March 19, 2024

Forecasting a Realistic Electricity Infrastructure Buildout for Medium- & Heavy-Duty Battery Electric Vehicles

Clean Freight Coalition

www.cleanfreightcoalition.org

Members of the Clean Freight Coalition

- American Bus Association
- American Truck Dealers
- American Trucking Associations
- National Association of Truck Stop Operators
- National Motor Freight Traffic Association
- National Tank Truck Carriers
- Truckload Carriers Association

Report prepared by Roland Berger 2024

List of Acronyms

MDHD	Medium-Duty Heavy-Duty
MD	Medium-Duty
HD	Heavy-Duty
BEV	Battery Electric Vehicle
ZEV	Zero Emission Vehicle
NREL	National Renewable Energy Laboratory
TCO	Total Cost of Ownership
L2	Level 2 Charger
L3	Level 3 Charger
DC	Direct Current
DCFC	Direct Current Fast Charger

List of Figures

List of Tables

EXECUTIVE SUMMARY

Numerous new pressures are being placed on the trucking industry. States and the federal government are examining regulations to quickly transition the industry by 2040 to full electrification with the goal to reduce commercial vehicle carbon emissions. The Clean Freight Coalition contracted a study with Roland Berger to determine the added costs to the freight industry and utilities if commercial vehicles reach 100% electrification. This study examined two scenarios- one with current vehicle and charging technology offerings, and the other with modest improvement in both vehicles and chargers- to determine the realistic electricity infrastructure buildout scenario for medium- and heavy-duty battery electric vehicles.

Key Findings:

- Preparing today's commercial vehicle fleet for electrification would require the industry to invest upwards of $620 billion in charging infrastructure alone, including chargers, site infrastructure, and electric service upgrades.
- Utilities will need to invest $370 billion to upgrade their grid networks to meet the demands of commercial vehicles exclusively.
- This nearly $1 trillion expenditure does not account for the cost of purchasing new battery-electric trucks, which, according to market research, can be 2 to 3 times as expensive as their diesel-powered equivalents.
- Given current economic and operational constraints, longhaul, over-the-road trucking is ill-suited for electrification today. However, if significant upfront infrastructure investments are made, opportunities for medium-duty (MD) vehicles and last-mile logistics exist. In addition to infrastructure investments, the feasibility of longhaul battery electric vehicles (BEV) will depend on further vehicle and charger technology advances.
- Policymakers will need to address these cost concerns and technological hurdles to ensure an electrified supply chain functions smoothly for the American economy.

Our findings highlight the significant electric infrastructure costs involved in transitioning to BEVs and emphasize its impact across sectors, notably the trucking industry, the supply chain, and the broader economy. Over the next two decades, a full transition to BEVs would require a substantial and direct expenditure shared by both fleets and utilities, with unknown consequences for the American consumer and ratepayer. Rather than mandating BEVs, policymakers should examine ways to incentivize these vehicles over realistic and reasonable timelines. At the same time, governments should encourage and incentivize the adoption of more efficient clean diesel and alternative-fueled vehicles on the road by eliminating the federal excise tax on trucks.

METHODOLOGY

We employed a scenario analysis based on a charging network simulation and utility infrastructure needs assessment to forecast the realistic electricity infrastructure buildout required for medium-duty and heavy-duty (MDHD) BEVs.

Charging Network Analysis

Our study began with a charging network analysis to understand the different operating dynamics of local, regional, and highway operations within the trucking industry, and the required charging networks for each. We conducted a comprehensive geographic analysis for local charging to delineate regional truck distributions across metro, suburban, and rural areas. This granular analysis enabled us to identify areas of high truck concentration that may necessitate grid upgrades. A charging strategy analysis was then employed to allocate truck populations to on-site or on-route charging stations based on factors such as battery capacity and route distances. In parallel, we devised a charging location network for the highway segment to map traffic flows and simulate a highway traffic network. This effort involved estimating the appropriate configuration of chargers, including their number and power capacity. Through these simulations, we derived a regional distribution of peak load profiles and identified an estimated number of depot or charging stations to support MDHD BEVs.

Utility Infrastructure Needs Assessment

Following the charging network simulation, we assessed the utility upgrades required in the existing infrastructure to accommodate MDHD BEVs. This assessment was comprised of several components:

1. **Electric load impact analysis:** We aggregated load profiles and overlaid geographical data to assess available capacity against projected demand.
2. **Site infrastructure analysis:** We estimated on-site infrastructure costs based on charger quantity and size.
3. **Distribution infrastructure analysis:** This involved evaluating local grid capacity upgrade needs and associated utility investment requirements.
4. **Power system infrastructure analysis:** We estimated investments in power system assets necessitated by increased capacity demand.
5. The results of the infrastructure needs assessment were synthesized to provide insights into the investment needs and challenges across both charging infrastructure and energy infrastructure.

Scenario Analysis

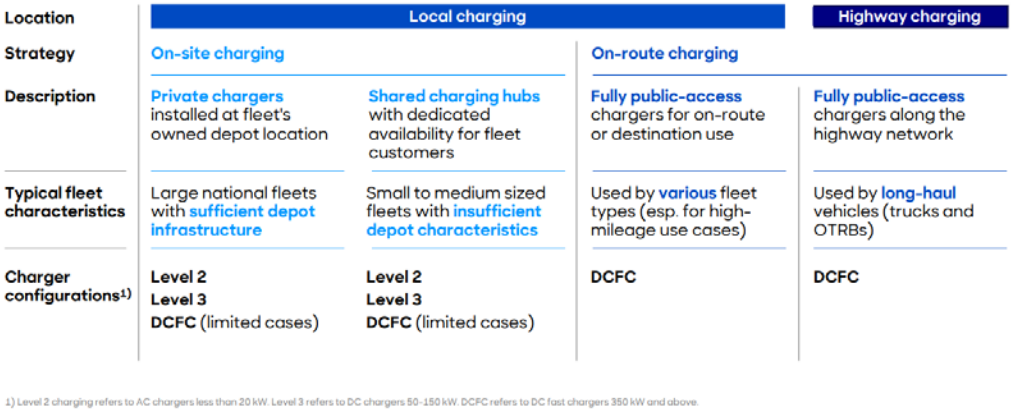
Our study uses two scenarios to explore pathways for electrifying the U.S. MDHD vehicle fleet based on the pace of technological improvement.

1. **Current technology scenario:** This scenario assumes the continuation of existing technology and performance characteristics. We assume a maximum Class 8 usable vehicle range of 180 miles and a maximum fast-charging capacity of 350 kW supported by real world fleet mileage.
2. **Improved technology scenario:** This scenario assumes advancements in battery density and charging speeds over the medium term. Due to an improved battery density of 40%, we assume an increased range for Class 6-8 vehicles. The maximum Class 8 usable vehicle range increases to 250 miles. Maximum fast-charging capacity increases to 500 kW for locally operated vehicles and up to 1MW for highway vehicles.

Table 1 summarizes the types of charging that would be used for different types of fleets operating electric commercial vehicles. For the local charging network, we analyzed where, when, and how vehicles will charge to determine the best network configuration and its load profile. On-site charging refers to private “behind the fence” chargers at a fleet's depot or terminal. These chargers are typically Level 2 (L2), slower than DC fast chargers (DCFC) but can charge a truck overnight. Depot charging is suitable for Class 3-6 trucks with operational profiles for urban package and delivery, point-to-point operations under 180 miles, and dedicated routes, like school buses.

On-route charging refers to chargers located along highways or other major roads, typically DCFC that provide a significant charge in a relatively short time. For this study, on-route charging is public but designed specifically for commercial vehicles. Chargers are designed for truck operations with pull through connections and in areas where trucks congregate. On-route charging is suitable for on-highway tractors, regional haul and MD trucks that require extended battery range. These truck fleets would use DCFC at least once daily.

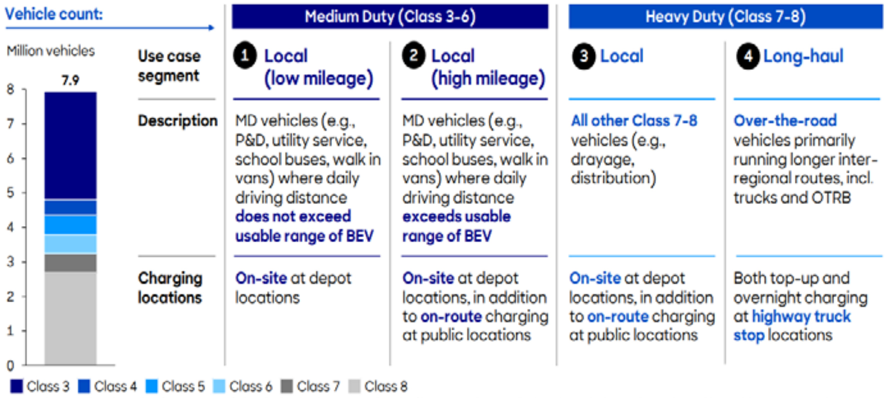
Table 1. Summary of local and highway charging strategies



Location	Local charging			Highway charging
Strategy	On-site charging		On-route charging	
Description	**Private chargers** installed at fleet's owned depot location	**Shared charging hubs** with dedicated availability for fleet customers	**Fully public-access** chargers for on-route or destination use	**Fully public-access** chargers along the highway network
Typical fleet characteristics	Large national fleets with **sufficient depot infrastructure**	Small to medium sized fleets with **insufficient depot characteristics**	Used by **various** fleet types (esp. for high-mileage use cases)	Used by **long-haul** vehicles (trucks and OTRBs)
Charger configurations[1)]	**Level 2** **Level 3** **DCFC** (limited cases)	**Level 2** **Level 3** **DCFC** (limited cases)	**DCFC**	**DCFC**

1) Level 2 charging refers to AC chargers less than 20 kW. Level 3 refers to DC chargers 50-150 kW. DCFC refers to DC fast chargers 350 kW and above.

Within the MDHD population, we mapped four broader use case segments to different charging location types (Figure 1).



	Medium Duty (Class 3-6)		Heavy Duty (Class 7-8)	
Use case segment	❶ Local (low mileage)	❷ Local (high mileage)	❸ Local	❹ Long-haul
Description	MD vehicles (e.g., P&D, utility service, school buses, walk in vans) where daily driving distance **does not exceed usable range of BEV**	MD vehicles (e.g., P&D, utility service, school buses, walk in vans) where daily driving distance **exceeds usable range of BEV**	**All other Class 7-8** vehicles (e.g., drayage, distribution)	**Over-the-road** vehicles primarily running longer inter-regional routes, incl. trucks and OTRB
Charging locations	**On-site** at depot locations	**On-site** at depot locations, in addition to **on-route** charging at public locations	**On-site** at depot locations, in addition to **on-route** charging at public locations	Both top-up and overnight charging at **highway truck stop** locations

Note: Simulations are based on today's fleet size, except for long-haul trucks. The incremental weight of batteries results in a payload penalty. Trucks that weigh out today would exceed the maximum GVW limit and additional truck capacity is needed to carry the same amount of freight. For each diesel long-haul truck today, ~1.1 battery electric trucks will be needed.

Figure 1. Four use case segments for MDHD vehicle population

We then analyzed when, where, and how often heavy-duty (HD) BEVs will charge for local vehicles to determine duty cycle and electric load profiles. These data points were based on National Renewable Energy Laboratory's (NREL) Fleet DNA telematics data project, which derived the daily driving mileage distribution to identify how much demand can be served by overnight and on-route charging.[1] Aggregated profiles for overnight and on-route charging demand identified how much charging occurs at base versus on-route, respectively, and the extent to which private or public stations need to be installed. The aggregation of these profiles revealed the overall load curve per vehicle class at the county level.

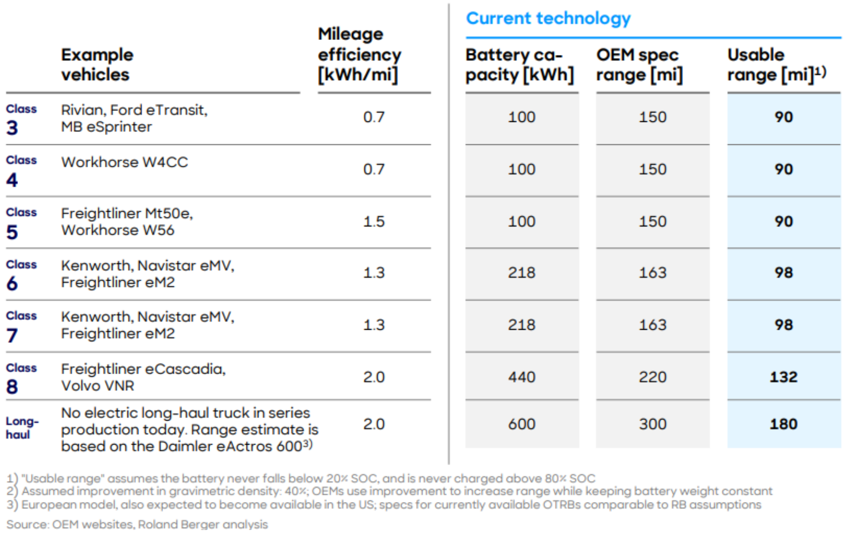
These analyses also used NREL's fleet data to create load profiles for the local charging network supporting Class 3-8 vehicles. We generated a mileage distribution and duty cycle curve to identify the proportions of charging demand best served by overnight versus on-route charging. This determined the respective amounts of charging occurring at base versus on-route locations. Combining these profiles yields electricity load curves for each region and vehicle class, which we then used to simulate county-level electricity demand. For longhaul trucks, we identified truck stop locations throughout the United States and simulated longhaul truck traffic. We analyzed longhaul duty cycles to determine top-up and overnight charging demand, revealing the infrastructure needed at each station type. The aggregated average load curve shows the expected charger needs and county-level electricity load curve.

CURRENT VEHICLE AND CHARGER TECHNOLOGY

Vehicles

Our study examined current BEV commercial vehicles available for purchase and the real-world range for each available truck. The average usable range was computed with a charge range of 20 to 80% per the recommendations from battery manufacturers. Table 2 below includes the vehicle classifications and available BEV trucks studied to determine the operational ranges and charging profiles required.

Table 2. Typical operational ranges of different classes of current technology BEV



			Current technology		
	Example vehicles	**Mileage efficiency [kWh/mi]**	**Battery capacity [kWh]**	**OEM spec range [mi]**	**Usable range [mi]¹⁾**
Class 3	Rivian, Ford eTransit, MB eSprinter	0.7	100	150	**90**
Class 4	Workhorse W4CC	0.7	100	150	**90**
Class 5	Freightliner Mt50e, Workhorse W56	1.5	100	150	**90**
Class 6	Kenworth, Navistar eMV, Freightliner eM2	1.3	218	163	**98**
Class 7	Kenworth, Navistar eMV, Freightliner eM2	1.3	218	163	**98**
Class 8	Freightliner eCascadia, Volvo VNR	2.0	440	220	**132**
Long-haul	No electric long-haul truck in series production today. Range estimate is based on the Daimler eActros 600³⁾	2.0	600	300	**180**

1) "Usable range" assumes the battery never falls below 20% SOC, and is never charged above 80% SOC
2) Assumed improvement in gravimetric density: 40%; OEMs use improvement to increase range while keeping battery weight constant
3) European model, also expected to become available in the US; specs for currently available OTRBs comparable to RB assumptions

Source: OEM websites, Roland Berger analysis

---

[1] "Fleet DNA Product Data." 2024. National Renewable Energy Laboratory.

Class 3-5 fleets with local usable ranges below 90 miles can utilize overnight charging for efficient operations. For MD vehicles that typically return to base within 12 hours, slower Level 2 (L2) or Level 3 (L3) overnight charging suffices. However, Figure 2 illustrates how the NREL vehicle profiles showed that approximately 7% of Class 3-6 vehicles exceed today's operational mileage, necessitating supplementary on-route charging. The picture becomes more pronounced among local fleets running heavier classed vehicles and operating with higher daily mileage requirements.

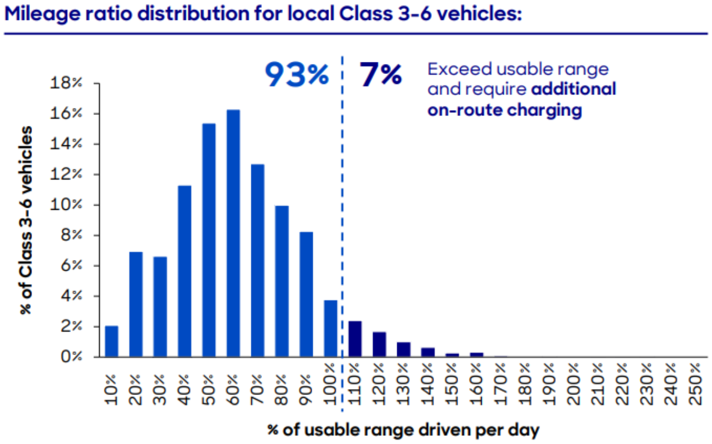


Figure 2. Local Class 3-6 routes as a percentage of usable range with current technology

Under current vehicle technology, local class 7 or 8 tractors returning to base may have as few as 2 to 6 hours available for charging, necessitating costlier L3 or DCFC on-site chargers. Given current vehicle ranges, roughly half of the HD local fleets could exceed the usable range of BEV trucks, requiring access to on-route fast charging to meet their operational needs (Figure 3). Before these high mileage vehicles can electrify, fleets require a sufficiently dense, geographically dispersed, and reliable local on-route charging network to avoid long wait times during peak charging hours.

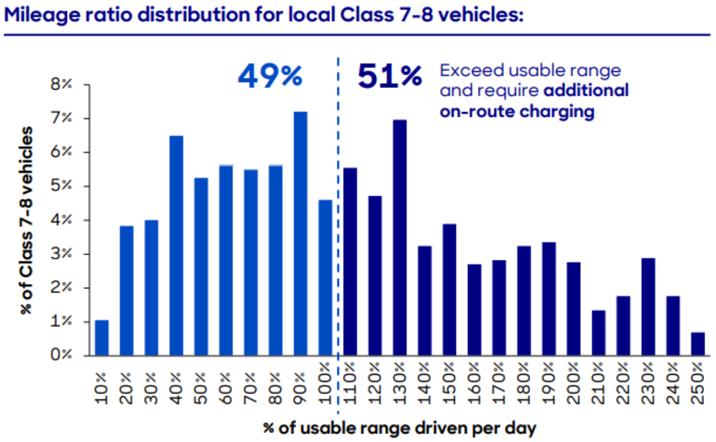


Figure 3. Local Class 7-8 routes as a percentage of usable range with current technology

Longhaul trucks face a significant challenge due to their limited range and the time required for charging. This results in a charging penalty of one to two hours per day for top-up charging, directly impacting fleets' total cost of ownership (TCO). Because most longhaul trucks cover daily mileages exceeding 200 miles, drivers must make at least one, and frequently two or more, stops for charging due to the current usable range being limited to 180 miles. Even with 350 kW chargers, nearly 80% of Class 8 longhaul trucks and truck drivers would need at least an hour of off-duty time during on-route charging, incurring a time penalty compared to traditional internal combustion engines vehicles.

Chargers

MDHD fleets will invest in on-site charging to support BEV deployments. Controlling charging times and costs will provide flexibility during the day charge time, cost containment for electricity costs, and management of departure and arrivals for trucks.

Local mileage operations for MD vehicles can rely on L2 chargers to minimize charger and utility investments. These low-mileage vehicles will have a larger opportunity window to charge at off-peak hours, reducing a fleet's electricity costs. A L2 charger can assist in minimizing on-site investment with longer charge times, though fleets might choose to invest in future on-site high capacity charging to support diverse vehicle operations, thus allowing for different charging profiles.

On-site costs per vehicle can vary depending on BEV fleet size, available power capacity at existing sites, and the local utilities' make-ready programs. While L2 chargers can minimize electric vehicle equipment investment at low vehicle adoption rates, scaling to higher BEV vehicles on-site can dictate significant power, which could require the utility to upgrade upstream infrastructure, such as new substations. New investment from a utility to on-site charging can quickly increase costs on a per vehicle basis.

Regardless of charger capacity on-site, several unknown costs and time constraints can impact a fleet's upfront costs to support electrification. Site improvements, utility investments to support energization of chargers, lead times for utility improvements, and any redundant power solutions can ultimately impact deployment, investment plans and operational costs.

HD local use cases will leverage on-site charging but will require higher energy on premises to support a higher battery range with reduced downtime due to charging. To support a fleet's duty operations, L3 or DCFC will be required on-site. Potential paths towards electrification for all these fleets involve significant costs and risks. Fleet investment can range from $150,000 to $600,000 per vehicle depending on on-site utility service upgrades. These upgrades would be outside of vehicle acquisition costs. If fleets cannot install the requisite power on-site for their operation, they will need to charge at lower rates with more BEV trucks—resulting in higher vehicle purchase and operational costs.

To electrify higher mileage MD or longhaul HD trucks, a reliable and robust on-route charging network needs to exist before these trucks can operate. At unknown utilization today and the need to overbuild on-site to reduce queuing times at chargers, investment for an on-route network is costly and comes with a first-mover disadvantage. Today's range for longhaul BEV trucks is insufficient to cover daily operations and would require multiple on-route charging stops (Figure 4). Even with today's 350 kW chargers, drivers would need to spend long periods of time charging on-route, impacting their hours-of-service requirements, downtime, and delays.

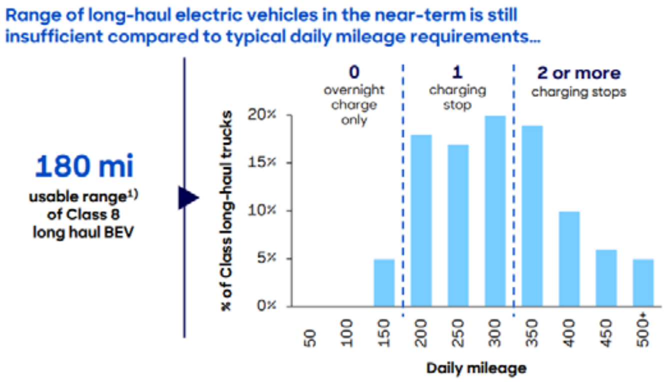


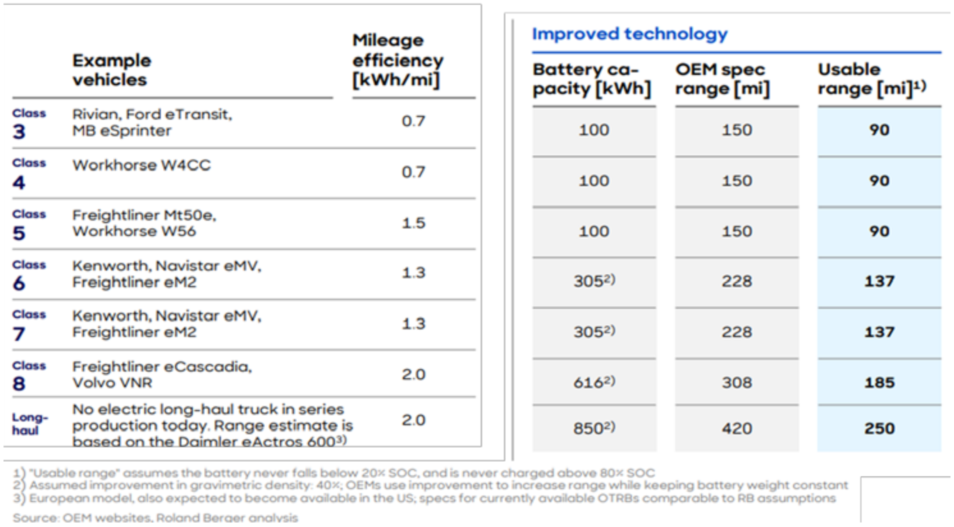
Figure 4. Expected charging stops required for longhaul Class 8 BEV using current technology

IMPROVED VEHICLE AND CHARGER TECHNOLOGY

Vehicles

Using the improved technology scenario, which assumes battery improvements that allow for a usable range of 250 miles (Table 3) and on-route charging improvements that allow for 500 kW or 1MW of power, a significant on-route charging network would still be essential for high-mileage vehicles for MDHD.

Table 3. Typical operational ranges of different classes of improved technology BEV



			Improved technology		
	Example vehicles	Mileage efficiency [kWh/mi]	Battery capacity [kWh]	OEM spec range [mi]	Usable range [mi][1]
Class 3	Rivian, Ford eTransit, MB eSprinter	0.7	100	150	**90**
Class 4	Workhorse W4CC	0.7	100	150	**90**
Class 5	Freightliner Mt50e, Workhorse W56	1.5	100	150	**90**
Class 6	Kenworth, Navistar eMV, Freightliner eM2	1.3	305[2]	228	**137**
Class 7	Kenworth, Navistar eMV, Freightliner eM2	1.3	305[2]	228	**137**
Class 8	Freightliner eCascadia, Volvo VNR	2.0	616[2]	308	**185**
Long-haul	No electric long-haul truck in series production today. Range estimate is based on the Daimler eActros 600[3]	2.0	850[2]	420	**250**

1) "Usable range" assumes the battery never falls below 20% SOC, and is never charged above 80% SOC
2) Assumed improvement in gravimetric density: 40%; OEMs use improvement to increase range while keeping battery weight constant
3) European model, also expected to become available in the US; specs for currently available OTRBs comparable to RB assumptions

Source: OEM websites, Roland Berger analysis

Class 3-5 fleets remain steady within their usable range as their duty cycles allow them a longer window of opportunity to charge on-site. Lower L2 chargers continue to suffice for charging management investment and planning for daily vehicle operations. Improved battery range begins to capture a larger percentage of the daily range for MD vehicles, though 3% of duty cycles still exceed the useable battery 250-mile range (Figure 5). A smaller portion of MD vehicles would still require an on-route charging network to complete their daily operations.

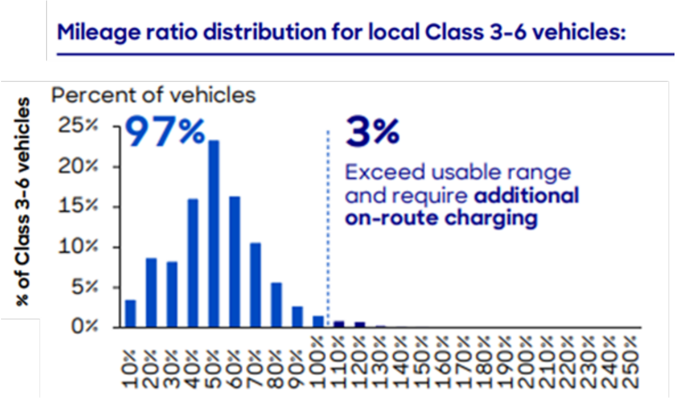


Figure 5. Local Class 3-6 routes as a percentage of usable range with improved technology

Even with improved technology, many Class 7-8 HD will still exceed their usable range to satisfy daily range requirements (Figure 6). To ensure uninterrupted operations, fleets will be required to invest in higher capacity L3 charging on-site and rely on on-route charging at higher outputs to manage charging times with drivers' hours of service requirements.

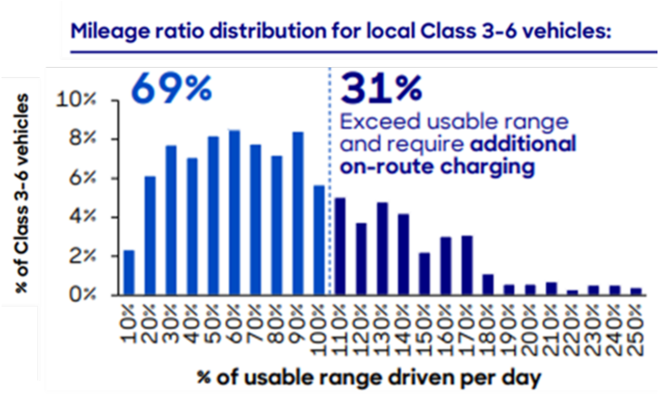


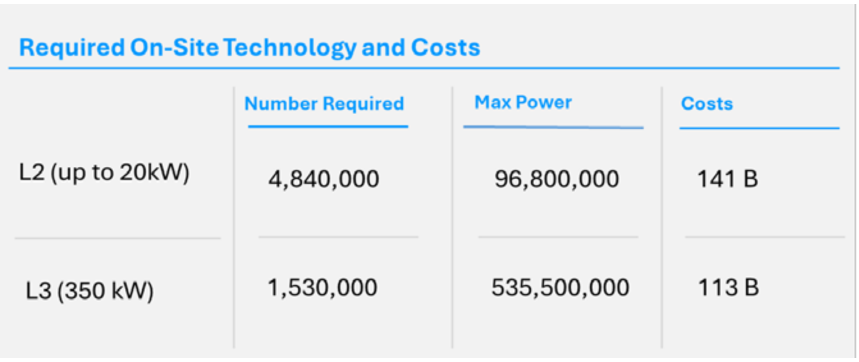
Figure 6. Local Class 7-8 routes as a percentage of usable range with improved technology

Fleets continue to face similar economic challenges for on-site infrastructure investment and costs of a robust on-route charging network. To support adoption and meet TCO requirements, on-route charging will need higher outputs to cover a truck's duty range. While these increased charging levels may reduce time penalties for on-route charging, they may also substantially increase distribution requirements, grid impacts, and, ultimately, cost.

Chargers

Using NREL data, assuming the technology improvements above, and assuming that as much on-site charging would be used as possible to meet electrification needs, we estimate significant on-site (Table 4) and on-route (Table 5) quantities of chargers would be necessary.

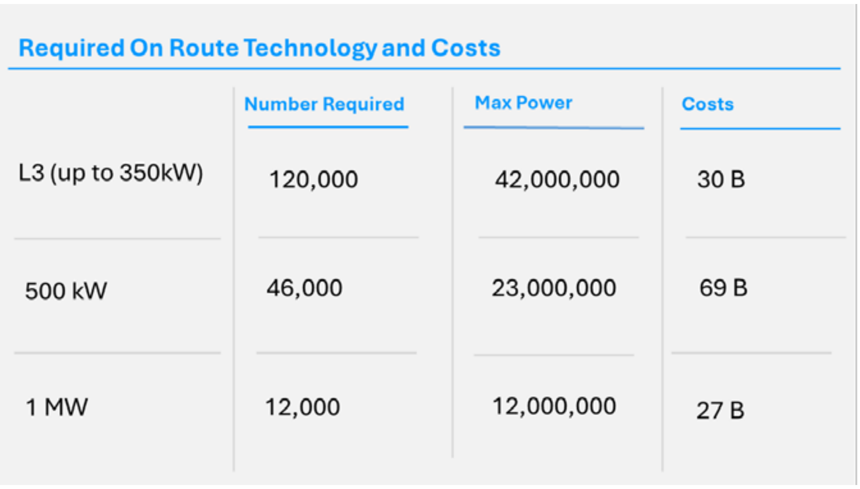
Table 4. On-site charger requirements to meet improved technology scenario



Required On-Site Technology and Costs

	Number Required	Max Power	Costs
L2 (up to 20kW)	4,840,000	96,800,000	141 B
L3 (350 kW)	1,530,000	535,500,000	113 B

Table 5. On-route charger requirements to meet improved technology scenario



Required On Route Technology and Costs

	Number Required	Max Power	Costs
L3 (up to 350kW)	120,000	42,000,000	30 B
500 kW	46,000	23,000,000	69 B
1 MW	12,000	12,000,000	27 B

Two important observations about these estimates stand out. First, achieving 100% electrification would demand a substantial quantity of on-site charging infrastructure. Installing over 6 million individual L2 and L3 charging units would necessitate tens or hundreds of thousands of separate projects involving various fleets. According to the U.S. Department of Energy's Alternative Fuels Data Center, 178,517 new L2 and L3 chargers were installed across the entire U.S. in 2023 for both public and private use. The build-out of on-site charging just for commercial vehicle electrification would take over 35 years to construct at the current pace.[2]

Second, although on-route charging requires fewer units, individual sites will still require significant power even with a small number of units. On-route charging requires the concentration of grid infrastructure at a limited number of locations, which are often situated away from existing infrastructure. Investments in equipment and distribution may need to be substantially higher to accommodate these elevated power requirements. It is also worth reiterating that on-route infrastructure is largely outside fleet control and therefore must be substantially completed along a given route before a fleet can acquire and plan to operate BEV on those routes. 500 kW and 1 MW chargers are not widely deployed, and there is significant uncertainty if these chargers will be available ahead of mandated adoption of BEVs. All stakeholders will

---

[2] https://afdc.energy.gov/stations/#/find/nearest?country=US

need to consider how the design and construction of high-power chargers will differ from L2/L3 chargers, particularly how to plan the on-route charging network to ensure usable routes created along major freight corridors.

A final point of emphasis is that all this infrastructure will require new construction, specifically designed for commercial vehicles, and generally not compatible with other road users. Commercial vehicle operations are time-sensitive and cannot rely on public charging solutions for which reliability and queue times are not controlled. In the case of on-site charging, fleets will need to acquire the land, plan the designs, and coordinate construction projects with each utility with which they need to build charging capacity. For on-route charging, that means pull-through designs specifically made for efficient commercial vehicle charging will need to be used, and 3- to –8-year lead times will need to be planned if new substation-level infrastructure is part of the construction.

UTILITY IMPACTS AND INVESTMENTS

Given the estimates of charging requirements for 100% electrification, we evaluated the impacts that charging build out would have on upstream utilities. Using the route data from the charging estimate and county-level utility data, we estimated some of the local-level impacts of commercial vehicle electrification.

Capacity

In many counties, the addition of on-site charging would significantly change daily electricity load profiles. On-site charging would predominantly be used during overnight dwell times, creating a new peak during overnight hours rather than mid-day. It would also push these new peaks well beyond current ones, eliminating existing headroom or overloading existing capacity. This new demand creates major risks for fleets as they try to identify which operations are the best candidates for electrification and how to plan those operations. If overhead is eliminated, there will be significant costs for charging during peak times, and if peak times shift, TCO will also dramatically shift. The most significant impacts would be felt the further away a site is from existing urban infrastructure. This is because the overloads are a greater percentage of existing capacity when starting from a lower baseline, and because of the increased cost to build that capacity in geographically distant locations.

Distribution & Transmission

Utilities have a limited toolbox for dealing with capacity upgrades to accommodate higher electricity demand from commercial vehicle electrification. They can add or replace lines at the feeder level to deliver the necessary power if existing infrastructure supports it. However, if these new loads are introduced in locations that still need significant infrastructure, then additional upgrades will be needed. This would entail adding or replacing transformers, or if capacity exceeds what is available with the current substation, replacing or adding substations themselves. This problem is particularly relevant to on-route charging, which may be located far away from existing urban infrastructure and would be focused on high-power charging solutions. In cases where entirely new transmission and substation infrastructure may be necessary, typical lead times are 3 to 8 years. At a higher level, we found that the overall cost of utility infrastructure per commercial vehicle electrified will increase exponentially with distance from urban centers. Policymakers should carefully consider this correlation when charting a path to electrification.

Aggregate Planning

Utilities will need to understand the individual charging needs of each fleet operation to build the infrastructure effectively, predict how demand will impact overall capacity, and ultimately provide fleets with accurate, predictable costs, and timelines. Although we furnished county-level estimates for commercial vehicle electrification needs in this report, utilities typically require fleet customers to provide concrete plans to commence infrastructure development. Currently, utilities face the hurdle of liaising with numerous individual fleets to address specific on-site charging requisites. This makes it difficult for utilities to aggregate demands or plan for industry-level technology shifts.

Individual fleets, particularly smaller fleets, may not be equipped to provide concrete long-term electrification plans to their utilities. Most early adopters of BEV technology in commercial vehicles are at the early stages of their first deployments of the vehicles. They are in the nascent stages of collecting operational data essential for providing utilities with long-term plans regarding the timing, location, and extent of infrastructure required. The net effect is that utilities face challenges building the cases for infrastructure investment to their stakeholders, they lack data to effectively plan how to handle aggregate needs across disparate fleets, and then cannot provide fleets with reliable estimates of what infrastructure and energy costs might be in order to justify BEV adoption.

Distribution Grid Investment

Chargers are not the only infrastructure that must be installed to enable commercial BEV adoption. In many cases components of the distribution grid (Figure 7) must be upgraded to handle the power being added at the site, local, and even regional level. Our study conducted a detailed analysis of distribution grid impacts and investment needs for select geographies across California, Texas, and North Carolina – covering rural and urban areas. Grid infrastructure models were available for selected geographies from NREL Smart DS.[3] The impact of MDHD electrification on every feeder and substation within each geography was analyzed.

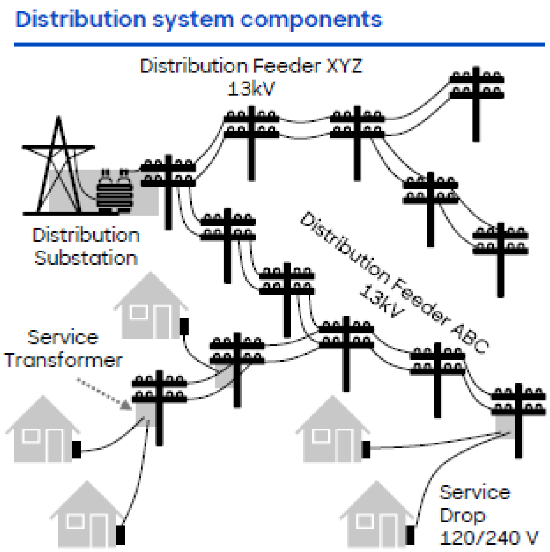


Figure 7. Diagram of the components in a distribution system

---

[3] Analysis was run on simulated NREL Smart DS simulated distribution grid architecture and customer load datasets for Austin, Greensboro and Northern California regions. The Smart DS dataset includes customer counts, load profiles, and detailed infrastructure data.

The analysis simulated the impact of MDHD charging on existing grid infrastructure and estimated the "overnight cost" of increasing the capacity of impacted grid assets. MDHD charging was layered onto existing loads for each feeder to determine impacted assets.[4] Based on each feeder's architecture, each upgrade cost was determined.

The grid impacts and investment needs for each county within the grid dataset were analyzed to determine the investment required on a per vehicle basis. For each region, the impact of MDHD charging on all grid assets in each county was analyzed to determine county-level distribution investment.

Investment needs per vehicle vary significantly across geographies. In more rural and industrial areas, utilities will need to spend more per vehicle primarily due to greater distances between customer locations (requiring more miles of conductor). Per vehicle distribution grid investment needs to increase farther away from denser urban areas. This correlation was applied to determine the "per vehicle" investment needs for all other U.S. counties.[5]

Based on this methodology, utilities will need to invest around $370 billion nationally on distribution grid upgrades and new construction to meet local charging demand from Class 3-8 trucks (Figure 8).[6, 7] In comparison, utilities cumulatively invested roughly $450 billion across the U.S. for all distribution investment over the last 15 years. The utility costs for MDHD charging represent 82% of what was spent on all distribution grid investments over the past 15 years.

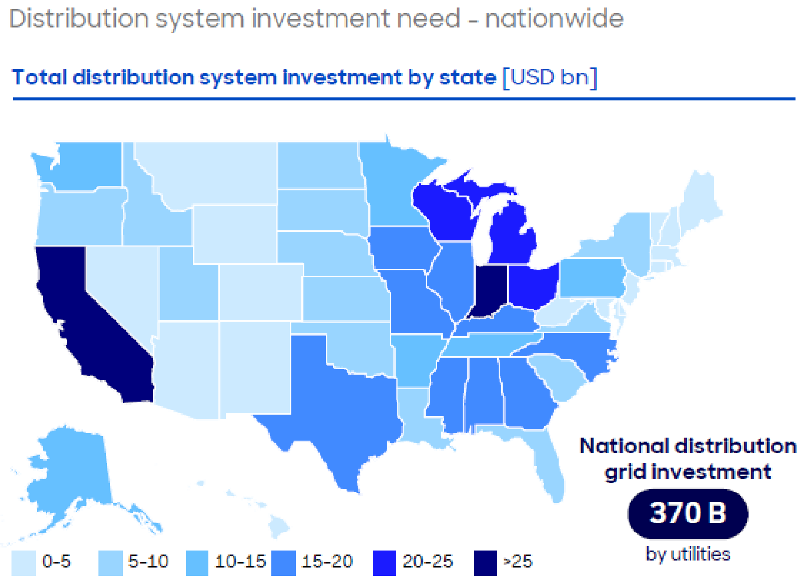


Figure 8. Investments required in distribution systems by U.S. state

---

[4] There is a limited solution set for utilities to expand the capacity of impacted grid assets.

[5] Predictor variable used for correlation is the percentage share of total county-level employment in agriculture, construction, and manufacturing sectors.

[6] Based on "overnight" capital cost of grid infrastructure at current price levels – actual utility investment will be higher due to 1) price inflation of labor and equipment, and 2) utility guaranteed rate of return.

[7] Distribution grids will serve on-site and on-route charging demand from local fleets. Longhaul trucks and highway charging stations will be served by the transmission grid and bulk power system.

Moreover, distribution spending is expected to continue increasing across multiple priorities (e.g., integration of distributed energy resources, resiliency) of which MDHD electrification is just one priority. Proactive investments will likely be constrained by limits on rate increases, potentially delaying charging infrastructure buildout.

Challenges:

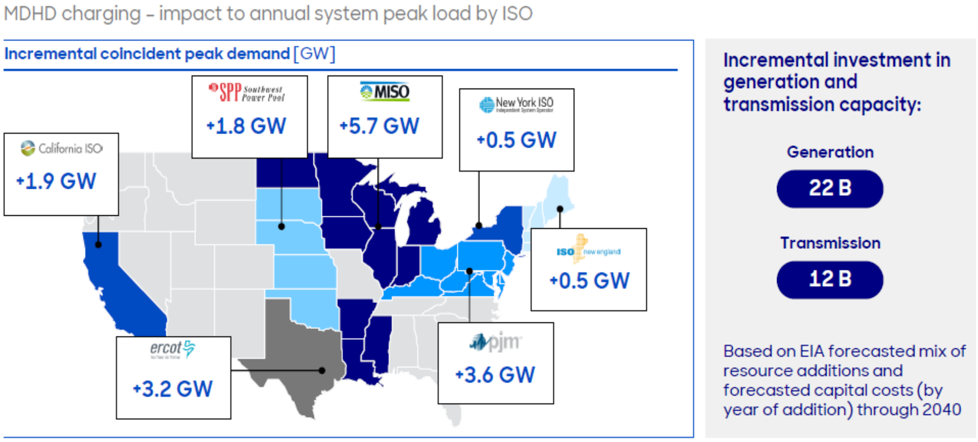
- Utilities will need to build infrastructure ahead of MDHD deployment to avoid bottlenecks and delays.
- These types of investments require more sophisticated grid planning, and regulatory support, which have been limited to date.
- The overall pace of investment will still be constrained by the need to control rate increases and maintain affordability.

Potential Mitigating Factors:

- If fleets can successfully shift or manage peak charging load (e.g., battery-integrated chargers), utility investment could be significantly reduced.
- Appropriate incentives and/or price signals need to exist to support fleet economics.

Power System Investment

MDHD charging will require a meaningful increase in energy generation. However, MDHD charging will have a less significant impact on system capacity requirements, primarily a function of peak energy demand across a region (Figure 9). The impact of MDHD charging on peak energy demand is diminished, as most charging occurs overnight – avoiding system peaks. Thus, increased energy generation needs typically translate to increased utilization of existing assets.



Based on EIA forecasted mix of resource additions and forecasted capital costs (by year of addition) through 2040

Figure 9. Incremental increases in peak demand for regional utilities due to MDHD charging

MDHD charging will create some incremental capacity and investment needs; however, power system operators are already planning for significant generation and capacity growth from transportation electrification, as well as other trends.

CONCLUSION

This study brings to light that fleets will bear a significant financial burden on the heavy-duty vehicle sector's transition to electrification. In addition to hurdles on the build and investment costs associated with infrastructure support for MDHD vehicles as mentioned in this report, fleets will continue to face operational constraints as they are required to electrify.

- Fleets expect that the price of BEV trucks will continue to be higher than their diesel equivalent for the foreseeable future due to increased battery capacity for range improvements.
- BEVs experience a weight penalty compared to their equivalent diesel trucks. Unless the BEV reduces weight to match the diesel equivalent truck, fleets will have a payload disadvantage. Fleets would be required to reconfigure business operations with higher freight rates to cover higher vehicle and operational costs. In addition, certain segments of the trucking industry that "weigh out" before they "cube out" would be penalized more than others, for example, tank trucks.
- Vehicle offerings must expand considerably because manufacturers' proposed product plans are currently limited. The dearth of scalable and commercially viable alternatives cannot cover the diverse vehicle needs of the industry. Many fleets are unable to purchase longhaul BEVs due to none being in production.
- Drivers will need to be compensated if they must wait for trucks to be charged during their federal hours-of-service window. Fleets will have to align drivers' utilization rates with the vehicles' charging windows, and if misaligned, will negatively impact a fleet's profitability and drive-up freight rates.
- Fleets are disproportionately penalized for purchasing the latest, cleanest technology on the market today. Eliminating the 12% federal excise tax on the purchase of a new vehicle will reduce emissions while the BEV technology and corresponding charging infrastructure improve to meet industry's needs.