ACT Now: Impacts of the Advanced Clean Trucks Rule on the Electric Grid and Fleets

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Note

The work presented is a product of RMI. Data used in the analysis was provided and approved by Geotab ITS in accordance with Geotab ITS privacy policies.

Data used in this analysis can be explored in greater depth at our accompanying web-based dashboard, available at: **https://rmi.org/early-trucking-electrification-in-act-states**.

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RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and nongovernmental organizations to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

About Geotab ITS

With access to one of the world's largest organically grown transportation data sets, Geotab ITS aggregates data from millions of connected vehicles to produce actionable transportation insights and urban analytics for transportation leaders across the United States and Canada. These insights are driven by privacy-by-design principles and are provided through the Geotab ITS Altitude Platform, a secure, modular, open-transportation analytics platform that enables partners and customers to quickly interact with the insights and to make informed decisions to improve safety, efficiency, sustainability, and profitability of the infrastructure they are responsible for. To learn more, please visit **its.geotab.com** and follow @GeotabITS on LinkedIn.

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The North American Council for Freight Efficiency (NACFE) works to drive the development and adoption of efficiency-enhancing, environmentally beneficial, and cost-effective technologies, services, and operational practices in the movement of goods across North America. NACFE provides independent, unbiased research, including Confidence Reports on available technologies and Guidance Reports on emerging ones, which highlight the benefits and consequences of each and deliver decision-making tools for fleets, manufacturers, and others. NACFE partners with RMI on a variety of projects (including the Run on Less demonstration series) and other work on electric trucks, emissions reductions, and low-carbon supply chains. Visit **NACFE.org** or follow on X (formerly Twitter) @NACFE_Freight.

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Executive Summary

Annually, trucks in the United States move 10 billion tons of goods over 300 billion miles and emit more than 400 million metric tons of carbon dioxide equivalent, representing 23% of the US transportation sector's carbon footprint. With this sizable contribution to emissions, electrifying medium-duty (MD) and heavy-duty (HD) vehicles will be critical to meeting climate targets.

Inadequate charging will likely be the biggest bottleneck to electrification. Electric trucks, whether charging at a depot or using public corridor charging, require high-power chargers ranging from 50 to over 750 kilowatts (kW). Strategic, proactive planning for these high-power charger installations is important as they often require grid infrastructure upgrades, which can be costly and slow.

In this report, we analyze telematics data from Geotab ITS in 15 states that, as of 2021 when this study began, planned to implement Advanced Clean Trucks (ACT) regulations.[i] To ensure this strategic, proactive planning, policymakers, utilities and their regulators, fleets, and electric vehicle service providers will need to answer the following questions:

1. **How much energy and how many chargers will electric MD and HD trucks need?**

   The most likely trucks to electrify in compliance with ACT regulations will be those internal combustion engine (ICE) trucks that drive up to 300 miles before returning to a depot to charge — the maximum range of a typical electric truck. In aggregate across our study geography, we find that 60% of ICE MD trucks and 43% of ICE HD trucks largely follow this operational pattern. Throughout this paper, we refer to those vehicles as "electrifiable" or "easily electrifiable." Based on this, we find that compliance with ACT is achievable until 2040 with today's technology, and states should have few reservations about their ability to meet ACT sales targets.

   For these electrifiable vehicles, we estimate average daily energy demands of 172 kilowatt-hours (kWh) per MD truck and 427 kWh per HD truck, based on observed travel patterns. Critically important, we find that almost all charging needs for those vehicles could be met with either a standard 75 kW power charger or a higher-power 150 kW charger, both readily available on the market today.

2. **Where will energy demand increase, and what will be the impact of this increase on the electric grid?**

   Energy demand and peak power from electrifiable trucks will be highest in urban areas that have larger truck populations. Rural areas generally have the lowest energy demand, although in many rural

i Since this study started, two additional states (Virginia and Nevada) have signed the 100% Zero-Emission Truck MOU, signaling alignment with the Advanced Clean Trucks rule, and one state (New Mexico) adopted ACT. These three states and Washington, D.C., are not included in our analysis.

counties, estimated daily energy demand can exceed 1 megawatt-hour (MWh). Even this relatively small new load could require grid infrastructure upgrades. Suburban counties have an intermediate, but still sizable, estimated energy demand, typically in the hundreds of MWh. We encourage policymakers and utilities to pay close attention to industry trends and how fleets balance costs and make depot siting decisions, as energy demand and associated investment could be much higher than we estimate depending on how truck depots cluster and charger power used at depots.

3. **Where is infrastructure investment needed, and how can costs be reduced?**

   Aligned with our expectation that early electric truck adopters will charge at a depot, we find that electric load peaks in the evening and overnight when trucks are parked and is significantly lower during the day when trucks are in operation. There is significant potential for MD and HD trucks to share chargers to help fleets reduce costs and avoid grid infrastructure upgrades. We find that approximately 10 typical MD trucks or five HD trucks could share a single 150 kW charger and still be fully charged by the next morning.

4. **How should stakeholders prioritize investments to ensure that they are made equitably?**

   Deciding where to prioritize charging infrastructure investments involves balancing factors such as fleet needs, equity, health impacts, and grid impact. We encourage readers to explore and view the data in this report more closely at our accompanying dashboard, available at **https://rmi.org/early-trucking-electrification-in-act-states**.

Introduction

Road freight and goods movement form the backbone of the American economy and are especially critical with the growth of e-commerce and increasingly important to global supply chains. Road freight in the United States moves 10 billion tons of goods over 300 billion miles annually,[1] emits more than 400 million metric tons of carbon dioxide equivalent,[2] and has a negative impact on air quality. The emissions generated by medium- and heavy-duty (MHD) vehicle classes are considerable: although they make up only 10% of vehicles on the road, they represent 23% of the US transportation sector's carbon footprint.[3]

Because of their outsize effects on air quality and significant greenhouse gas emissions, MHD vehicle electrification will be critical to meeting climate targets. Fortunately, electric MHD (eMHD) vehicle adoption continues to grow, thanks to technological advances including decreasing battery costs, new policies that improve affordability, and wider availability of electric models. Today, there are more than 150 eMHD vehicle models available in North America from more than 30 manufacturers, and many more are expected to enter the market.[ii]

Regulation spearheaded by California, including the Advanced Clean Trucks (ACT)[4] rule and the Advanced Clean Fleets (ACF) rule,[5] requires automakers and fleet operators to electrify their trucks at increasing rates over the coming decades starting in 2024. The federal Inflation Reduction Act (IRA) also provides funding for electric trucks and associated charging infrastructure, bringing electric truck costs down, closer to parity with diesel trucks.[6]

Although this progress is encouraging, today's inadequate charging infrastructure is likely to become the most critical bottleneck to widespread MHD electrification. The ACT rule focuses on requirements for vehicle sales, and it is likely that the purchasing fleets will be those operating in market segments that are well suited to electric trucks — moderate range, return-to-base applications. Early adopters are generally reliant on depot charging because public and shared charging infrastructure for trucks is still in its earliest phase.[iii]

To meaningfully advance MHD electrification, stakeholders will need to focus on installing the high-power depot chargers that eMHDs require — electric trucks will need charging power ranging from 50 to 750 kW or more. Strategic, proactive planning for these high-power charger installations is critical, as they often require grid infrastructure upgrades that can be costly and slow.[7]

The need for immediate action becomes clear when we consider the alarming growth of utility interconnection queues and new service request wait times:[iv] according to a recent study, mandatory

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ii We note that the number of available model options does not necessarily reflect sales of actual vehicles or production volume.

iii Depot charging also allows the charging operator to earn low-carbon fuel standard credits and other incentives to help offset the capital cost of the trucks, something not possible with public charging.

iv The interconnection queue is the list of electricity generation projects awaiting utility assessments to connect to the electric grid; this will affect only very large depots or service plazas that are more likely to connect directly to transmission. Wait times are less of a concern for smaller depots that submit new electric service requests to their utilities for on-site chargers.

grid impact studies can take more than three years to complete in most regions.[8] Fleets will also need to engage with their utility up to a year before a connection request is made, further lengthening an already considerable lead time. This is particularly worrisome for fleets facing electrification regulations.

If we don't take meaningful steps toward improving eMHD vehicle charging infrastructure, we risk hindering or even stalling electric truck adoption. Policymakers, utilities and their regulators, fleets, electric vehicle service providers (EVSPs), and local, state, and regional governments need to answer the following questions to develop and implement successful charging infrastructure strategies:

1. **How much energy and how many chargers will electric MD and HD trucks need?**

2. **Where will energy demand increase, and what will be the impact of this increase on the electric grid?**

3. **Where is infrastructure investment needed, and how can costs be reduced?**

4. **How should stakeholders prioritize investments to ensure that they are made equitably?**

This report addresses these questions through a robust analysis, using aggregated and anonymized MHD telematics data from Geotab ITS. Our analysis focuses on the 15 states that had signed the 100% Zero-Emission Truck Memorandum of Understanding (MOU), or ACT MOU, as of 2021; however, our insights can be used broadly to inform strategic infrastructure investment priorities.[9] We focus on these ACT states because they have committed to advancing trucking electrification on a faster timeline and with more support than other states.

Although the barriers to grid preparation are considerable, they are not insurmountable. Stakeholders, armed with robust data such as that included in this paper (and available to explore in this report's accompanying dashboard at **https://rmi.org/early-trucking-electrification-in-act-states**), can and should take steps today to ensure that eMHDs can get on the road as seamlessly as possible.

How Much Energy and How Many Chargers Will eMHDs Need?

To address how much energy and how many chargers eMHDs will need, we need to know (1) which trucks will electrify and (2) the duty cycles (i.e., travel patterns) of those trucks. To do so, we need to understand the state of today's MHD vehicle market and what factors affect electrification potential.

Factors That Have an Impact on MHD Electrification

The eMHD vehicle market is in a state of rapid transition with several factors playing outsize roles:

ACT and ACF regulations: California has led the charge in regulating truck electrification, beginning with the ACT rule in 2020 and the Advanced Clean Fleet rule, approved in April 2023. ACT requires truck manufacturers to sell zero-emissions vehicles as an increasing percentage of their annual sales from 2024 to 2035.[10] ACF is designed to complement ACT and requires fleets to adopt an increasing percentage of zero-emissions trucks with an emphasis on drayage trucks, government-owned fleets, and larger fleets (those with 50 or more vehicles or at least $50 million in gross annual revenue).[11] Because of the size of their combined markets, these regulations could have a potent impact that drives national-scale adoption of eMHD vehicles especially as other states adopt similar rules. Today, 11 states have adopted the ACT rule — Oregon, Washington, New Jersey, New York, Massachusetts, Colorado, California, New Mexico, Maryland, Rhode Island, and Vermont. One state, Maine, has rulemaking underway; and six states — North Carolina, Connecticut, Pennsylvania, Virginia, Nevada, and Hawaii — and Washington, D.C., have signed the ACT MOU.[12]

Availability of eMHD vehicle models: In 2023, nearly 150 eMHD models were available in North America, mostly in the MD weight class comprising vans, walk-in vans, and box trucks.[13] Of these, about 35 models were available in the heavy-duty Class 7–8 weight class.

Improved eMHD vehicle range: For years, automakers have worked to improve eMHD vehicle range by increasing battery capacity and vehicle efficiency, a difficult task given that these powerful batteries are heavy and costly and that they tend to take up space that could be used for freight. Many of today's eMHD models are equipped with larger battery packs and designed to be aerodynamically efficient, resulting in ranges between 100 and 300 miles, with more model options becoming available that can travel greater than 300 miles on a single charge.[14] A single battery charge, though, does not cap how far a truck can travel in a day: adding opportunity charging at a depot has been demonstrated to enable significant distances, even exceeding 1,000 miles in a 24-hour multishift operation.[15]

Fleet commitments to electrify: Industry advancements, regulations, and sustainability goals have helped prompt fleet operators to commit to full vehicle electrification. eMHD trucks belonging to multinational corporations and smaller businesses that have participated in the North American Council for Freight Efficiency (NACFE) Run on Less event have shown that truck electrification is well under way and that real-world duty cycles can be electrified.[16]

Charging infrastructure network in development: Trucks that drive distances greater than the range of available eMHD models will likely need opportunity depot or public charging to electrify. Currently, there are few publicly available, high-power chargers that can support on-route charging for eMHD trucks. Helpfully, electric vehicle infrastructure tax credits are available through the IRA that cover 6% of installation costs for commercial uses up to $100,000 with an additional requirement that the chargers be installed in a low-income or non-urban area.[17] In the absence of available on-route chargers, fleets will in many cases prioritize electrifying trucks that return to and charge at a depot and will bear the cost of installing depot chargers and, potentially, the associated grid infrastructure upgrades.

Installing chargers at a depot today is a challenge for fleets. As noted previously, mandatory grid impact studies now take years to complete, and the time from an initial interconnection or service request to a fully operational site has increased to nearly four years.[18] Fleets planning a charging depot will also typically need to engage with their utility up to a year before the interconnection request is made.

"Our primary focus is on the urgent need to accelerate near-term electrification for those vehicles and duty cycles that are the easiest to electrify."

Defining Electrifiable MHD Vehicles

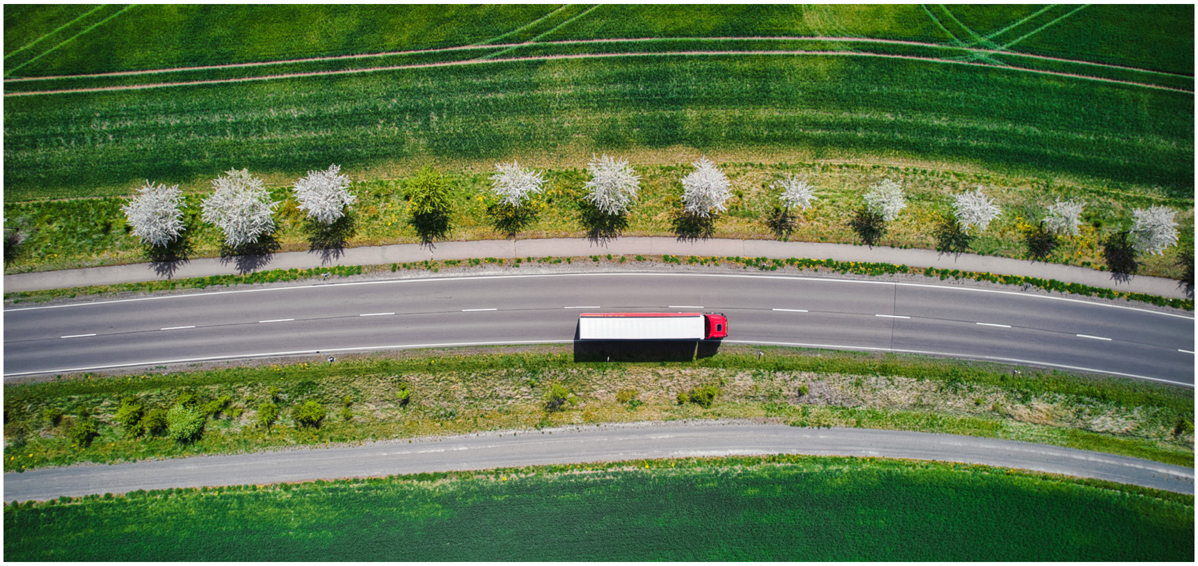
Given the state of today's eMHD market, the most likely trucks to electrify in compliance with ACT and ACF regulations will be those that drive 300 miles or fewer before returning to a depot to charge.

For our analysis, we define electrifiable vehicles as those that return to a depot after fewer than 300 miles of travel in 95% of trips. These criteria — limited travel distance and a return to a fixed base — are intended to capture the two primary constraints on the real-world operation of electric trucks: limited mileage range and lack of public or shared charging infrastructure. This definition of "electrifiability" aims to capture the segment of the trucking market that can be most easily electrified in the near term.[v]

In the long term, electric truck ranges will increase and public truck charging infrastructure will likely become more prevalent. Truck operations may also evolve over time to accommodate electrification more easily; for example, industry trends for the past few years have shown an increase in shorter journeys and a shift away from high-mileage routes.[19]

Our primary focus is on the urgent need to accelerate near-term electrification for those vehicles and duty cycles that are the easiest to electrify. This focus allows for accurate sizing of the near-term eMHD market and charging requirements, information that utilities and others can incorporate into their planning so that the grid will be prepared to meet projected demand while also reducing costs and wait time for fleets.

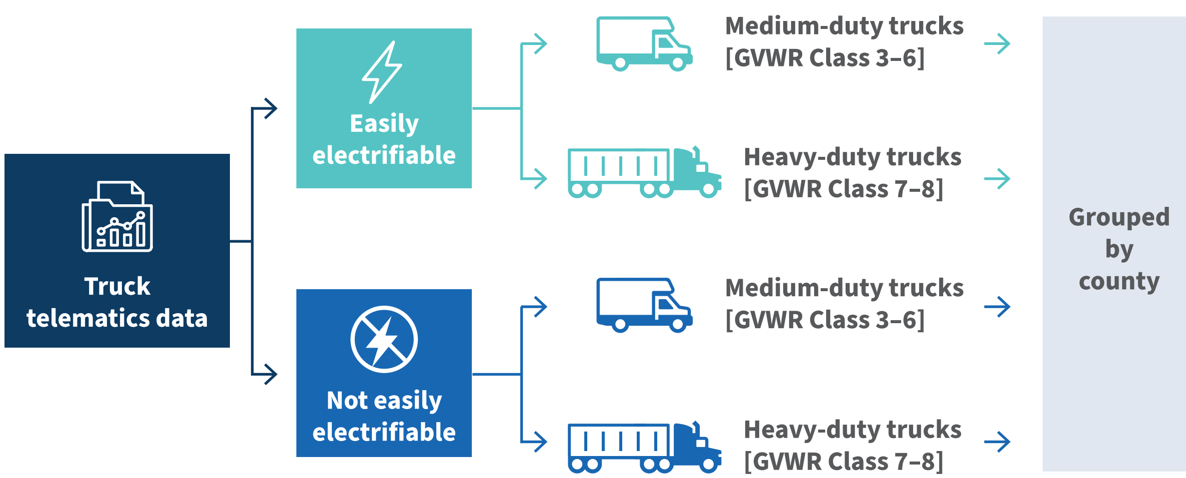
v We recognize that 300 miles is at the upper end of the range of existing models but will be within the demonstrated range of soon-to-be available models (based on preliminary results from the NACFE Run on Less DEPOT demonstration).



Travel Patterns of eMHD Vehicles

To estimate energy and charging needs for electrifiable MHDs, we need to know these vehicles' travel patterns. To this end, we analyze anonymized trucking telematics data from Geotab ITS, collected for calendar year 2022 from trucks operating in the 15 ACT states considered in this study. As shown in Exhibit 1, data was aggregated at the county level based on (1) trucks that meet our definition of electrifiability versus those that do not and (2) vehicle weight class. Because our definition of electrifiable trucks includes only trucks that return to a depot, Geotab ITS then identified and assigned a depot location to each truck, defined as the 1 square km area in which trucks spend the most time parked. All trucks domiciled in the same county are then aggregated together.

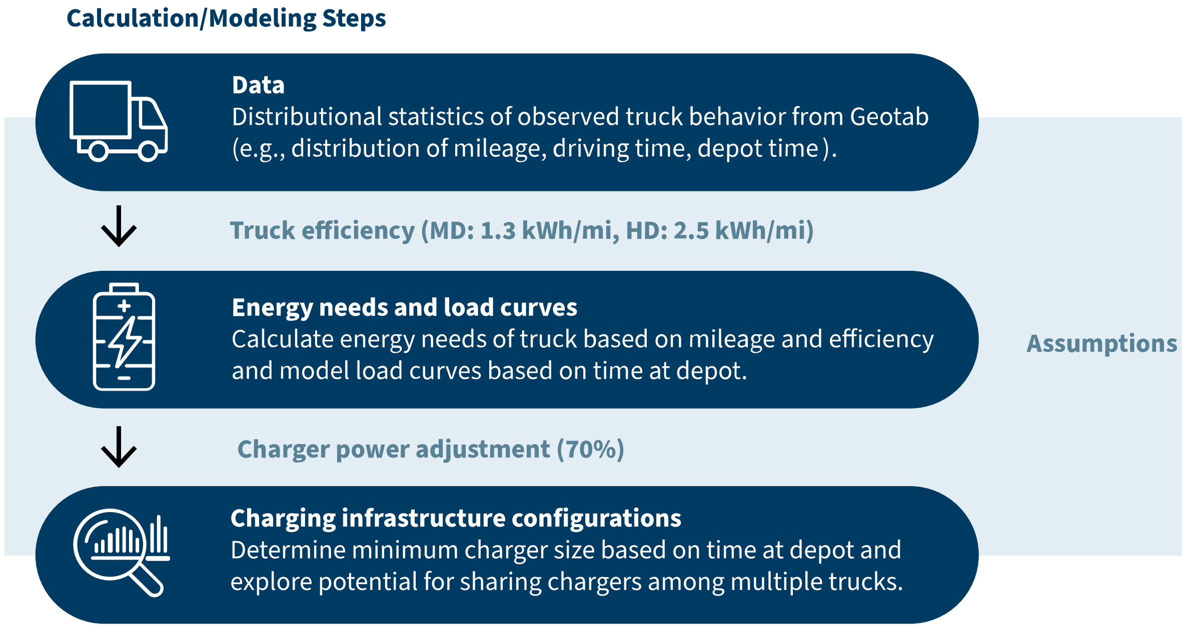
Exhibit 1 **Overview of Geotab ITS truck telematics data aggregation**



Note: GVWR stands for gross vehicle weight rating.

RMI Graphic. Source: Geotab ITS

Exhibit 2 **Graphical overview of methodology used to quantify energy needs and infrastructure configurations**



RMI Graphic. Source: Geotab ITS based on real-world truck telematics data

As outlined in Exhibit 2, the data provides aggregated distributional statistics of truck travel patterns (e.g., daily distance traveled, when and for how long vehicles are stopped at or away from depot, time driving). From those statistics, we calculate the energy needed to electrify those trucks' daily miles driven and charging infrastructure configurations that meet those energy needs. The travel pattern statistics are percentile-based (e.g., 50th or median, 75th, 95th percentiles): a 75th percentile day for miles traveled means that a typical truck drove fewer miles on 75% of all other days and drove more miles on 25% of other days.

We estimate daily energy demand per truck using daily mileage multiplied by energy efficiency. We assume that MD trucks consume an average of 1.3 kWh/mile and that HD trucks consume an average of 2.5 kWh/mile, consistent with the conservative estimate from demonstration results obtained from NACFE.[vi] We also assume that (1) chargers transfer power to vehicles at 70% of nameplate power rating and (2) efficiency is reduced 30% during winter months for vehicles in all states except Hawaii to account for reduced EV efficiency due to low temperatures.

We then estimate minimum charger power (kW) required to meet that energy demand using the 75th percentile of daily energy demand divided by the 50th percentile of time available at the depot to charge. This approach leads to a slightly conservative estimate for charger power because we are using a higher-mileage day (the 75th percentile) with fewer hours to charge (the 50th percentile). We will refer to this methodology as the "baseline charging scenario."

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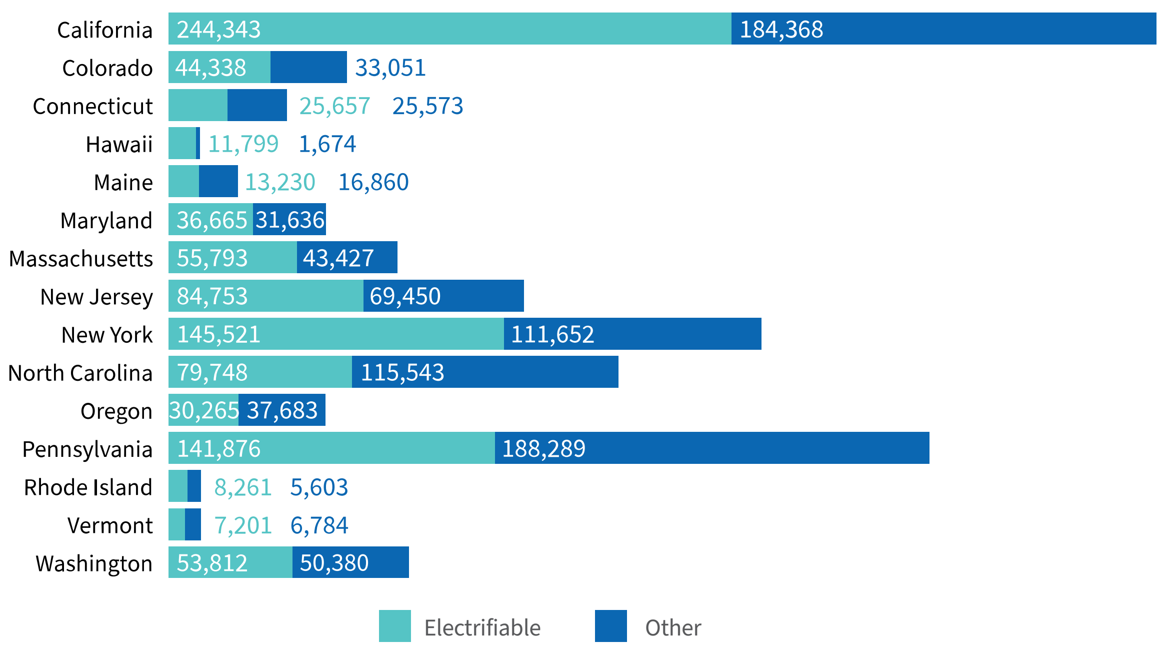
vi Real-world reports from NACFE show that eMHD vehicles are capable of better efficiencies with Tesla Semis (Class 8) reaching 1.7 kWh/mi while fully loaded.

Our final step is to scale the Geotab ITS population to correspond to the entire truck population based on the assumption that the Geotab ITS trucks are representative of the broader truck population. Our analysis includes telematics data from 156,369 trucks representing approximately 8% of the total MHD truck population in the 15 states covered by this study. More specific information about the data schema can be found in the Appendix.

Estimating Feasibility of Compliance with ACT Regulations

To begin, we identify which trucks can electrify based on our definition in the previous section. In aggregate, we find that 60% of MD trucks and 43% of HD trucks are electrifiable. Exhibit 3 shows total truck populations by state, categorized by whether electrifiable or not. By state, the electrifiable proportion of MD trucks ranges from 49% (North Carolina) to 90% (Hawaii) and, for HD trucks, between 33% (Oregon) and 83% (Hawaii).

Exhibit 3 **Combined MD and HD truck population by state, categorized by near-term electrifiability**

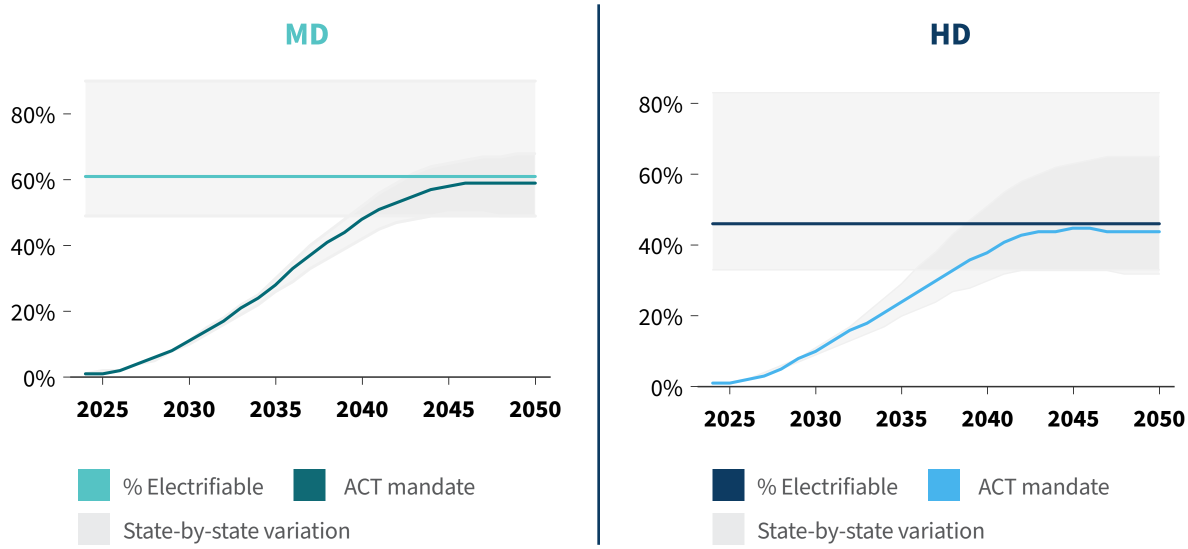


RMI Graphic. Source: Geotab ITS

These percentages are remarkable because, even using our narrow definition of electrifiable vehicles for this report, they are quite close to ACT sales targets, as shown in Exhibit 4 (next page). Although ACT mandates a varying percentage of electric truck sales, the solid curved lines convert those sales requirements into the proportion of MD and HD truck stock in operation (averaged over all states) that must be electrified based on ACT regulations. The horizontal line shows the proportion of vehicles that

Exhibit 4

Percentage of MD and HD trucks requiring electrification to comply with ACT sales targets versus percentage of each vehicle class that could electrify today



RMI Graphic. Source: Geotab ITS and Advanced Clean Trucks rule

are electrifiable today. The shaded areas in both show the upper and lower bounds of these values based on variation by state. When the two shaded areas overlap, this represents trucks that may not be able to electrify in compliance with ACT. The horizontal line is based on today's technology and will shift upward over time as technology improves (e.g., battery density, vehicle efficiency), reducing overlap between the two curves.

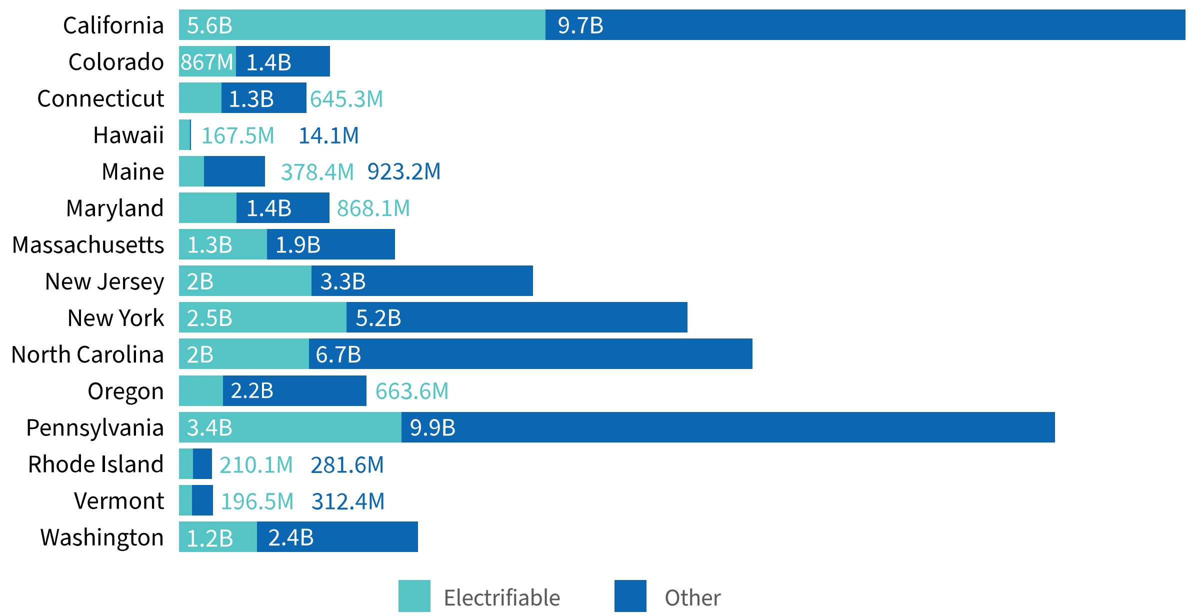
For MD trucks, by 2050, we find that the difference between the percentage of trucks required to be electrified versus those able to electrify never exceeds 15% (i.e., 15% more trucks will need to electrify than can with current technology and infrastructure) and that ACT-mandated sales exhaust the stock of easy-to-electrify MD vehicles in 2040. For HD trucks, which typically have higher-mileage duty cycles, there is a larger difference, with 30% more trucks required to electrify than currently can. HD trucks unable to comply with ACT regulations likely drive more than 300 miles per trip or do not always return to the depot.

Based on this, compliance with ACT is achievable until 2040 with today's technology, and states should have few reservations about committing to ACT sales targets. After 2040, ACT compliance becomes more challenging in certain regions, but electric truck ranges will increase and robust public charging infrastructure will develop in parallel. Given the progress in EV technology and charger availability in markets today, it is highly likely that the definition of "electrifiable" will become considerably more expansive in the coming decade and a half.

This significant early customer base reinforces our emphasis on targeting shorter-range vehicles to accelerate the electrification transition. While states focus investment on supporting these trucks, truck capabilities will continue to improve, a robust highway infrastructure network will begin to develop, and fleets will have time to learn from the operational challenges of managing a fleet of electric trucks. By aggressively electrifying lower-mileage, return-to-depot vehicles, we will be better prepared to electrify higher-mileage vehicles and vehicles that do not charge at a depot.

Because our definition of electrifiability selects for trucks with lower daily mileage that return to a depot, the percentage of vehicle miles traveled (VMT) that can be electrified is lower than the share of trucks that can be electrified. Overall, we find that 49% of MD truck VMT and 23% of HD truck VMT are electrifiable. Exhibit 5 shows total truck VMT by state, categorized by electrifiability. The electrifiable proportion of MD VMT ranges from 37% (North Carolina) to 90% (Hawaii) while the electrifiable proportion of HD VMT ranges from 17% (North Carolina and Pennsylvania) to 86% (Hawaii).

Exhibit 5 Combined MD and HD truck VMT by state, categorized by near-term electrifiability



RMI Graphic. Source: Geotab ITS

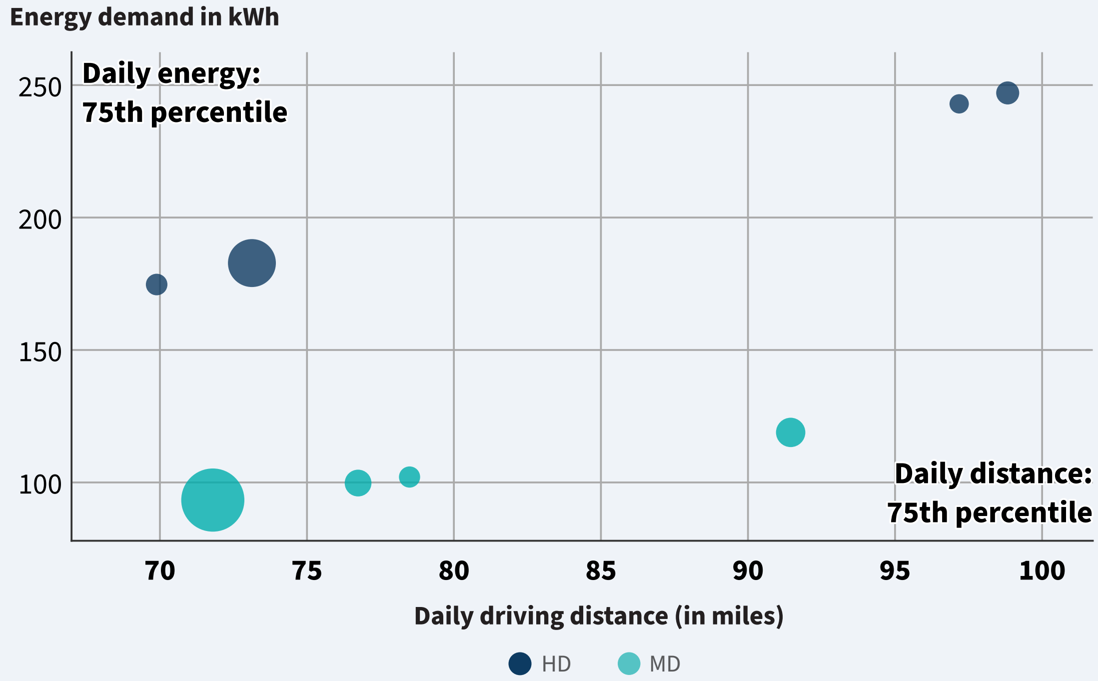
These findings are significant because truck emissions are proportional to VMT (not truck population). In other words, to reduce trucking emissions, we need higher-mileage vehicles to electrify. This is a downside of ACT regulations: they will initially accelerate electrification primarily of lower-mileage, return-to-depot vehicles that represent fewer total emissions. This serves to highlight what states need to focus on next: increase investment in public corridor charging to support higher-mileage vehicles and vehicles that don't charge at a depot. As corridor charging becomes more available,[vii] this investment will unlock the ability of higher-mileage vehicles to electrify and lead to an even greater reduction in trucking emissions.

vii Because the topic of this report is electric trucks, we focus here on corridor charging investments that support high-mileage duty cycles. We recognize that hydrogen is another possible solution for these duty cycles and otherwise remain agnostic as to which technology will best serve high-mileage use cases.

Sidebar: Electrification Potential in Hawaii (and Island Regions)

The results for Hawaii stand out as particularly instructive for smaller island regions. In particular, the constraints imposed by Hawaii's geography result in trucks with lower daily mileage and an extremely high proportion of electrifiable trucks. Although Hawaii has a smaller total truck population than other states considered in this report, nearly all trucks operating in the state — 90% of MD trucks and 83% of HD trucks — could electrify today. And even more critically, the electricity used to fuel those trucks will be increasingly clean: Hawaii Electric has committed to generating 100% renewable energy by 2045 (it achieved 32% in 2022).[20] This puts Hawaii on a path to eliminate tailpipe and electricity generation emissions, which together account for about 86% of Hawaii's total greenhouse gas emissions.[21]

Exhibit 6 Hawaii: Daily driving distance and energy demand



Note: Each data point represents a county with its size proportional to the number of electrifiable trucks.

RMI Graphic. Source: Geotab ITS

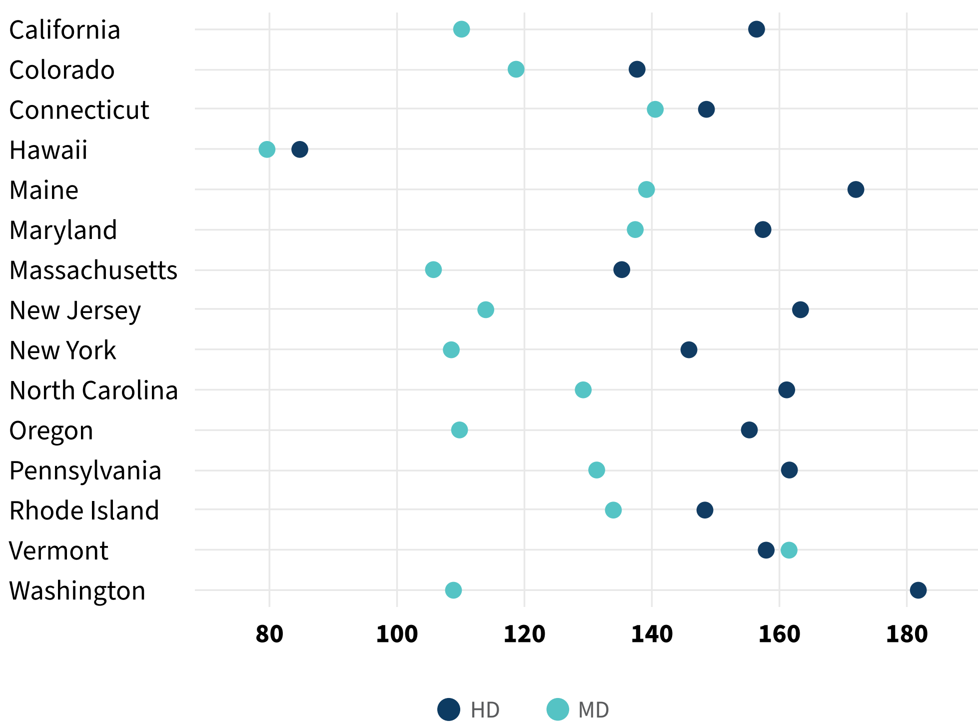
Exhibit 6 emphasizes the opportunity for Hawaii to rapidly electrify its MD and HD trucks, with each circle representing a county in Hawaii. The largest county, Honolulu, represents more than half the trucks in the state. Across all counties, even for higher-mileage 75th percentile days, both MD and HD trucks typically drive fewer than 100 miles per day and return to the depot needing less than 250 kWh of energy. Such low mileage and energy requirements mean truck fleets can keep their costs low by prioritizing lower-power chargers and sharing each charger with multiple trucks.

Though outside of the scope of this study, we expect other small island regions to find themselves in a similar position. This transition will still require significant investment in charging infrastructure and grid infrastructure to serve the additional electric load, but making those investments without delay can lead to a near-immediate payoff: an electrified trucking sector with dramatically reduced transportation costs and emissions. If paired with a transition to a grid mix with significant renewable energy generation, these island regions could nearly eliminate their trucking carbon emissions with today's truck and charger technologies.

Energy and Charging Needs from Travel Patterns

Based on these estimations of the population of trucks that could electrify today, we compute their energy needs using statistics for daily driving distance and calculating how much energy a truck would need per day to travel that distance. Exhibits 7 and 8 (next page) show the 75th percentile of daily mileage driven and the corresponding energy needs (kWh) for electrifiable MD and HD trucks for each state (state-level values are an unweighted average of all county values within the state). Nationwide, we use the average 75th percentile of daily distance traveled for electrifiable trucks to arrive at a conservative estimate of 121 miles per MD truck and 156 miles per HD truck, corresponding to average daily energy demands of 172 kWh for MD trucks and 427 kWh for HD trucks.

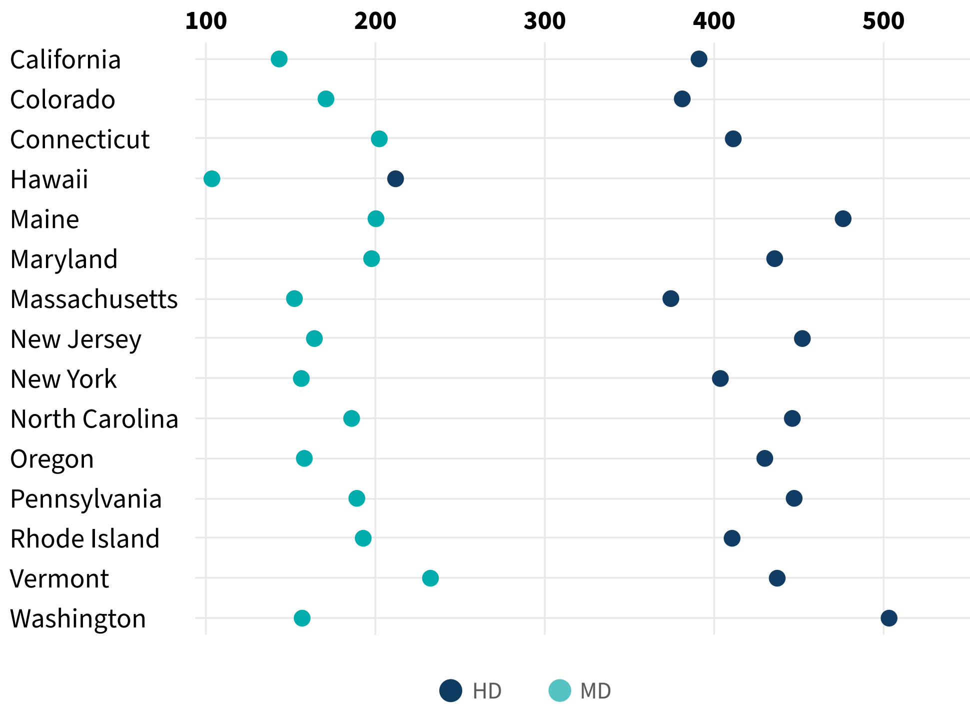
Exhibit 7 **Statewide daily mileage driven per truck (75th percentile) for electrifiable MD and HD trucks**



RMI Graphic. Source: Geotab ITS

Exhibit 8

Statewide daily energy (kWh) needed per truck (75th percentile) for electrifiable MD and HD trucks

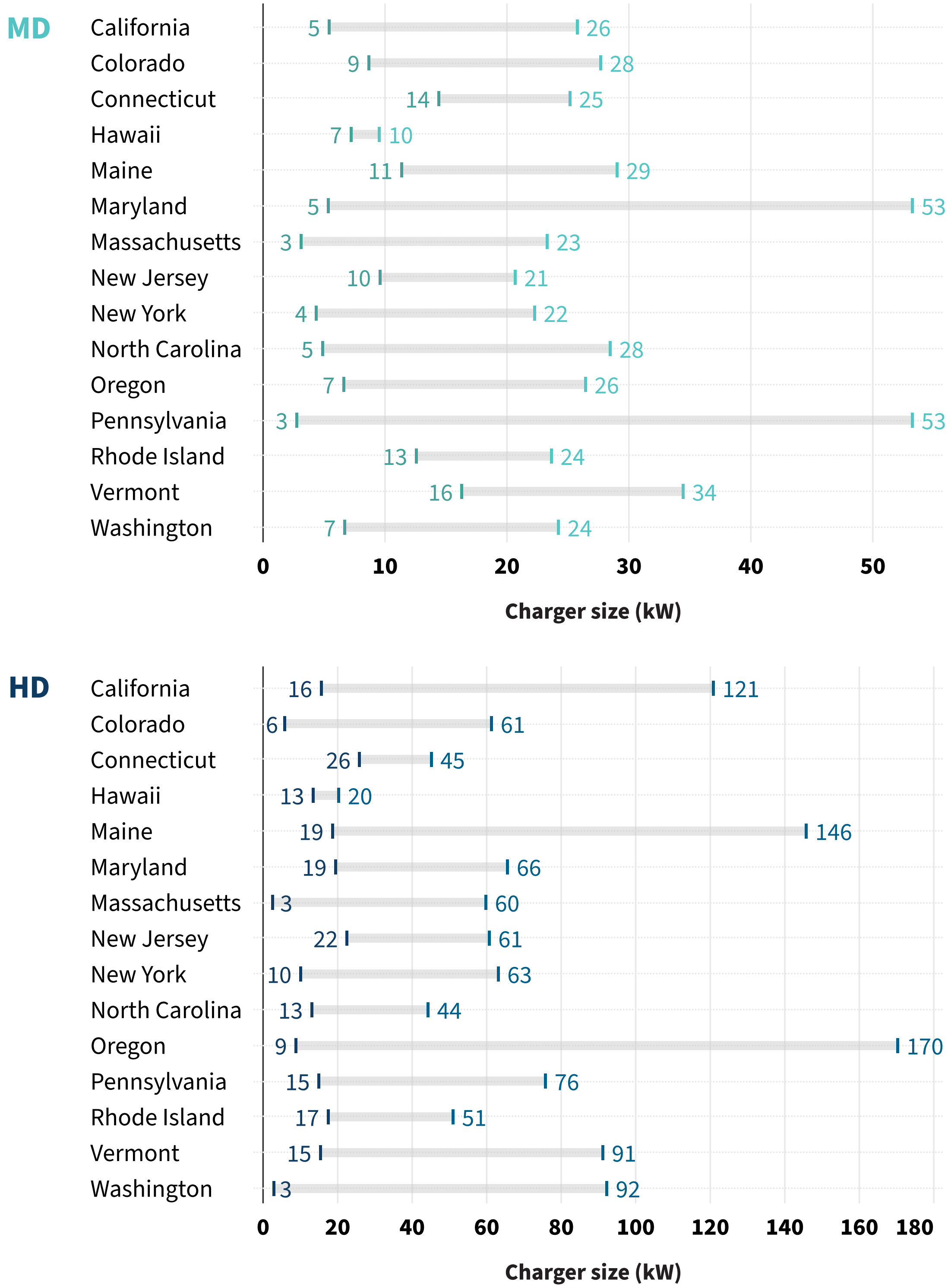


RMI Graphic. Source: Geotab ITS

Based on energy needs and time at depot, we calculate the minimum charger power needed to meet the energy demand of electrifiable trucks. Because we are focused only on return-to-depot duty cycles, we need to understand how long trucks are typically parked at a depot. We find that many trucks are parked at their depot long enough that low-power chargers can be used to fully recharge the vehicles.

Low-power chargers are important for both fleets — because they cost less than high-power chargers — and utilities, because they draw less power from the grid during peak hours. It's important, then, to understand the minimum charge size required to meet daily energy demands from electric trucks, shown in Exhibit 9 (next page). This scenario also assumes a 1:1 truck-to-charger ratio.

Exhibit 9 **Range of minimum necessary charger size (kW) for eMHD trucks to fully recharge at depot, by state**



RMI Graphic. Source: Geotab ITS

The range represents variation in results for the counties within each state. For example, trucks operating in a dense, predominantly urban county might drive lower average daily mileage and therefore require lower power charging (or may even go multiple days between full charges). In contrast, trucks operating in a less dense county might drive greater distances and return to the depot with a lower state of charge. These trucks will need a higher-power charger to fully charge in the same amount of time.

As shown in Exhibit 9, a 50 kW charger will be sufficient for almost all electric MD truck needs, with a greater variation of minimum charger power for electric HD trucks. A relatively higher-power 150 kW charger would fully charge most eMD vehicles in under two hours and most eHD vehicles in three hours, while a 75 kW charger would do the job for eMD vehicles in three hours and eHD vehicles in seven hours, effectively overnight at a depot. In fact, in more than half of all analyzed charging sessions, a 25 kW charger was sufficient for a full recharge — comparable to Level 2 charging.

A key takeaway from this chart is that a standard 75 kW power charger or a higher-power 150 kW charger — both available on the market today — can meet the needs of electrifiable trucks on most days, though supplemental capacity may still be required for longer-mileage days.

These relatively short charging times indicate that there is significant opportunity for fleets to strike a cost-effective balance between purchasing a cheaper, low-power charger for each vehicle and deploying higher-power chargers and sharing those chargers across multiple trucks. We will explore this balance further in the section titled *Where Is Infrastructure Investment Needed, and How Can Costs Be Reduced?* (page 26).

What is clear from this state-level analysis is that if all return-to-depot vehicles driving fewer than 300 miles daily were electrified, the industry would nearly meet 2040 ACT targets. ACT has real potential to shift the electric transition into overdrive; if automakers meet the challenge of ramping up production of eMHD vehicles, ACT sales targets can be fully realized with acceptable charger cost.

In the next section, we will further explore how aggregate energy demand across all trucks can be significant at the county level and how the electric grid and charging infrastructure will soon become the limiting factors to ACT compliance. States implementing ACT regulations need to invest heavily in and support fleet compliance, including with investments in grid capacity to energize chargers. These investments will have an outsize impact on decreasing emissions by maximizing electric VMT. Legislation or regulation that enables utilities to proactively plan for fleet electrification will also be critical.

States that aren’t implementing ACT regulations also have a critical role to play because eMHD truck adoption is likely to accelerate due to competitive cost and performance. Electrifiable trucks may need to use corridor or depot charging no matter which state they travel through and should be supported regardless of state regulations. Except for Hawaii, the states analyzed in this report have a comparable percentage of electrifiable MD and HD trucks — approximately two-thirds of MD trucks and one-third of HD trucks. Many non-ACT states will likely have similar percentages of electrifiable vehicles that will require charging infrastructure investment and other support for electrifying fleets.

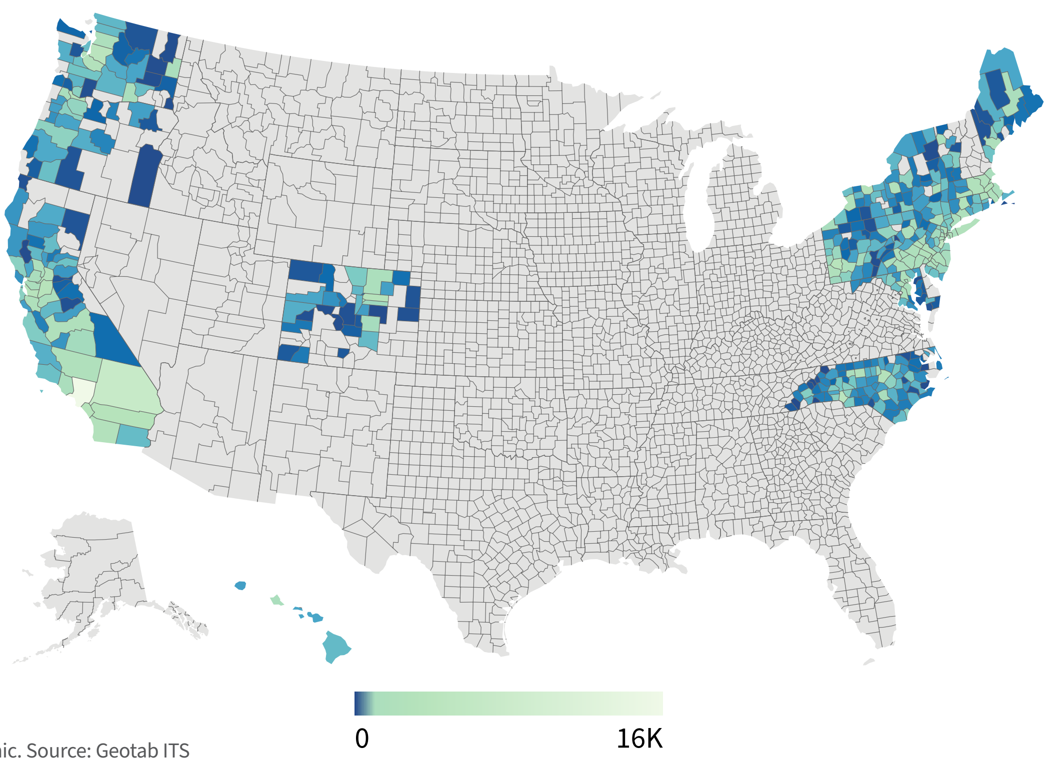
We note that predominantly rural states (e.g., Nebraska, North Dakota, South Dakota, Wyoming) may have fewer electrifiable trucks due to their overall lower population densities. Nevertheless, states not implementing ACT should analyze near-term electric truck needs to ensure that fleets domiciled in those states have access to the cost savings that electrification will likely create in the near future.

Where Will Energy Demand Increase, and What Will Be the Impact of This Increase on the Electric Grid?

As shown in the previous section, state-level results indicate that there is significant variation from county to county in terms of number of trucks, truck daily miles, and truck energy needs. Here we dig deeper into these county-level variations to provide more tailored guidance and insights for policymakers and stakeholders, especially at the local and regional levels.

As shown in Exhibit 10, energy demand from electrifiable trucks is highest in urban areas because these densely populated areas tend to have more trucks. (To explore and view the data more closely, we encourage readers to visit the accompanying dashboard at **https://rmi.org/early-trucking-electrification-in-act-states**.) Although some rural counties have too little data to analyze without compromising fleet or driver privacy, rural areas with available data have the lowest energy demand, which aligns with general industry sentiment that rural counties should mostly be concerned with corridor charging for long-haul trucks. However, we note that in many rural counties, estimated load from electrified trucks that depot in those counties — primarily MD delivery vehicles — can exceed 1 MWh, roughly equivalent to a neighborhood of 30 homes. Because rural electric grids tend to be older than those in urban areas and often operate at or above 90% capacity, even this relatively small new load could require grid infrastructure upgrades.[22]

Exhibit 10 **County-level daily energy demand from MD and HD trucks in ACT states**



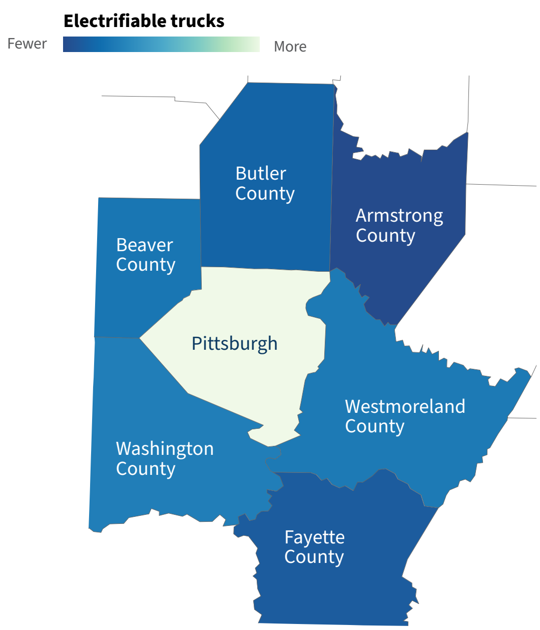
RMI Graphic. Source: Geotab ITS

Suburban and exurban counties fall in between, with an intermediate but still sizable energy demand. Exhibit 11 shows that the aggregate energy demand across suburban collar counties around Pittsburgh is greater than the energy demand from electrifiable trucks in Allegheny County (the urban county where Pittsburgh is located). It's also important to note that almost all of the suburban counties have hundreds of additional MWh of estimated new energy demand.

Exhibit 12 (next page) showcases more broadly how daily energy need per truck is similar regardless of how urban or rural a county is (though there are obviously more trucks in urban counties than in rural ones, so aggregate demand will be greater in urban counties). The impact of this energy demand will then depend on how constrained the grid is at specific locations.

For suburban and exurban counties that surround or border urban cores, it is possible that future load will be higher than we have estimated here. Why? Fleet operators can change their practices quickly to optimize for newer technologies, but we don't know how fleets will optimize their operations for electric trucks, nor do we know how freight and goods movement will grow in the coming decade (though long-term projections expect US freight activity to grow by 50% in tonnage and double in value by 2050).[23] This expected growth will translate to more miles driven by more electric trucks, more chargers and grid capacity needed, and more space needed for those chargers and depots.

Exhibit 11 **Electrifiable trucks in Allegheny County (Pittsburgh) and surrounding counties**

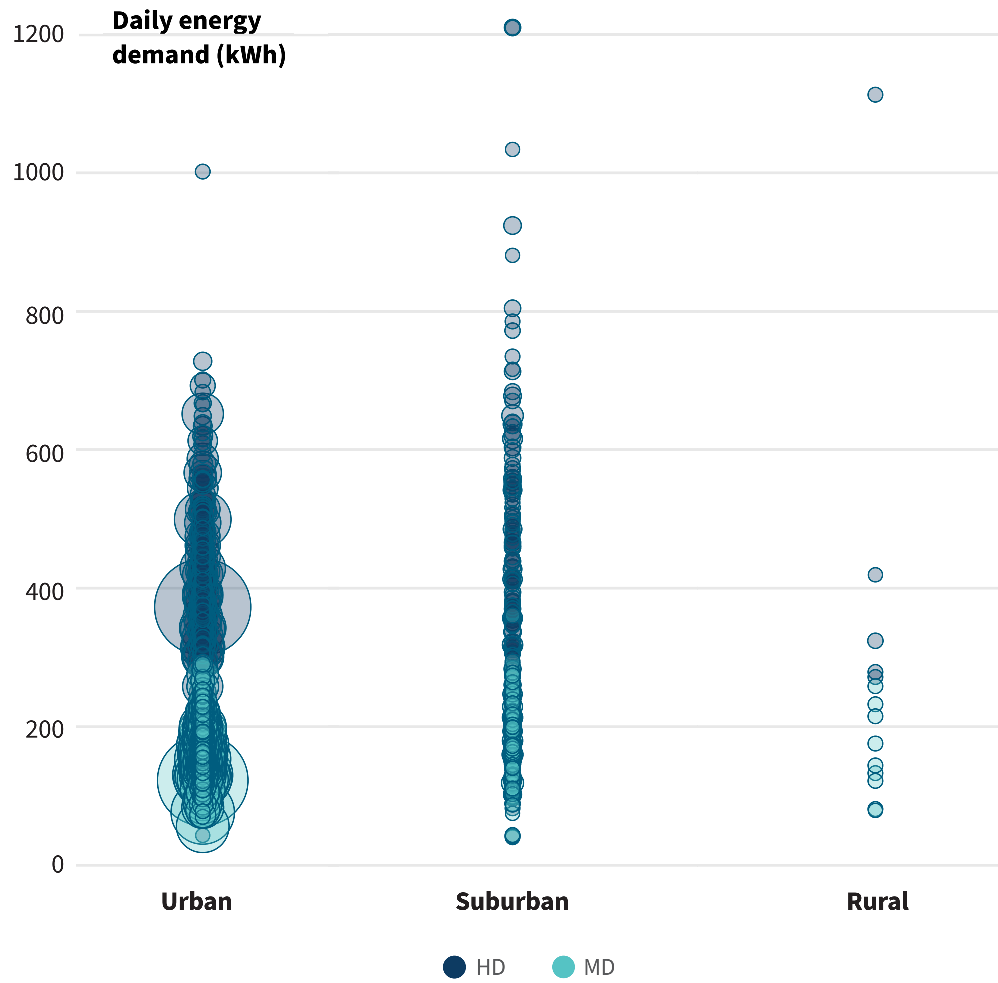


County	Electrifiable trucks	Daily energy demand (MWh)
Allegheny (Pittsburgh)	**17,164**	**3,660**
Armstrong	112	24
Beaver	4,039	713
Butler	2,389	676
Fayette	1,701	584
Washington	4,826	1,982
Westmoreland	4,397	1,829
Total	**17,465**	**5,809**

RMI Graphic. Source: Geotab ITS, Environmental Protection Agency (EPA) Co-Benefits and Risk Assessment (COBRA) model

What we can reasonably expect is that fleets will seek the most cost-effective path forward, balancing physical space to install infrastructure, available site grid capacity, grid infrastructure requirements, and real estate costs. Because urban cores have higher real estate costs, less space, and high competition for use of grid capacity, we will likely see more depot siting in suburbs and exurbs with newer grids, more available grid capacity, and cheaper real estate in the coming decade.

Exhibit 12 **Comparison of daily energy demand for HD and MD trucks, categorized by how urban their depot location is**



Note: Size of each circle is proportional to the number of electrifiable trucks in each county.

RMI Graphic. Source: Geotab ITS

Today, we're already seeing fleets choose to site depots in less dense areas with cheaper real estate.[viii] More than 6,000 new warehouses were expected to be built in 2023, with many in suburban or exurban locations where real estate is cheaper and space is more readily available.[24] These warehouses are often near lower-income communities, which will be disproportionately affected by emissions from trucks loading or unloading at these locations — all the more reason to ensure that those trucks are electric.[25]

New depot construction also represents an important opportunity. During design stages, power for truck charging can be included in overall electrical planning, better fitting with existing utility approval practices and timelines. Policymakers and utilities, especially those in suburban counties, need to pay close attention over the next decade to industry trends and how fleets balance costs and make depot siting decisions. If there is a shift toward building new depots in more suburban or exurban areas, electric truck charging should be integrated into site design and planning.

viii Choosing a depot location includes consideration of other factors, such as shifting market conditions, lease rates, competitors, and customers.

Where Is Infrastructure Investment Needed, and How Can Costs Be Reduced?

Fleets can minimize costs and changes to their operations today by leveraging load flexibility through managed charging and making intentional depot design decisions (e.g., total number of chargers, peak site load). In its simplest form, managed charging can be used to reduce costs and electricity system peak load by shifting charging to align with time-of-use (TOU) rates when electricity prices are lower, typically overnight.[ix] Trucks that charge overnight at a depot already align their charging reasonably well with existing TOU rates and system load peaks. However, there will likely be localized charging demand that is difficult for distribution infrastructure to serve throughout the day.

Intentional depot design — balancing cheaper, low-power chargers with expensive, high-power chargers to reduce the total number of chargers installed — is key to reducing the maximum peak site load if all chargers are used simultaneously, potentially reducing or eliminating the need for expensive grid infrastructure upgrades.

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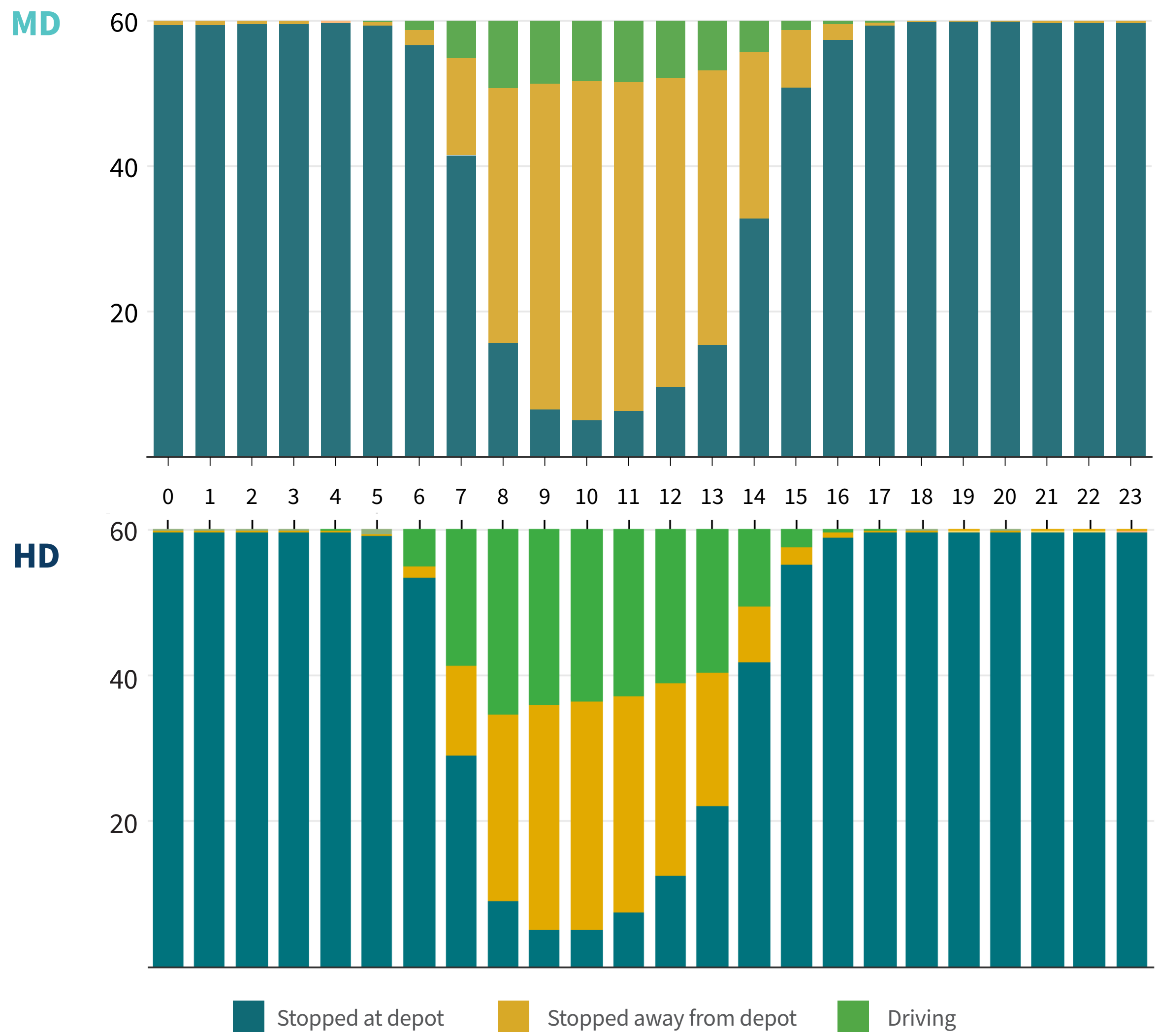
Temporal Impacts on the Grid: Load Profiles

To understand the opportunity for fleets to reduce their costs using these approaches, we need to understand how load from electric trucks is expected to vary during a single day (i.e., load profile). Because our definition of electrifiability focuses on trucks that return to the depot, we expect the electric load from truck charging to be concentrated in late afternoon and overnight hours, when trucks are most likely to be parked at the depot. Exhibit 13 (next page) shows truck activity (whether stopped at the depot, stopped outside the depot, or driving) at each hour of the day for all electrifiable trucks. Most activity outside the depot, whether driving or stopped, occurs between 6 a.m. and 5 p.m., and most trucks return to and stay parked at their depot by 5 p.m.

ix In other instances, fleets can have a contracted maximum load, and managed charging is used to set charging power to balance load not to exceed that level.

Exhibit 13 **Median activity by hour of day for MD and HD electrifiable trucks across all states analyzed**

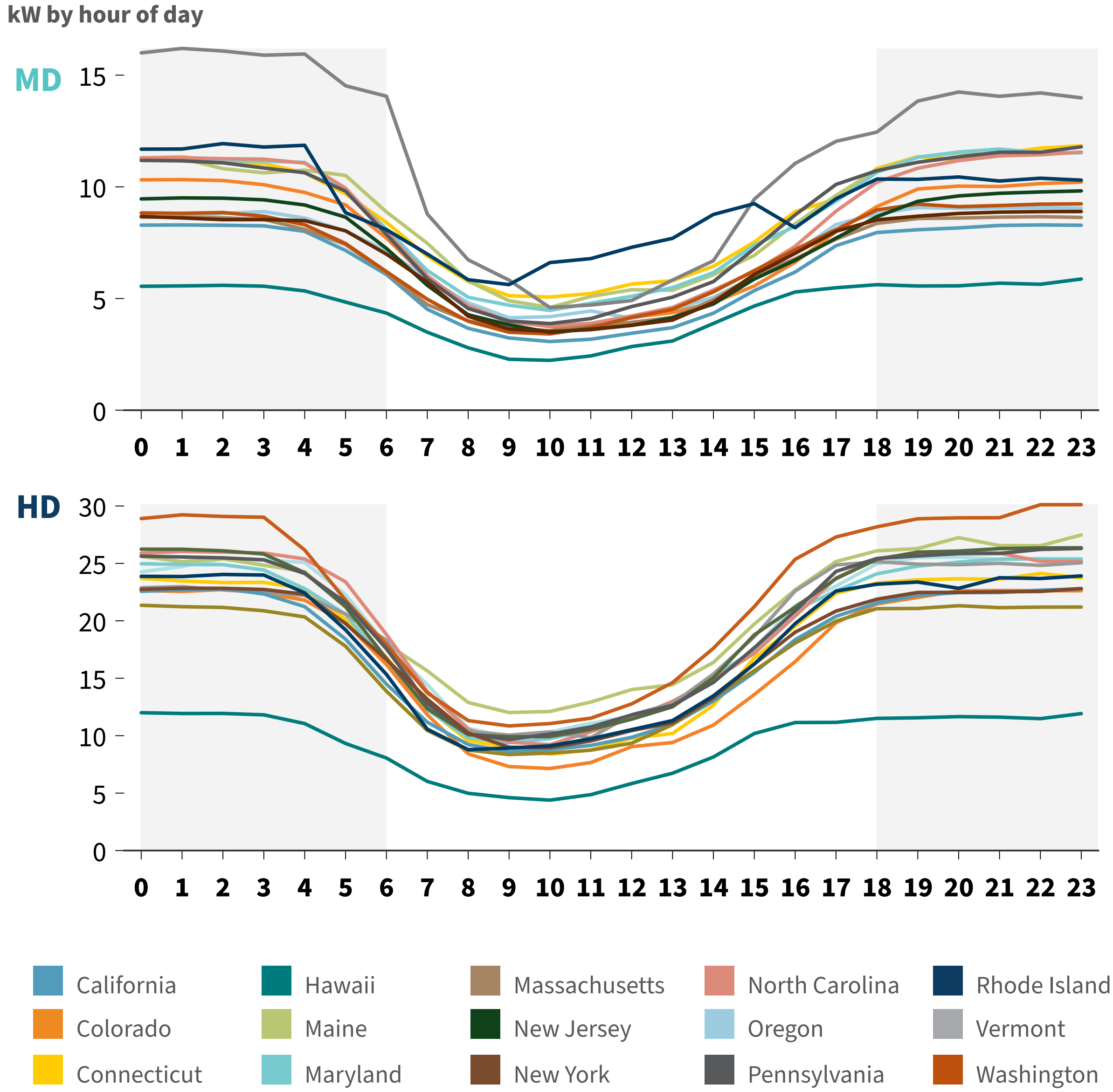


RMI Graphic. Source: Geotab ITS

Equipped with statistics that show when trucks are parked at a depot, we model 24-hour load profiles for each county using a Monte Carlo simulation.[x] The resulting load profiles are shown in Exhibit 14 (next page). These show a best case scenario in which trucks charge only at depot and at the right power to return to full state of charge while parked at depot; as expected, electric load at the depot peaks in the evening and overnight hours when trucks are parked and is significantly lower during the day when trucks are in operation.

x We adjust the magnitude of the load curve to ensure that the area under the curve is equal to the total daily energy needed by all electric trucks to fully recharge. This methodology is useful because it does not require us to assume a particular charger power or portfolio of chargers to meet the energy demand each hour.

Exhibit 14 **Load profiles for MD and HD trucks averaged over all counties, by state**



RMI Graphic. Source: Geotab ITS

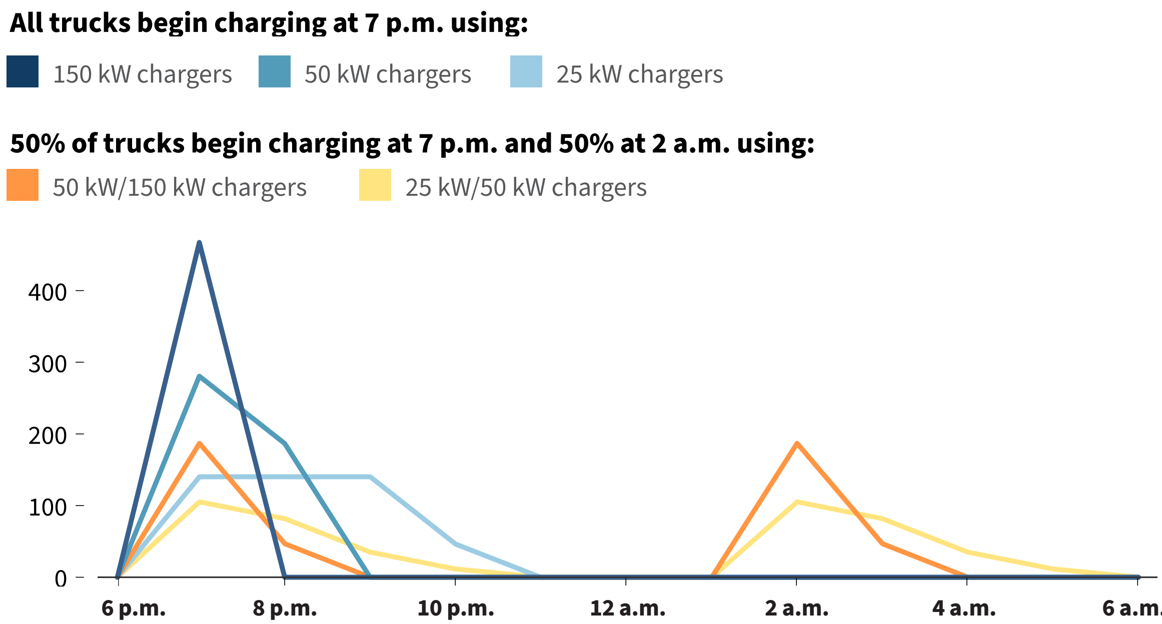
The variation in these load curves using different charging scenarios illustrates how charger portfolio and scheduling decisions can have significant impacts on the grid. Exhibit 15 (next page) demonstrates this using load profile sensitivities for all electrifiable MD trucks in Bronx County, New York. The impact to the grid is most significant in a scenario when all trucks charge at the same time (in this case, 7 p.m., when trucks in Bronx County are statistically most likely to be at a depot), using high-power 150 kW chargers. In the most aggressive scenario, in which all trucks plug in at 7 p.m., the maximum site peak load is significantly reduced when trucks use lower-power 50 kW or 25 kW chargers.

Two other load curve sensitivities shown use a staggered charging scenario: half of trucks charge at 7 p.m., and the other half charge at 2 a.m. In both scenarios, peak load is lower than when all trucks charge at the same time using 150 kW or 50 kW chargers. However, even when the trucks start charging at different times, the power of the chargers has an impact on the shape of the load. The shape of the load is much peakier when half of trucks use high-power chargers.

Ultimately, fleets will install the charging infrastructure that works for them so that trucks can charge on a schedule that works with their duty cycle and costs remain manageable. Price signals via TOU rates and demand charges can shape a fleet's charging behavior within the constraints imposed by vehicle duty cycles.

Exhibit 15 **Load profiles for eMD trucks in Bronx County, New York, under various charging scenarios**

MW over time for all eMD in Bronx County



RMI Graphic. Source: Geotab ITS

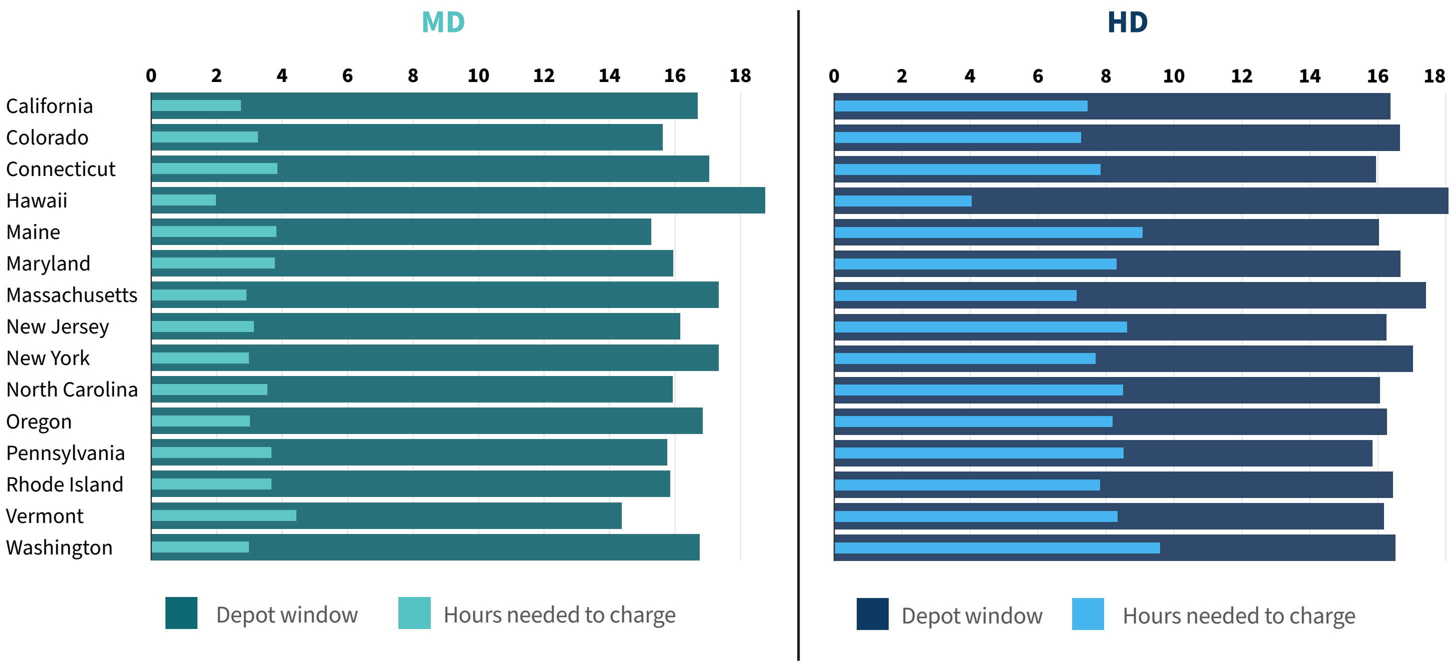
Reducing Infrastructure Upgrade Costs and Peak Loads

In these early stages of eMHD truck adoption, fleet operators often install more and higher-power chargers than needed (e.g., one charger per vehicle) to minimize the risk of trucks not receiving a full charge by the time the truck needs to start driving. As noted previously, operating high-power chargers can lead to high demand charges and electricity bills as well as the need for expensive grid infrastructure upgrades. Our data suggests that multiple MD and HD trucks can share a single charger on most days.

Exhibit 16 (next page) shows the portion of depot time required to fully recharge using a 75 kW charger. MD trucks are fully charged in four hours or less, leaving up to 12 additional hours when that charger is not being used. Similarly, HD trucks need up to 10 hours to fully recharge, leaving up to six hours when the charger could be used by another truck. These relatively short charging times show that fleets can readily share chargers across multiple trucks operating under similar duty cycles, even with lower-power 75 kW chargers.

For higher-power chargers that fleets favor today, there would be even greater flexibility to share each charger among multiple trucks. Hybrid configurations, which could use low- and high-power chargers, allow fleets to further balance charger costs and demand charges as well as ensure that trucks can accomplish their daily tasks reliably.

Exhibit 16 Portion of total hours at depot needed to complete charge using a 75 kW charger for MD and HD trucks, by state



RMI Graphic. Source: Geotab ITS

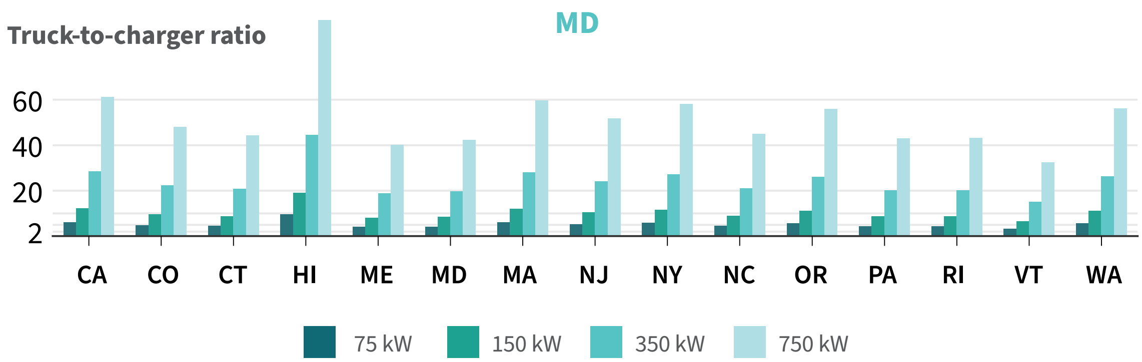
In addition to sharing chargers among multiple vehicles, Exhibit 16 demonstrates the flexibility available when fleets start charging their vehicles. As discussed above, this load flexibility is beneficial from the fleet side (reducing costs through shared chargers) but also from the utility's perspective by moving load to a time that is beneficial for the grid. In other words, if a truck arrives at the depot at 6 p.m., rather than charging immediately, the operator can wait to charge until later — possibly taking advantage of favorable electricity prices and avoiding peak load on the grid — knowing the truck will still be fully charged by the morning.

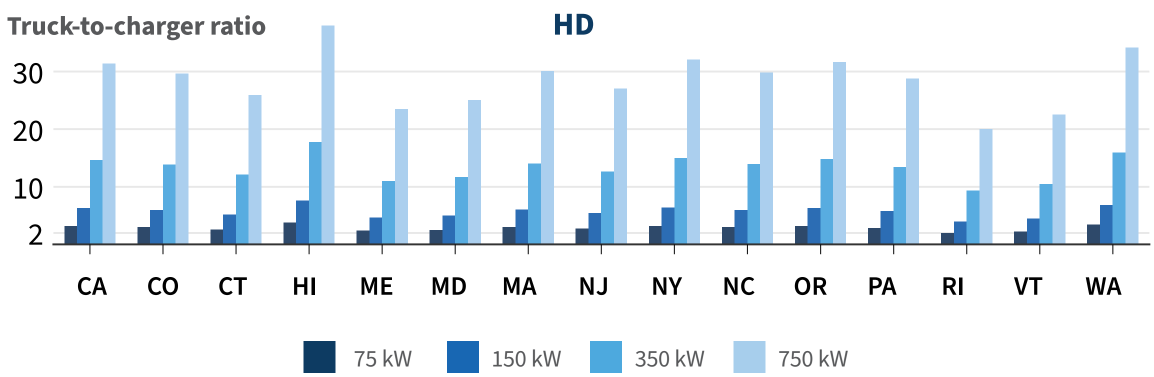
If fleets use smart charging, load flexibility is not necessarily operationally complex. Waiting to charge until off-peak hours does not mean plugging in the vehicle late at night; sharing chargers does not actually mean having to move trucks or cables in the middle of the night. Smart charging uses load management software to operationalize these decisions without having to share a cable or move vehicles. Fleets can plug in their trucks when they arrive at the depot, and software decides when they charge. Further, fleets can enable trucks to share chargers by separating power management from the charging cable, allowing for a completely zero-touch process.

Exhibit 17 shows the potential for MD and HD trucks to share a single charger in terms of a truck-to-charger ratio for different charger sizes, up to 750 kW. Remarkably, for the readily available 150 kW charger, approximately 10 typical MD trucks or 5 HD trucks could share a single charger.

Though comparing actual costs is outside the scope of this report, the potential to share a very high-power charger (e.g., 750 kW) may be dwarfed by the high cost of installing these fast chargers. Additionally, a single 750 kW charger at a depot site represents a very significant load that could trigger large demand charges if used at the wrong time (i.e., coincident with electric system peak load). Such systems may be attractive for depot-based vehicles doing several long trips a day from a single depot, especially when on-site batteries can reduce peak metered power use, but are likely not needed for most applications.

Exhibit 17 **Potential to share chargers for varied charger powers for MD and HD trucks, by state**





RMI Graphic. Source: Geotab ITS

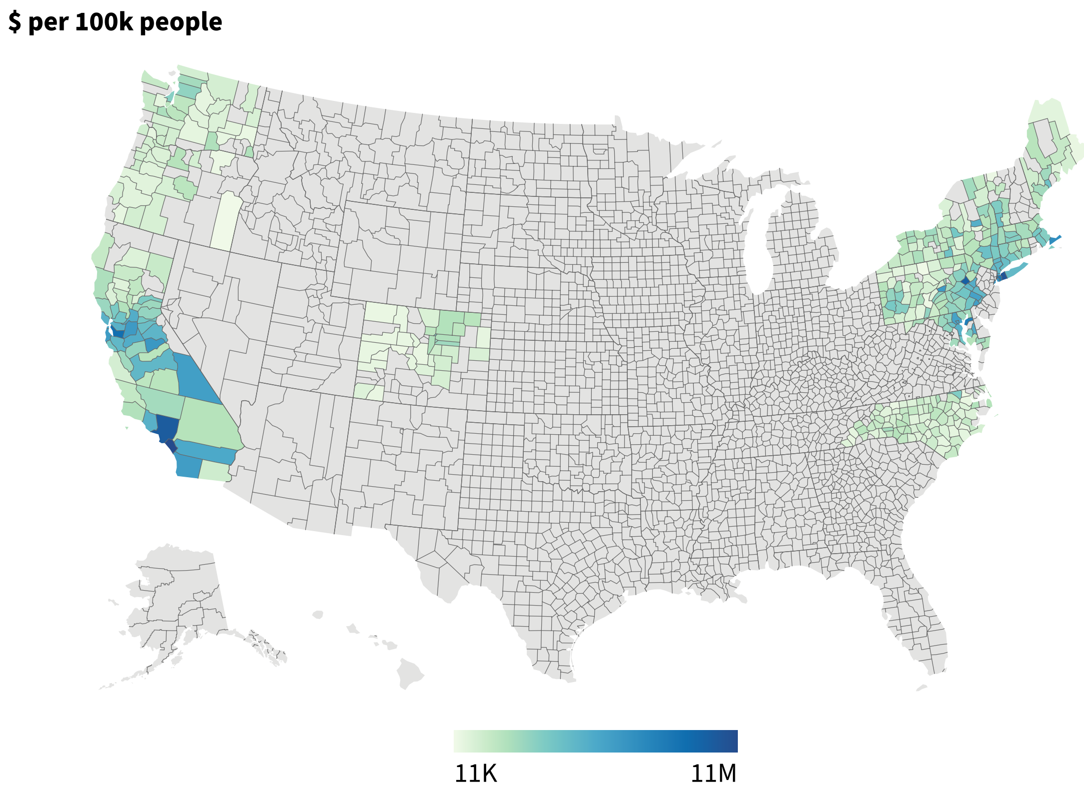
How Should Stakeholders Prioritize Investments to Ensure That Investments Are Made Equitably?

In previous sections, we've highlighted the need to direct significant investments toward fleets as well as to the development of a robust public charging network. However, deciding where to prioritize these investments is not simply a matter of knowing where estimated energy demand will be highest (indeed, this would provide suburbs, exurbs, and rural areas with very little investment). Policymakers must balance many factors when prioritizing investments, including fleet needs (e.g., counties with high truck populations or through which freight corridors pass), equity (e.g., investing in underserved or low-income communities), health (e.g., communities with poor air quality or increased incidence of respiratory illness), and grid impact.

Although exploring these factors is outside the scope of this study, we have published an accompanying dashboard where all data found in this report is available for readers to explore alongside many different map layers, available at **https://rmi.org/early-trucking-electrification-in-act-states**. To illustrate how users can explore the data, we provide one example of how a stakeholder making or influencing investment decisions could investigate the factors most important to that stakeholder.

In Exhibit 18, we use the online data explorer to isolate one such factor — per capita health benefits (dollars per 100,000 people) from trucking electrification using the EPA COBRA model — for all counties analyzed for this study,[xi] as shown on the map.

Exhibit 18 **Potential health benefits from early trucking electrification in ACT states**



RMI Graphic. Source: Geotab ITS; EPA COBRA model

In Exhibit 19 (next page), we then use the data dashboard to identify the 15 counties with the highest per capita health benefits and the number of electrifiable trucks that have a depot in each of those counties. Unsurprisingly, many of the counties on this list are very large urban counties with significant numbers of trucks — Alameda, Kings, Los Angeles, Nassau, New York, Orange, Queens, and San Mateo counties — where a lot of electric truck investment is already targeted.

Several other counties appear to be downstream of poor air quality from major urban areas — Kent County in Maryland is across the Chesapeake Bay from Baltimore; Barnstable County in Massachusetts is west of Boston and Providence — and would likely benefit most from electrification of trucks in those major cities.

xi The COBRA scenario included all states in this study. The selected sector/subsector was "Highway vehicles — diesel fuel — heavy-duty." Modify emissions was selected as "Reduce (PM 2.5/ SO2/ NOx/ NH3/ VOC) by 100%."

Also of interest is San Joaquin County in California's Central Valley, with both a significant number of trucks and high per capita health benefits; the valley has notoriously poor air quality due to heavy local truck traffic and the surrounding topography. Based on these two factors, San Joaquin County should be a very high priority for trucking electrification investments.

Exhibit 19 **Top 11 counties by potential health benefits**

State	County	$ per 100,000 people	Electrifiable trucks
California	Orange	11M	17,129
New York	Nassau	10M	6,818
California	Los Angeles	10M	62,433
New York	New York	9M	7,332
California	Alameda	9M	16,748
New York	Queens	8M	20,416
Massachusetts	Barnstable	7M	1,379
New York	Kings	7M	13,483
New York	Richmond	7M	5,144
California	San Joaquin	6M	9,262
California	San Mateo	6M	5,011

RMI Graphic. Source: Geotab ITS and EPA COBRA

Recommendations

Utilities and their regulators, policymakers, fleets, EVSPs, and site operators play critical roles in the transition to a carbon-free trucking future, and each can act today. We highlight, in this section, recommendations, based on our analysis, for how these stakeholders should navigate trucking's transition away from fossil fuels.

Utilities

The primary role of utilities in this transition is to develop and submit plans to their regulators that propose charging infrastructure and grid-upgrade investments. These charging investments need to support new EV load, minimize impacts to the grid, benefit all ratepayers, and ensure reliable service. A utility is also the customer interface for a fleet owner, for example, when it submits a request to provide new electricity service for a charging depot. Recommended actions for utilities include:

- Combine granular travel data with distribution grid-hosting capacity to proactively plan and build grid infrastructure where eMHD truck demand is expected. In many places, new substations with significantly long lead times will be required.
- Dedicate staff to electric transportation to reduce wait time for site-specific grid impact studies and processing interconnection requests.
- Dedicate staff to proactively identify and engage with fleet customers and to understand their electrification plans. Provide education to fleets on rates and demand-response programs.
- Incorporate truck electrification scenarios and load estimates into long-term grid planning.
- Consider changes to rate structures, including (1) TOU-based or fleet-specific demand charges to incentivize fleets to minimize or shift site peak load and (2) fleet-specific commercial TOU rates to incentivize charging at times optimal to the grid and to reduce charging costs.

Utility Regulators

Regulators must evaluate distribution grid plans and charging infrastructure investments that utilities develop. Regulators are typically required to ensure that these plans are well designed to support new EV load, effectively recover costs, provide a fair return to investors, use ratepayer funds appropriately and equitably, balance competition with private-sector EVSPs, and align with state and local goals. Recommended actions for utility regulators include:

- Engage with utilities in anticipatory grid planningand charging infrastructure investments submitted by utilities that ensure that new electric truck load will be served, based on a charging needs analysis that combines truck travel data with grid-hosting capacity.

- Approve proactive grid planning and charging infrastructure investments to ensure that charging infrastructure is built ahead of or alongside need. Revisit proactive plans in future years to minimize risk of underutilization.

- Work with utilities to integrate truck electrification scenarios into grid planning, including scenarios with significant adoption of electric trucks. Evaluate and require rate structures that would cost-effectively integrate truck charging with other current and expected grid loads to minimize overall investment.

- Protect ratepayers from excessive utility investment while not compromising the ability of fleets and manufacturers to comply with vehicle-focused policies like ACT and ACF.

State, Regional, and Local Policymakers

Policymakers, whether at the state or local level — for example, state legislatures, city councils, and state energy offices — typically determine priorities for other stakeholders by setting goals and targets and can also provide funding directly to support those goals. State legislatures (and city councils with respect to municipal utilities) can direct or authorize utility regulators to take specific actions.

For states that have adopted or are considering adopting ACT regulations:

- Support fleets with investments to reduce transition costs, including subsidies for site assessments or grid impact studies, chargers, and charger installation.

- Although our study only considers charging needs associated with depot charging, corridor charging will add new electric load. Identify corridor-charging sites and invest in corridor charging to support higher-mileage trucks that are unable to comply with ACT today.

- Ensure that regulators, such as public utilities commissions, are directed to consider the ability to comply with ACT and similar regulations in utility investment planning and rate cases.

For states not adopting ACT regulations:

- Engage with fleets in your state to understand their electrification plans.

- Replicate the analysis in this study. Analyze truck travel patterns to estimate the truck population most likely to electrify and associated energy and charging needs.

- Support infrastructure investment commensurate with anticipated electrification.

For regional and local policymakers, including counties and metropolitan planning organizations:

- Watch industry trends for how fleets choose to site new depots. Prioritize investments in underserved areas to attract fleets to electrify depots in those areas.

- Conduct analysis of truck travel patterns to anticipate electrification, using granular data if available to identify specific sites and needed charging infrastructure.

- Focus on high-touch relationships with local fleet owners, site operators, and real estate developers to create a supportive environment and target investment where needed.

Fleet Owners

As the owners of electric trucks (in many cases with dedicated depot locations also owned by the fleet), fleet owners will manage overall operations of the truck fleet, including installing and operating charging infrastructure to refuel them. Recommended actions for fleet owners include:

- Analyze your fleet's data to realistically assess electrification potential based on actual duty cycles and operational needs.

- Develop an electrification plan and share your plan with your utility early. Work with your utility or third-party consultants to assess your depot site to identify cost-effective charging strategies.

- Understand your utility's rate structure to understand optimal charging scenarios and anticipate electricity costs.

Charging Station Operators

EVSPs are third-party private entities that install and operate charging infrastructure, including public chargers.

- Provide consulting services to fleets, including managed charging and depot design best practices to avoid grid upgrades and minimize costs.

- Build out corridor charging in high-traffic areas that will have higher utilization and best return on investment.

In conclusion, electric trucks are here. Model availability, increased battery capacity and range, fleet commitments, and regulations like ACT are accelerating their adoption. Lack of adequate charging and grid infrastructure will be the primary bottlenecks that could impede the transition to electric trucks and slow progress toward eliminating tailpipe emissions. The time is now to take meaningful steps to build electric truck charging infrastructure and support fleet owners as they navigate compliance with the ACT rule and the transition to electric trucks.

Appendix

Exhibit A1 **Truck telematics data provided by Geotab ITS**

Distributional statistics of the listed variables are provided for each county (most counties in ACT states), each vehicle class (MD and HD), and each electrifiability tag (electrifiable and non-electrifiable). Distributional statistics include mean, standard deviation, 5th, 25th, 50th, 75th, and 95th percentiles.

Variables
Active vehicle days
Inactive vehicle days
Number of vehicles
Number of depot visits (daily)
Number of out-of-depot visits (daily)
Number of stops
Minutes spent stopped at depot (daily and hourly)
Minutes spent stopped away from depot (daily and hourly)
Minutes spent driving (daily and hourly)
Minutes spent stopped (daily)
Miles driven (daily)
Speed driven (daily)

RMI Graphic. Source: Geotab ITS

Endnotes

1 "MOVES4: Latest Version of Motor Vehicle Emission Simulator," EPA, accessed January 30, 2024, **https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves**.

2 "MOVES4," accessed January 30, 2024.

3 "Fast Facts on Transportation Greenhouse Gas Emissions," EPA, accessed January 30, 2024, **www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions**.

4 Marie McNamara, *Understanding California's Advanced Clean Truck Regulation*, RMI, 2023, **https://rmi.org/understanding-californias-advanced-clean-truck-regulation/**.

5 Marie McNamara, *Understanding California's Advanced Clean Fleet Regulation*, RMI, 2023, **https://rmi.org/understanding-californias-advanced-clean-fleet-regulation/**.

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