleet electrification.

Methodology

This analysis assesses both the suitability of individual fleet vehicles for EV replacement and the aggregate charging demand across a fleet at increasing levels of fleet electrification. This analysis is based on Sawatch Labs' "ezEV" and "ezIO" tools. The ezEV tool develops EV suitability assessments, which provide fleets with recommendations for EV acquisitions based on a scoring system that considers both financial and operational feasibility and establishes the foundation for the second component of this project: understanding the implications of increased fleet electrification on energy demands at each parking facility. EV suitability assessments like these are a common way to determine which vehicles are the best candidates for replacement with an EV. The ezIO tool builds on the vehicle-specific ezEV results to help inform electric vehicle supply equipment (EVSE) infrastructure planning and consider potential electric utility bill impacts.

Understanding the details of these two concerns—vehicle electrification opportunities and charging demand impacts—is critical when planning for an electric fleet. Although both concerns are of great importance, some factors are more prominent in state fleets vs. university fleets. The results of this analysis on state fleets focus on charging demand considerations, as this is a greater concern due to the wide geographic regions in which the fleets operate. A similar study was performed concurrently on university fleets, in which the results focus more on electrification opportunities and why particular vehicles make good candidates for electrification.[1]

ezEV Suitability Assessment

The ezEV analysis assesses each vehicle for which telematics data were available to determine if there is an available EV model that meets both the operational needs and economic requirements based on the actual travel the vehicle covered. The ezEV tool analyzes the telematics data for each vehicle, determining the energy needed to move the vehicle every mile it traveled. Those energy needs are then modeled to determine the gasoline needs for the comparable internal combustion engine (ICE) vehicle and the electricity needs for all comparable EVs.[2] Employing high-fidelity telematics data affords a highly precise determination of a vehicle's energy needs

[1] Sarah Booth, Jesse Bennett, Matthew Helm, Devin Arnold, Bridget Baker, Remmy Clay, Mary Till, and Ted Sears. 2022. *Identifying Electric Vehicles To Best Serve University Fleet Needs and Support Sustainability Goals*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-81596. https://www.nrel.gov/docs/fy22osti/81596.pdf.

[2] The comparable ICE and EVs models were provided by the participating fleet, based on the procurement mechanism used for fleet purchases. This was typically from its state contract and/or Sourcewell.

based on both the speed and distance traveled in sub-minute increments.[3] This level of detail is important when considering operational feasibility and total energy costs, because the energy requirements to move an EV or an ICE vehicle depend on the speed at which the vehicle is moving in addition to vehicle miles traveled.

The ezEV analysis is characterized by three main aspects:

- Economics
- Energy
- Parking.

The economic portion of the ezEV analysis determines the total cost of ownership (TCO) for the comparable ICE vehicle and all comparable EV models and allows one to discern if the TCO would be higher or lower for an ICE vehicle compared with the likely EV replacement option. Many variables that impact the TCO can fluctuate over the lifetime of a vehicle, with a key parameter being price of gasoline, as compared to the use of fleet-owned EVSE.[4] As a result, to account for possible fluctuations in the price of gasoline, the analysis identifies an EV as a good fit to replace an ICE vehicle when the TCO for the EV is no greater than 5% more expensive than the TCO for the comparable ICE vehicle.

The energy portion of the ezEV analysis assesses the daily driving needs for each vehicle, identifying which days an EV would have required midday charging. Any vehicle that would require midday charging more than 4 days per month is not considered a good candidate for EV replacement because it would require the driver to find the time for midday charging at least once a week on average. Midday charging events are important to support long-distance travel, but for this study it was decided that midday charging more than once per week could impact operations.

The parking portion of the ezEV analysis identifies locations where extended dwell periods occur after each day of travel, representing the best opportunities for charging.[5] The locations of these parking events, which typically occur overnight, help determine where charging infrastructure should be placed to support these vehicles. Vehicles with more than 25% of their extended dwell periods occurring at disparate locations are not considered good candidates for EV replacement because they may not have consistent access to dedicated EVSE. This parking analysis is meant to be an indicator of the ability for the vehicle to have access to charging infrastructure at a single location for at least 75% of extended dwell periods. It does not mean that a vehicle with disparate parking patterns cannot be replaced with an EV; instead, it simply means that it may be more difficult to ensure consistent access to EVSE for these vehicles. In the future, as charging infrastructure is installed across the fleet's facilities, these vehicles may have ready access to EVSE at multiple locations.

[3] The granularity of the telematics data provided by the participating fleets varies based on the telematics provider. Each telematics provider has unique methods that determine the frequency with which data are pulled. The telematics data for all participants in this project covered increments of at least every 2 minutes, if not more frequently.

[4] The price of electricity is generally stable. The Alternative Fuels Data Center provides the average retail price for various liquid fuels and electricity: https://afdc.energy.gov/fuels/prices.html.

[5] Extended dwell periods are times during which the vehicle is parked at the same location for 9 or more hours.

These three components of the ezEV analysis—energy, economics, and parking—are intended to help identify which vehicles are most likely to be successful applications for an EV. While the telematics data provide granular insight into each vehicle's driving, there are many other operational insights that fleet managers understand about unique vehicle requirements that could affect a determination as to whether an EV will meet the drivers' needs. For example, vehicles that are used for towing or plowing activities may not be good candidates for replacement with a currently available EV, even if they are good candidates based on the ezEV analysis. Conversely, a vehicle that receives a low ezEV score may be a good candidate for replacement once other factors are considered. For example, a vehicle that does not meet the parking consistency threshold (at least 75% of extended dwell periods at the same location) may have access to EVSE at its other dwell locations. In this case, this vehicle could have consistent access to EVSE for more than 75% of its extended dwell periods, and the fleet manager may determine that this vehicle is a good fit because access to EVSE will not be a barrier. Additionally, it may be possible for drivers to change their parking location to consistently park at a single parking facility if a dedicated charger were available. Similarly, the economic threshold (a TCO no greater than 5% higher than in a comparable ICE vehicle) may not be of much concern for fleets that have access to grant funding to purchase EVs or statewide policy guidance to purchase EVs. The ezEV analysis and scores are intended to provide guidance to fleets about the vehicles that will likely be the easiest to replace with an EV with the least amount of impact on the fleet, drivers, and budget.

Until more options for EVs enter the market, it may be necessary to transition vehicles to EVs that are of similar model types. For example, until more electric pickup trucks and minivans become available, and in the context of fully transitioning fleet vehicles to electric versions, some fleet managers are considering replacing an ICE pickup truck with an electric SUV. For this reason, the analysis includes the option to compare pickups and minivans with electric SUVs. If an electric SUV is identified as a good replacement, that vehicle model is listed. Understanding that an SUV may not meet the same mission requirements of a pickup or minivan, this approach is intended to best support fleets that are looking to electrify their fleet more aggressively, even in the absence of identical replacement EV models, and particularly for fleets looking to right-size their fleet vehicles by finding smaller, more efficient vehicle options. The online Sawatch dashboard provided participating fleets with the ability to filter to see this different-class vehicle replacement option or only class-to-class comparisons.

ezIO Charging Demand Analysis

Deploying and managing an EV fleet can be complex and require planning across several areas, some of which are not traditionally within the fleet management realm. The effort requires attention to vehicle procurement, fueling infrastructure, and facilities planning. The ezIO tool leverages historical travel data for each vehicle to model vehicle charging requirements as if the current fleet of vehicles are EVs. The daily driving needs for each vehicle determine the energy that must be recovered from the next charging session, which occurs at the location of the vehicle's extended dwell period for that day. This charge session begins as soon as the vehicle has finished driving for the day, and the duration is determined by the time it would take a standard 6.9-kilowatt (kW) Level 2 EVSE to recharge the battery with the energy consumed the prior day.

The time and duration of each vehicle's daily charge session is aggregated to model the peak demand from vehicle charging at each location for every month during the period of analysis. The highest peak demands will result from the coincidence of multiple vehicles plugging into EVSE to charge at the same time. This highlights the minimum number of EVSE required, aiming to reduce the deployment of charging infrastructure in locations where the number of EVSE required is less than the number of EVs. These data also detail the EV charging peak demand and can help fleet managers and facility staff identify when the potential charging peaks may coincide with facility peak demand, resulting in higher demand charges from the local utility. Under some circumstances, this new load could require policy or technical strategies to shift charging later in the evening to avoid increased demand charges from the local utility. At a minimum, it will require coordination among the fleet and facility managers.

Fleet Participants

Beginning in late 2019, the Sawatch and NREL teams reached out to several EPAct-covered state fleets to recruit participants for this study. Three state fleets agreed to participate:

- State of Colorado – Department of Personnel and Administration
- State of Minnesota – Department of Administration
- State of North Carolina – Department of Administration.

The period of analysis varied for each state based on the telematics data available, and is listed in each of the fleet's respective appendices. The analysis was customized for each fleet to reflect its costs, vehicle procurement options, fleet management practices, and other inputs, including:

- Gas price
- Electricity rate
- Greenhouse gas (GHG) emissions factor for electricity generation
- Social cost of carbon
- ICE vehicle maintenance costs
- EV maintenance costs
- Vehicle life cycle
- ICE vehicle procurement options and pricing
- EV procurement options and pricing.

Detailed results for each fleet are summarized in their respective appendices, with the key takeaways outlined in the following section.

Fleet Charging Analysis

The data for the three participating states covered the travel or trips for a total of 8,336 vehicles. Throughout the total period of analysis—ranging from approximately 1 to 2 years per fleet—these vehicles traveled over 90 million miles across more than 4 million trips. A breakdown of vehicle count per fleet is summarized in Figure 1, representing the portion of each fleet for which telematics data were made available for analysis. The majority of vehicles analyzed were in North Carolina, with a fleet of 5,901 vehicles. The data for these vehicles also covered a wide range of trips taken and miles traveled, with North Carolina also representing the largest data set with over 64 million miles of travel data provided. A summary of approximate trips and miles traveled is provided in Table 1.

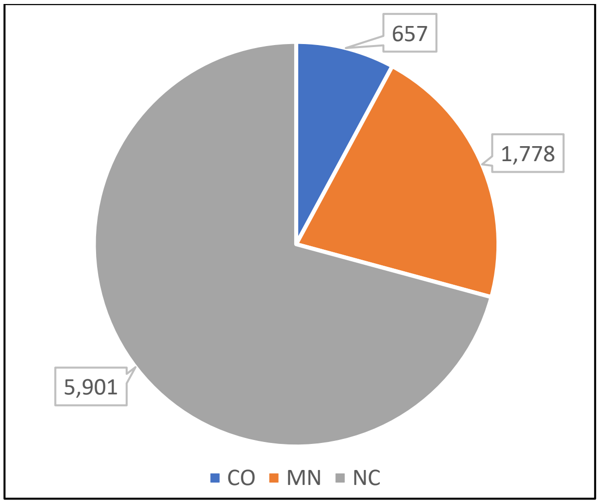

Figure 1. Analyzed vehicle count for participating states

Table 1. Analyzed Trips and Vehicle Miles Traveled for Participating States

Fleet	Trips Recorded	Miles Traveled
Colorado	460,000	5,200,000
Minnesota	883,000	21,000,000
North Carolina	2,990,000	64,000,000
Total	4,333,000	90,200,000

Fleetwide Electrification Analysis

As fleet interest in electrification grows, the need for analysis of whether a vehicle is a good candidate for EV replacement becomes increasingly important. The conclusions from the ezEV and ezIO assessments require detailed telematics analysis. While each participating fleet was able to share data on some of its vehicles, the following results only account for the vehicles for which telematics data were provided to the research team. Therefore, vehicles that do not have telematics devices and/or vehicles with sensitive missions were omitted from the results presented here.

EV Candidate Replacement Vehicles

On average, 46% of the vehicles in each fleet were identified as good candidates for electrification. The highest concentration of good candidates for replacement with EVs was in Minnesota, where 58% of vehicles analyzed were determined to have a suitable EV replacement option available in the market. Of the 1,778 vehicles analyzed in the Minnesota fleet, 1,022 were identified as good candidates for electrification. The breakdown of fleet vehicles and EV candidates identified for each fleet is outlined in Figure 2, and the results are summarized in Table 2.

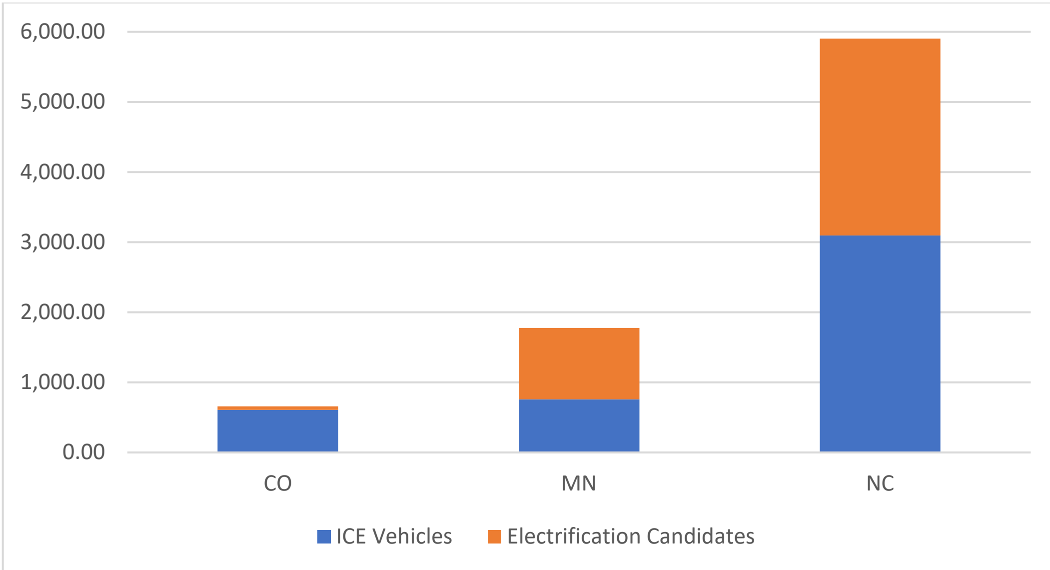

Figure 2. Electrification candidates per fleet

Table 2. Fleet Electrification Opportunities

Fleet	Total Vehicles	EV Candidates	Possible Fleet Electrification %
Colorado	657	49	8%
Minnesota	1,778	1,022	58%
North Carolina	5,901	2,804	48%
Total	8,336	3,875	46%

Fleet Charging Impacts

As fleets begin planning for near-, medium-, and long-term fleet electrification goals, it is critical to consider each facility's long-term charging needs. Infrastructure upgrades can be time-consuming and costly, particularly when done through many iterations at each site. Understanding the projected charging demand at each location in advance enables fleets to deploy the optimal number of EVSE to meet the current charging demand while also incorporating upgrades that will support future EVSE buildout as electrification expands. This planning can be complex and often requires coordination between fleet, facility, sustainability, and utility stakeholders.

Vehicle Dwell and Charging Duration

When planning for EVSE deployments, it is important to understand the level of demand that will occur at these sites to discern how many EVSE will be needed to meet the fleet's energy needs. This demand is best characterized through two key metrics: the aggregate daily charge session duration and vehicle dwell period. Across the more than 8,000 vehicles analyzed, the average Level 2 (6.9-kW) charging required after a typical day of driving was projected to be 2.9

hours.[6] These average charge session durations must occur within the vehicle's dwell period, which ranged from an average of 14.8 hours for North Carolina to 15.3 hours for both Colorado and Minnesota. This indicates that Level 2 charging is sufficient to meet the needs of most state fleet light-duty vehicles. The average vehicle dwell period far exceeds the typical charge session duration, resulting in flexibility for when the vehicle's charge session occurs. In the event a fleet needs to mitigate peak demand or take advantage of lower rates, this flexibility can be leveraged through the use of smart charging technologies to shift charging to times that are not coincident with facility peak demand or to when electricity prices are lower.

Peak Demand Considerations

Peak demand is defined as the highest level of power within a period of time. It is most often used to describe the highest level of power consumed within a given billing period, which is the key factor to determine a facility's monthly demand charge. The demand charge (defined in $/kW) typically accompanies an energy charge (defined in $/kilowatt-hour) and may increase as EV charging increases. In addition to the demand charge, peak demand is also a factor when determining electrical upgrades that may be required due to the installation of increasing amounts of EVSE.

Understanding this peak demand is important when planning how much EVSE to install, how expensive the installation process will be, and the impacts EV charging will have on a site's utility bills. In addition to the charge session duration and vehicle dwell period, the peak demand will also be determined by when the charge session occurs during the vehicle dwell period. For this study, a simple charging approach was employed for which all charge sessions began at the start of each dwell period, which typically occurs at the end of a driver's shift. All the daily charge sessions for the vehicles at a given location were plotted on a 24-hour chart, where the power increases when multiple vehicles are charging at once. Examples of these charts are provided in Figure 3 and Figure 4, representing two separate parking locations for the Colorado fleet.

[6] This average is calculated only based on the days the vehicle is used, so as to not underestimate the hours needed to charge.

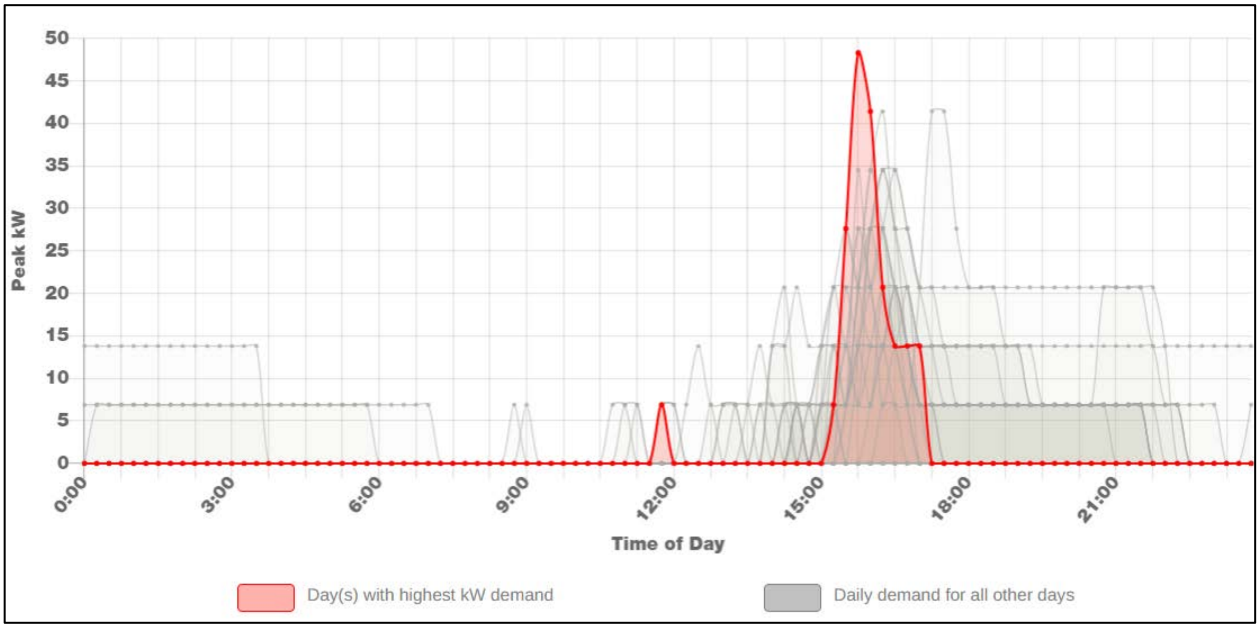

Figure 3. Projected charging demand at 80% fleet electrification: Location A

Figure 3 shows the projected charging demand at Location A when the state fleet hits 80% electrification. An entire month's worth of data is captured in this chart, but only the day where the peak demand occurs is highlighted in red. When the state fleet reaches 80% electrification, Location A is projected to have 12 EVs out of the total 13 vehicles that park there. However, the peak demand is a result of only seven of those vehicles charging at the same time (at approximately 16:00) for a total of 48.3 kW. Additionally, all the charging for these vehicles occurs within a 3-hour window, suggesting smart charging could shift the charge sessions for a few of these vehicles to a later period in the evening, reducing the peak. This would help mitigate the monthly demand charge by lowering the peak demand and could potentially reduce installation costs if the smart charging was designed to ensure the site peak demand was kept below a given power level.[7]

Figure 4 also represents the Colorado fleet at 80% electrification, with Location B having a total of 10 EVs out of 13 vehicles that park there. During the peak day, highlighted in red, there is a period when all 10 EVs are charging at the same time. However, unlike in Location A, in which the charge sessions for each vehicle were relatively short, the EVs at Location B would need to charge for a longer period to fully charge their batteries, which is apparent from how wide the red curve is relative the narrow spike in Location A. For Location B, the fleet manager could likely shift some charging to occur later in the evening, but the longer charge sessions mean the vehicles have less charging flexibility. Therefore, it would be more challenging to mitigate the peak demand at Location B, and demand charges and equipment upgrades could be an important consideration.

[7] The NREL garage reduced equipment upgrade costs through smart charge management, as detailed in this case study: https://www.energy.gov/eere/femp/evse-upgrades-nrels-parking-garage-generate-financial-benefits.

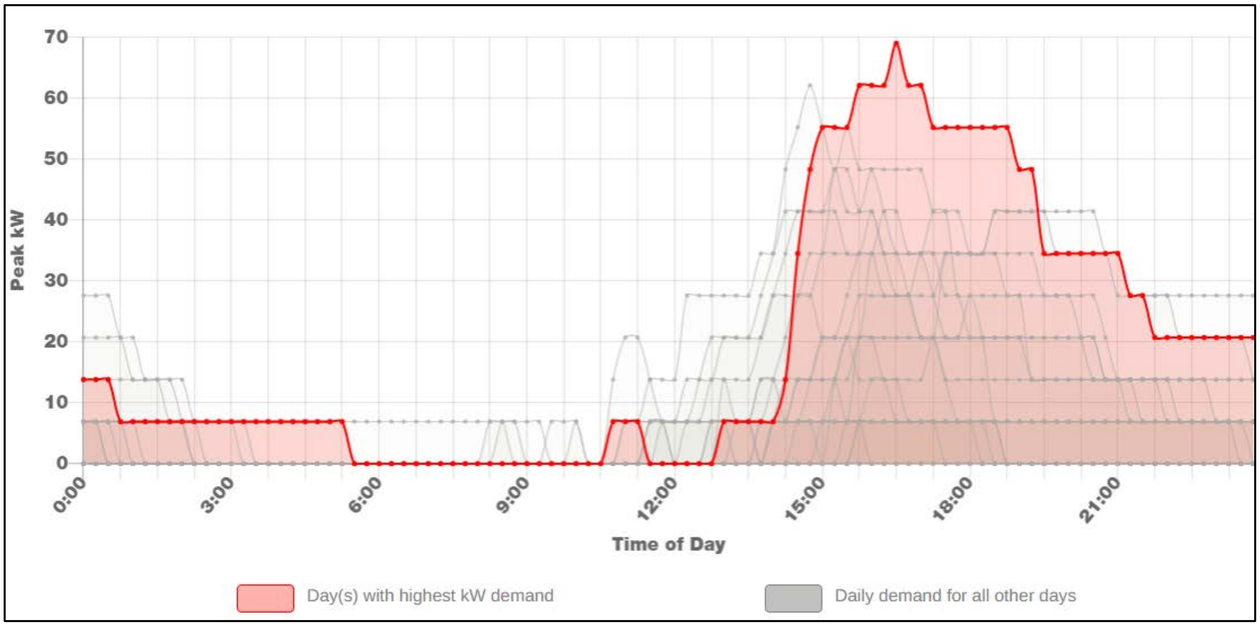

Figure 4. Projected charging demand at 80% fleet electrification: Location B

EVSE Deployment Planning

The impact of charging and the need for EVSE at each state fleet parking facility is projected to vary greatly, based not only on the number of EVs, but also the time and duration of charging. The impact at each individual facility will be unique, and planning for a growing charging demand could be complex for fleet and facility staff. For example, the projected maximum charging demand at 10 parking facilities for the State of Minnesota is provided in Figure 5. This graph displays how some parking facilities may experience a substantial increase in charging demand early in the fleet electrification process because many vehicles that park at that location are good candidates for electrification (e.g., Location 1). Conversely, there would be no EVs charging at Location 8 until the fleet achieves 70% electrification. These locations highlight the complexities and necessity for planning EVSE infrastructure and charging impacts in combination with near-, medium-, and long-term EV procurement planning.

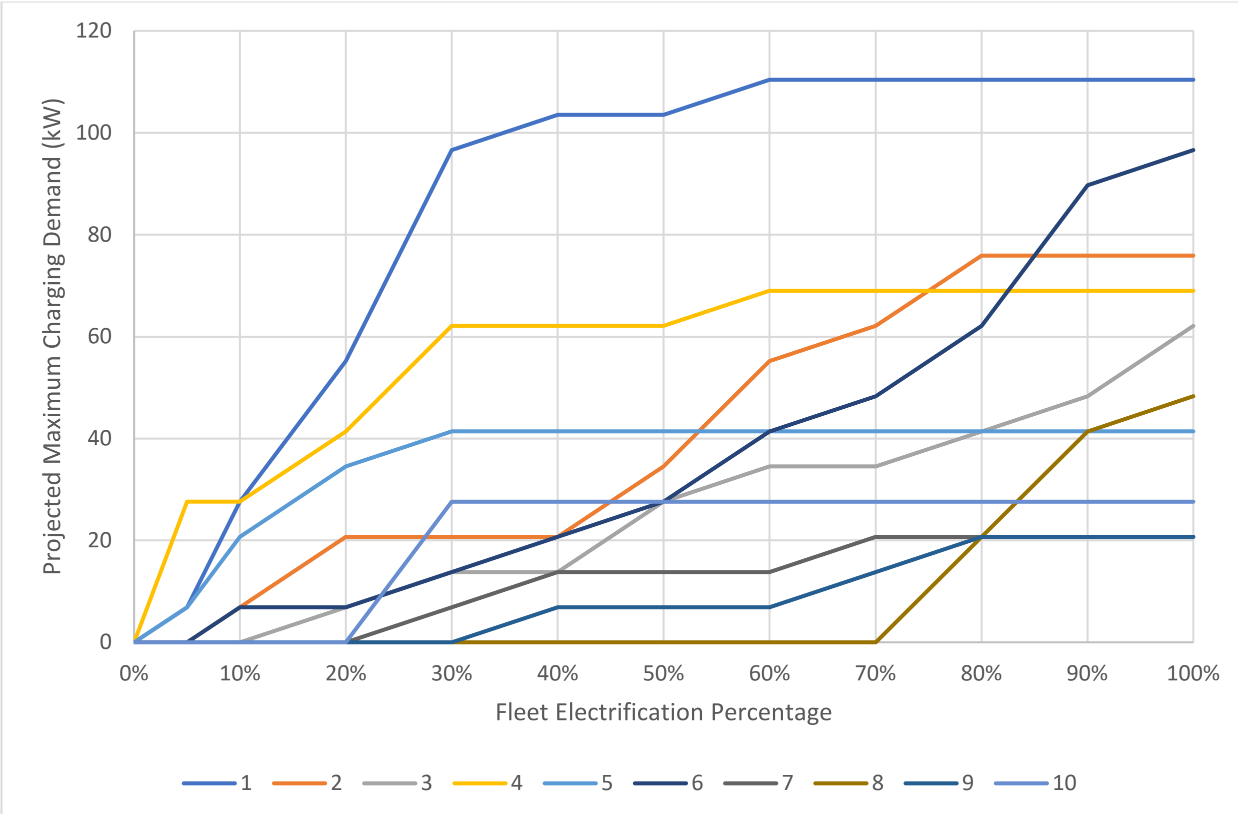

Figure 5. Maximum charging demand increase at select locations: Minnesota

As highlighted in Figure 5, the optimal deployment of EVs based on the ezEV analysis will not be uniformly distributed across all locations. Some locations will see electrification increase quicker than others, resulting in higher maximum charging demands and the need for more EVSE. This is clear with Locations 1, 4, and 5 seeing the most rapid increases in charging demand, with Location 5 reaching the highest peak demand (62.1 kW) after 30% fleet electrification and Locations 1 and 4 each reaching their highest demand (110.4 and 69.0 kW, respectively) after 60% fleet electrification. These fleet electrification percentage metrics are based off fleets prioritizing EV acquisitions by their ezEV scores, with the highest-scoring vehicles being acquired first. However, in order to optimize EVSE deployment, fleets may want to look at all of the electrification candidates in Locations 1, 4, and 5 to consider focusing on electrifying those vehicles first. This would mean vehicle acquisitions, as well as EVSE installations, would be focused at these three locations first, while a fleet may hold off on acquisitions at locations where charging demand ramp is more delayed.

An example of this delayed ramp is most apparent with Locations 7 and 9, where electrification does not even begin until 30% and 40%, respectively. Each of these locations also do not reach their maximum charging demand (20.7 kW each) until 70% and 80%, respectively. This suggests that fleets may want to consider holding off initial EV acquisitions until later years, when all required EVSE at each site can be installed at once. These discrepancies between location demand ramp and EVSE needs help fleets understand the best timelines for EV acquisitions, as informed by both operational feasibility through EV suitability assessments and optimal EVSE deployment through charging demand analysis.

This same discrepancy can be found throughout different fleets, with projected charging trends varying across the three states analyzed. Figure 6 details the maximum charging demand for each of the three participating fleets across varying levels of fleet electrification. Both Colorado and Minnesota are projected to see rapid increases in charging demand at some state fleet parking facilities. This suggests a need for more rapid deployments of EVSE to serve this need. However, North Carolina is projected to see a more gradual increase in projected maximum charging demand, likely resulting in the option to deploy EVSE more gradually over time as demand increases.

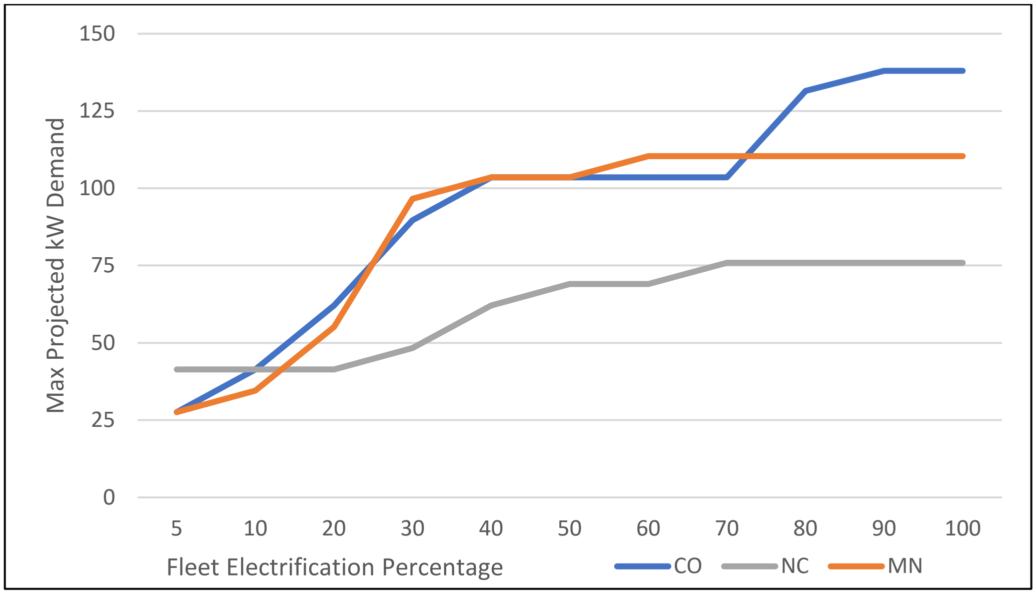

Figure 6. Projected maximum kilowatt demand at location with highest demand: all fleets

Conclusions

As state fleets move beyond initial EV procurement to meeting broader fleet electrification goals, it will be critical for fleet managers to understand the potential impact of EV charging on their facility's overall electricity demand. Due to the complexity of installing EVSE at some facilities, it is critical for fleet managers to consider their near-, medium-, and long-term EV procurement plans. This will help fleets ensure the deployment of necessary charging infrastructure is completed in tandem with vehicle procurement and a growing demand. This analysis is intended to help identify peak demand concerns and opportunities for state fleets to mitigate the impacts of this new load on the broader facility and the level of EV charging demand at state fleet parking facilities. The following list of considerations summarizes the key takeaways from this analysis:

- It is critical to understand a vehicle's energy needs (based on daily vehicle miles traveled) and charging window (based on vehicle dwell periods) to assess potential charging impacts.
- Locations where many vehicles are charging concurrently will result in a high charging demand. If this charging demand coincides with nearby facility peak demands, EV charging could create an increase in utility bill demand charges.

- Vehicles with a dwell period that exceeds the duration required to charge could reduce charging power or shift charging to later periods in the day to mitigate peak demand.
- When planning for electrification, fleets should consider optimizing EVSE installations by focusing early EV acquisitions and EVSE deployment at locations where charging demand is projected to increase quickly, as well as delaying EV acquisitions and EVSE installations where charging demand is expected to increase more gradually.

Fleet electrification planning and implementation efforts expand beyond the typical fleet staff responsibilities and often require coordination across departments such as facilities, sustainability, and procurement. Understanding the peak demand of EV charging is just the beginning. Fueling with electricity and the impact that has on a location's utility bills is new to many fleet managers, but part of the daily requirements for most facility managers. Therefore, many fleets must coordinate with facilities to incorporate this analysis with facility load management to determine the coincident peak between fleet charging and facility loads and the resulting energy bill impacts. This coordination is also important when planning for EVSE deployment and selecting the optimal locations for early adopters, which in addition to being impacted by charging demand predictions, should also be scheduled with other facility construction projects such as resurfacing parking lots or garage improvements.

Analyzing the daily driving for each vehicle allows fleets to determine a vehicle's energy needs and dwell period, as well as predictions for charging demand. This level of detail can offer fleet personnel the confidence needed to justify changes to operations and information needed to determine the optimal electrification plan. Indeed, these are crucial metrics when planning for the acquisition of EVs and can also highlight the value of sophisticated solutions such as managed charging that can coordinate fleet and facility needs in a way that keeps energy costs low.

Future Research

This analysis focuses on light-duty EVs because models of those vehicles are becoming more widely available to fleets. Growth in medium- and heavy-duty EVs is expected over the next few years, and there is much interest on the part of state fleets in understanding how those vehicles could meet their needs and how to best manage charging. As more medium- and heavy-duty EVs become available, fleets may find it useful to conduct a similar analysis with their medium- and heavy-duty vehicles.

This analysis also makes some assumptions on fleet operations. All charging demand analysis in this report assumes vehicle travel patterns and dwell periods for EVs will be similar to current ICE vehicle fleets. However, charging EVs nightly at fleet facilities will be quite different from current fueling behaviors, introducing both opportunities and challenges. It is highly likely that fleet electrification efforts will result in updated operations that meet the same mission requirements. Therefore, fleets that have already begun the electrification process may benefit from updated telematics analysis to determine if fleet operations have changed, and how those changes can better inform future electrification efforts.

Appendix A. State of Colorado

Colorado provided telematics data for 657 state fleet vehicles. The data covered operation of these vehicles from October 19, 2018, through April 3, 2021. Notably, this period includes months in which the COVID-19 pandemic affected fleet operations and associated vehicle operations such that driving patterns were less than normal, according to Colorado personnel.

Table A-1. Colorado Fleet Summary

Category	Stats
Vehicles	657
Telematics provider	Geotab
Period of analysis	10/19/2018–4/3/2021
Miles analyzed	5,200,000
Total trips analyzed	460,000

A.1 EV Suitability Assessment

Of the 657 Colorado fleet vehicles analyzed, 49 are good candidates for replacement with an EV within the same vehicle class, and 110 are good candidates if pickups and minivans can be replaced with an SUV. If all the vehicles with a good in-class replacement are replaced, the estimated lifetime savings[8] for the entire set of vehicles analyzed would be about $160,000, and the GHG emissions reductions would be about 1,500 metric tonnes.

Table A-2. Colorado EV Suitability Assessment Results

Vehicle Class	# of Vehicles Analyzed	EV Candidates (in class)
Cargo-van	42	3
Minivan	52	8
Pickup	162	9
Sedan	191	14
SUV	210	15
TCO savings	-	*$160,000*
GHG emissions reductions	-	*1,500 metric tonnes*

- About 7% of the sedans and SUVs analyzed were identified as good candidates for replacement with an EV. There is an EV on the market that meets the daily driving range of 76% of the sedans analyzed and about 92% of the SUVs analyzed.
- The driving range of EVs available on the market today can meet the needs of about 86% of the Colorado vehicles analyzed. For the remaining 14%, the EV driving range would be a limiting factor, requiring midday charging more frequently than three times per month.

[8] Lifetime savings are calculated based on the estimated TCO and include the cost of the vehicle, maintenance, fueling, insurance, and depreciation.

- Economics is the primary reason that many vehicles were not determined to be a good fit for replacement with an EV. The projected TCO of an EV is more than 5% higher than the comparable ICE vehicle for 67% of the vehicles analyzed.
- Approximately 58% of the vehicles parked at multiple locations more than 25% of their extended parking periods. This could present difficulties in ensuring these vehicles have access to charging infrastructure. It is worth noting that this high frequency of disparate parking may be due, in part, to the fact that the data set included over 2 years of data. If vehicles were reassigned to different departments or use cases, this change in parking would be captured in the analysis, but without the context that the vehicle has moved permanently to a new location. For vehicles that do not consistently park at the same location, it is worthwhile for the fleet to consider the most recent parking patterns and if those are indicative of the parking patterns that might be expected to continue.
- The pickup trucks were compared against the Rivian R1T, the Ford F150 Lightning Pro, and two theoretical pickup trucks intended to reflect the likely vehicle models available in the next few years from major original equipment manufacturers. Of the 162 pickups analyzed, 9 were identified as good candidates for an electric pickup truck. Economics is the primary limiting factor, as the cost of the electric pickup models is expected to initially be much higher than fleet pricing on ICE pickup trucks. Only 13% of the trucks had daily energy demands that would exceed the driving range of the electric pickup options.
- Approximately 15% of the minivans analyzed are good candidates for replacement with the Chrysler Pacifica, and about 7% of the cargo vans are good candidates for replacement with the Ford eTransit.

A.2 EV Charging Impact at Varying Electrification Levels

Based on the telematics data, the primary extended dwell locations were identified for each vehicle to locate the likely charging location. For Colorado, there were about 280 unique primary extended dwell locations identified across the fleet. The daily projected charging demand at varying levels of fleet electrification was determined based on (1) the time at which each vehicle arrived at the parking facility and did not take another trip for the rest of the day, and (2) the amount of energy needed to support the driving conducted that day. The projected charging demand for each vehicle at a location was layered together to build a charging demand curve for each day analyzed. The analysis assumes unmanaged charging where vehicles begin charging immediately upon being parked, and charging occurs on Level 2 6.9-kW EVSE until the battery is fully charged.

At increasing levels of fleet electrification from 5% to 100%, the projected charging demand was determined at each primary dwell location (Figure A-1). At 5% fleet electrification, the parking facility with the highest projected charging demand would have four vehicles charging concurrently, and the peak charging demand is estimated as 27.6 kW. For the Colorado fleet, increasing fleet electrification up to 40% is projected to result in a steep increase in charging demand at the location with the highest projected charging demand. From 40% to 70% fleet electrification, there is no additional impact on the charging demand at the location with the highest projected demand as vehicles across different locations are converted to EVs.

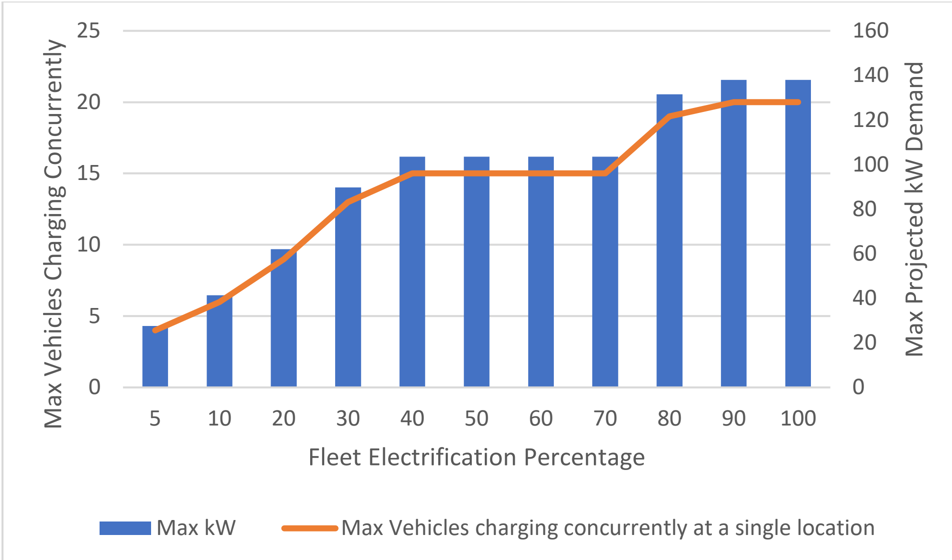

Figure A-1. Projected EV charging demand at increasing fleet electrification levels at the parking facility with the highest projected demand: Colorado[9]

The projected maximum charging demand for each month was addressed at all Colorado parking facilities. The results for a single state parking facility at increasing levels of fleet electrification are provided in Figure A-2. For this location, the energy demand from charging increases 400% from 5% to 40% fleet electrification. However, the charging demand at higher fleet electrification is projected to remain stable because no additional vehicles would charge concurrently.

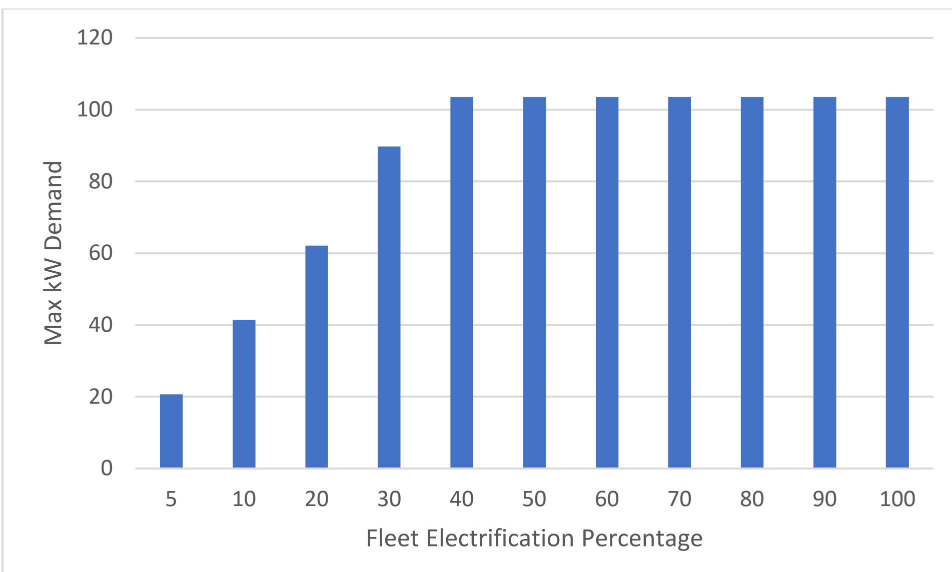

Figure A-2. Projected EV charging demand at a single parking facility at increasing fleet electrification levels: Colorado

[9] The parking location at each level of fleet electrification may be unique. The figure identifies the maximum charging demand at the parking facility with the highest demand at that electrification rate.

Appendix B. State of Minnesota

Minnesota provided telematics data for 1,778 state fleet vehicles. The data covered operation of these vehicles from February 28, 2019, through March 1, 2020.

Table B-1. Minnesota Fleet Summary

Category	Stats
Vehicles	1,778
Telematics provider	Verizon Networkfleet
Period of analysis	2/28/2019–3/1/2020
Miles analyzed	21,000,000
Total trips analyzed	883,000

B.1 EV Suitability Assessment

Of the 1,778 Minnesota fleet vehicles analyzed, 1,022 are good candidates for replacement with an EV within the same vehicle class and 1,162 are good candidates if pickups and minivans can be replaced with an SUV. If all the vehicles with a good in-class replacement are replaced, the estimated lifetime savings[10] for the entire set of vehicles analyzed would be about $4.7 million, and the GHG emissions reductions would be about 10,280 metric tonnes.

Table B-2. Minnesota EV Suitability Assessment Results

Vehicle Class	# of Vehicles Analyzed	EV Candidates (in class)
Cargo-van	54	20
Minivan	361	173
Pickup	101	71
Sedan	647	344
SUV	615	414
TCO savings	-	*$4,700,000*
GHG emissions reductions	-	*10,280 metric tonnes*

- About 70% of the pickup trucks and SUVs analyzed were identified as good candidates for replacement with an EV.
- The driving range of EVs available on the market today can meet the needs of about 93% of the Minnesota vehicles analyzed. For the remaining 7%, the EV driving range would be a limiting factor, requiring midday charging more frequently than three times per month.
- Even with only a 5-year expected lifetime in the fleet, 88% of the vehicles are projected to achieve sufficient operational savings to offset the higher upfront cost of the comparable EV.

[10] Lifetime savings are calculated based on the estimated TCO and include the cost of the vehicle, maintenance, fueling, insurance, and depreciation.

- Approximately 28% of the vehicles parked at multiple locations more than 25% of their extended parking periods. This could present difficulties in ensuring these vehicles have access to charging infrastructure. It is worth noting that this high frequency of disparate parking may be due, in part, to the fact that the data set included a full year of data. If vehicles were reassigned to different departments or use cases, this change in parking would be captured in the analysis, but without the context that the vehicle has moved permanently to a new location. For vehicles that do not consistently park at the same location, it is worthwhile for the fleet to consider the most recent parking patterns and if those are indicative of the parking patterns that might be expected to continue.
- The pickup trucks were compared against the Rivian R1T, the Ford F150 Lightning Pro, and two theoretical pickup trucks intended to reflect the likely vehicle models available in the next few years from major original equipment manufacturers. Of the 101 pickup trucks analyzed, 71 were identified as good candidates for an electric pickup truck. Variable parking is the primary limiting factor, as 29 of the pickup trucks parked at multiple locations more than 25% of the time. Only 10 of the trucks had daily energy demands that would exceed the driving range of the electric pickup options.
- Nearly 50% of the minivans analyzed are good candidates for replacement with the Chrysler Pacifica, and about 37% of the cargo vans are good candidates for replacement with the Ford eTransit.

B.2 EV Charging Impact at Varying Electrification Levels

Based on the telematics data, the primary extended dwell locations were identified for each vehicle to locate the likely charging location. For Minnesota, there were about 980 unique primary extended dwell locations identified across the fleet. The daily projected charging demand at varying levels of fleet electrification was determined based on (1) the time at which each vehicle arrived at the parking facility and did not take another trip for the rest of the day, and (2) the amount of energy needed to support the driving conducted that day. The projected charging demand for each vehicle at a location was layered together to build a charging demand curve for each day analyzed. The analysis assumes unmanaged charging where vehicles begin charging immediately upon being parked, and charging occurs on Level 2 6.9-kW EVSE until the battery is fully charged.

At increasing levels of fleet electrification from 5% to 100%, the projected charging demand was determined at each primary dwell location (Figure B-1). At 5% fleet electrification, the parking facility with the highest projected charging demand would have four vehicles charging concurrently, and the peak charging demand is estimated as 27.6 kW. For the Minnesota fleet, increasing fleet electrification from 5% to 40% is projected to result in a 275% increase in charging demand at the location with the highest projected charging demand. However, fleet electrification levels above 60% are not projected to result in increasing charging demand at the location with the highest charging demand.

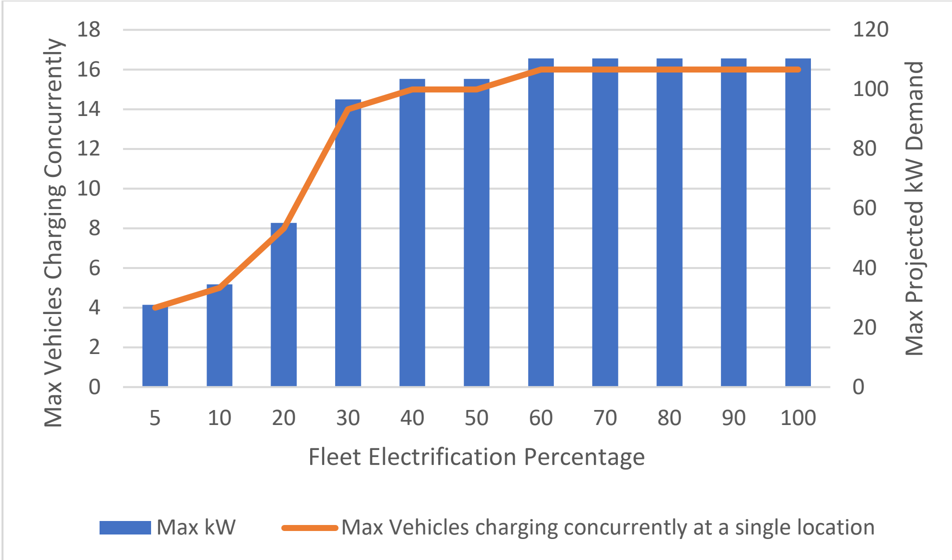

Figure B-1. Projected EV charging demand at increasing fleet electrification levels at the parking facility with the highest projected demand: Minnesota[11]

The projected maximum charging demand for each month was addressed at all Minnesota parking facilities. The results for a single state parking facility at increasing levels of fleet electrification are provided in Figure B-2. For this location, the energy demand from charging increases 1,400% from 5% to 40% fleet electrification. However, the charging demand at higher fleet electrification is projected to remain stable because no additional vehicles would charge concurrently.

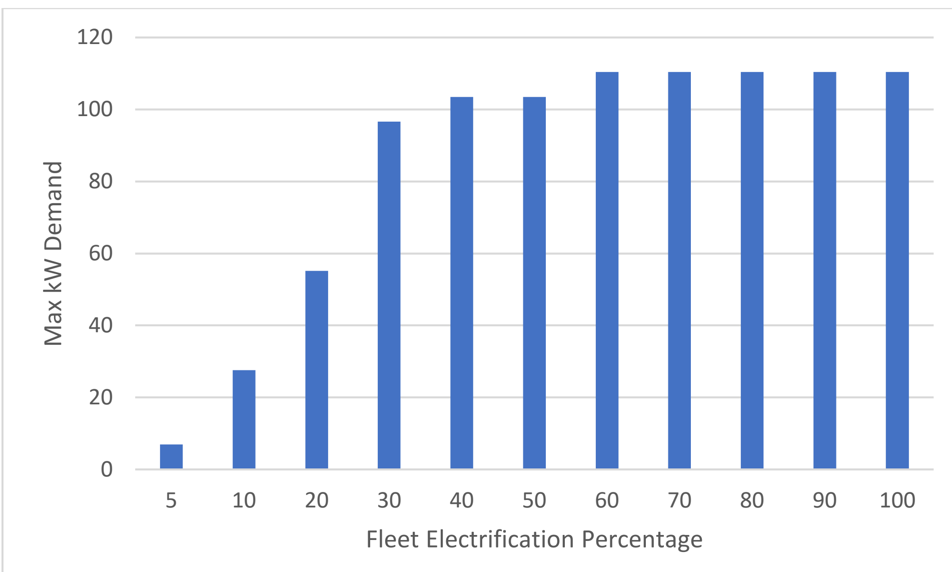

Figure B-2. Projected EV charging demand at a single parking facility at increasing fleet electrification levels: Minnesota

[11] The parking location at each level of fleet electrification may be unique. The figure identifies the maximum charging demand at the parking facility with the highest demand at that electrification rate.

Appendix C. State of North Carolina

North Carolina provided telematics data for 5,901 state fleet vehicles. The data covered operation of these vehicles from February 23, 2018, through January 16, 2020. Although more recent data were available, the fleet preferred the analysis be conducted on the vehicles based on their normal operations prior to the COVID-19 pandemic.

Table C-1. North Carolina Fleet Summary

Category	Stats
Vehicles	5,901
Telematics provider	Geotab
Period of analysis	2/23/2018–1/16/2020
Miles analyzed	64,000,000
Total trips analyzed	2,990,000

C.1 EV Suitability Assessment

Of the 5,901 North Carolina state fleet vehicles analyzed, 2,804 are good candidates for replacement with an EV within the same vehicle class, and 3,040 are good candidates if pickups and minivans can be replaced with an SUV. If all the vehicles with a good in-class replacement are replaced, the estimated lifetime savings[12] for the entire set of vehicles analyzed would be about $13 million, and the GHG emissions reductions would exceed 66,000 metric tonnes.

Table C-2. North Carolina EV Suitability Assessment Results

Vehicle Class	# of Vehicles Analyzed	EV Candidates (in class)
Cargo-van	25	5
Minivan	687	235
Pickup	170	30
Sedan	3,968	2,020
SUV	1,051	514
TCO savings	-	*$13,000,000*
GHG emissions reductions	-	*66,000 metric tonnes*

- The driving range of EVs available on the market today can meet the needs of about 93% of the North Carolina vehicles analyzed.
- About 50% of the sedans and SUVs analyzed were identified as good candidates for replacement with an EV. There is an EV on the market that meets the daily driving range of 95% of the sedans analyzed and about 76% of the SUVs analyzed.
- It is projected that operational savings would not be sufficient to offset the higher upfront cost of an EV for 18% of the vehicles analyzed. However, that leaves a substantial

[12] Lifetime savings are calculated based on the estimated TCO and include the cost of the vehicle, maintenance, fueling, insurance, and depreciation.

number of vehicles projected to achieve a lower TCO than a comparable ICE vehicle already, based on the EV models and pricing available to the state as of May 2021.

- Approximately 55% of the vehicles parked at multiple locations more than 25% of their extended parking periods. This could present difficulties in ensuring these vehicles have access to charging infrastructure. It is worth noting that this high frequency of disparate parking may be due, in part, to the fact that the data set included nearly 2 years of data. If vehicles were reassigned to different departments or use cases, this change in parking would be captured in the analysis, but without the context that the vehicle has moved permanently to a new location. For vehicles that do not consistently park at the same location, it is worthwhile for the fleet to consider the most recent parking patterns and if those are indicative of the parking patterns that might be expected to continue.
- The pickups were compared against the Rivian R1T, the Ford F150 Lightning Pro, and two theoretical pickups intended to reflect the likely vehicle models available in the next few years from major original equipment manufacturers. Of the 170 pickups analyzed, 30 trucks were identified as good candidates for the theoretical pickup trucks. Economics is the primary limiting factor, as the cost of the electric pickup models is expected to initially be much higher than fleet pricing on ICE pickups.
- Approximately one-third of the minivans analyzed are good candidates for replacement with the Chrysler Pacifica, and about one-fifth of the cargo vans are good candidates for replacement with the Ford eTransit.
- The ezEV scores for the fleet indicate that sedans and SUVs are most suitable for conversion to EVs.

C.2 EV Charging Impact at Varying Electrification Levels

Based on the telematics data, the primary extended dwell locations were identified for each vehicle to locate the likely charging location. For North Carolina, there were about 3,270 unique primary extended dwell locations identified across the fleet. The daily projected charging demand at varying levels of fleet electrification was determined based on (1) the time at which each vehicle arrived at the parking facility and did not take another trip for the rest of the day, and (2) the amount of energy needed to support the driving conducted that day. The projected charging demand for each vehicle at a location was layered together to build a charging demand curve for each day analyzed. The analysis assumes unmanaged charging where vehicles begin charging immediately upon being parked, and charging occurs on Level 2 6.9-kW EVSE until the battery is fully charged.

At increasing levels of fleet electrification from 5% to 100%, the projected charging demand was determined at each primary dwell location (Figure C-1). At 5% fleet electrification, the parking facility with the highest projected charging demand would have six vehicles charging concurrently, and the peak charging demand is estimated to be 41.4 kW. For the North Carolina fleet, increasing fleet electrification from 20% to 70% is projected to result in an 83% increase in charging demand at the location with the highest projected charging demand. However, fleet electrification levels above 70% are not projected to result in increasing charging demand at the location with the highest charging demand.

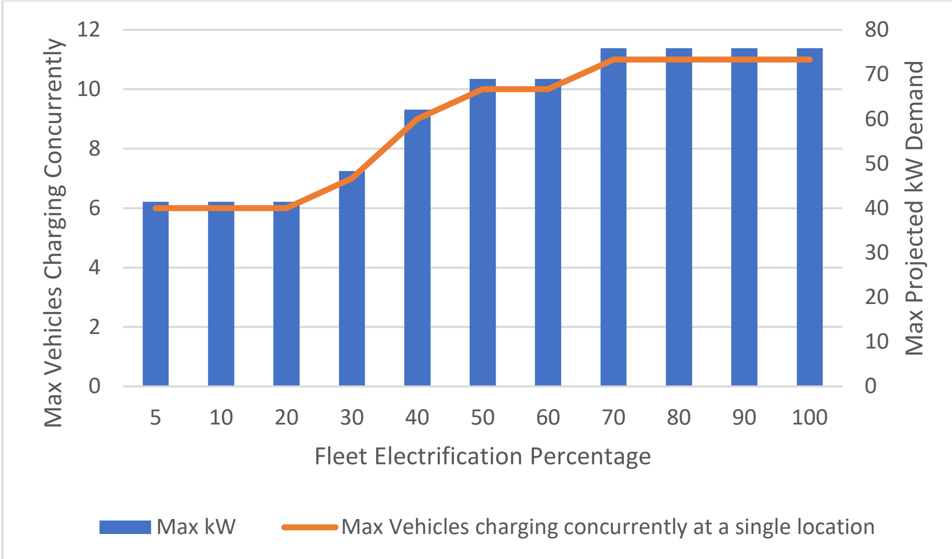

Figure C-1. Projected EV charging demand at increasing fleet electrification levels at the parking facility with the highest projected demand: North Carolina[13]

The projected maximum charging demand for each month was addressed at all North Carolina parking facilities. The results for a single state parking facility showing the projected charging demand at increasing levels of fleet electrification are provided in Figure C-2. For this location, the energy demand from charging increases 900% from 5% to 50% fleet electrification. However, the charging demand at higher fleet electrification is projected to remain stable because no additional vehicles would charge concurrently.

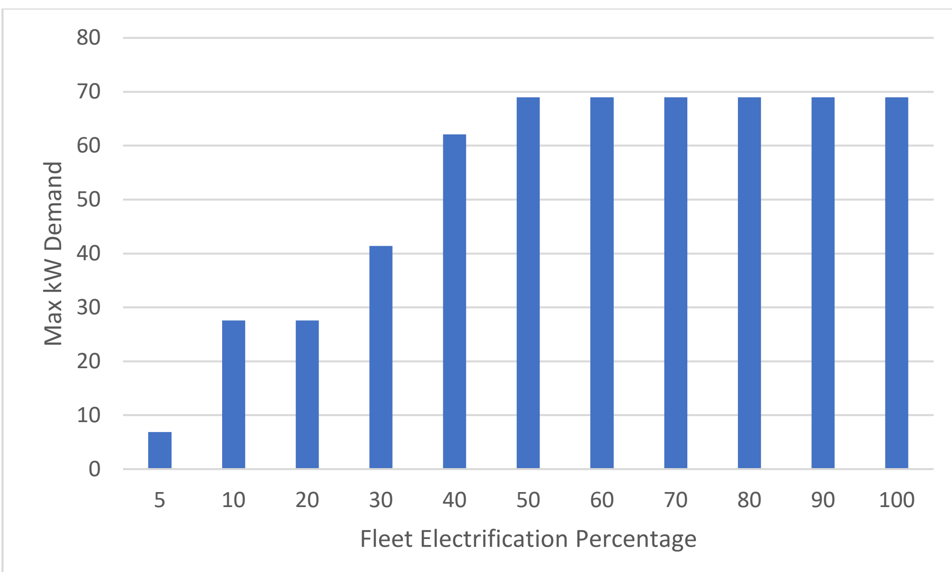

Figure C-2. Projected EV charging demand at a single parking facility at increasing fleet electrification levels: North Carolina

[13] The parking location at each level of fleet electrification may be unique. The figure identifies the maximum charging demand at the parking facility with the highest demand at that electrification rate.