Estimating Electrification Potential for Class 8 Regional-Haul Trucks

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Key Takeaway

Simulated Tesla trucks, with an average efficiency of 1.8 kWh/mi and daily driving distances ranging from an average of 445 to 1,100 miles, face challenges on longer routes and struggle to achieve full operational coverage with the current battery and charging configurations. However, where ubiquitous charging exists, 100% EV coverage is possible for the given drive cycles.

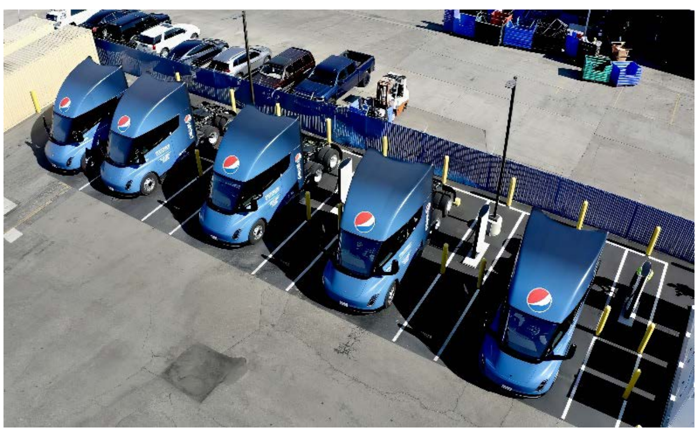

Figure 1. A row of Tesla semitrucks. *Photo from North American Council for Freight Efficiency*

In September 2023, the North American Council for Freight Efficiency collected data on Class 8 regional-haul tractors for approximately 2 weeks at various depots, such as the United Parcel Service, Frito-Lay, and PepsiCo.

As part of the Run on Less depot data workshop, the National Renewable Energy Laboratory (NREL) sought to understand how Tesla semitrucks would perform in real-world regional-haul applications.

NREL constructed a vehicle model to simulate the Tesla trucks in PepsiCo's fleet using the Future Automotive Systems Technology Simulator (FASTSim™) tool and NREL's Fleet Research, Energy Data, and Insights (FleetREDI) data analysis platform. Deployment statistics for each dataset are shown in Table 1.

Table 1. Fleet Overview for PepsiCo Tesla and FleetREDI Diesel Class 8 Trucks

	Number of Class 8 Trucks	Types	Calendar Days	Vehicle Days	Miles
PepsiCo Tesla	3	Regional haul	17	46	27,606
FleetREDI Diesel	49	Regional haul	61	494	219,870

Duty Cycle Analysis

Data for the duty cycle analysis included information such as truck identification, time, speed, distance, ignition status, energy usage (for driving, regenerative braking, and idling), charging status, and state of charge.

Figure 2 shows long daily distances with an average of 600 miles, as well as higher speeds, indicating that the driving is primarily on highways for the Tesla trucks. The diesel trucks exhibit similar driving patterns but have an average daily distance of 445 mi, with a maximum recorded distance of 1,100 mi.

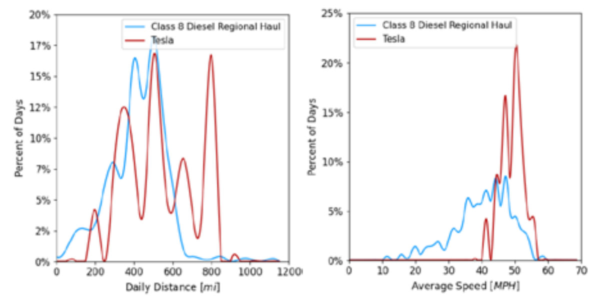

Figure 2. Distributions over daily distance (left) and average speed (right)

Figure 3 shows an average efficiency of 1.78 kWh/mi and an average daily energy consumption of 992 kWh for the Tesla trucks. In comparison, the diesel trucks have a slightly higher flywheel energy rate (energy output at the flywheel of the engine) of 2.04 kWh/mi and an average daily flywheel energy production of 910 kWh.

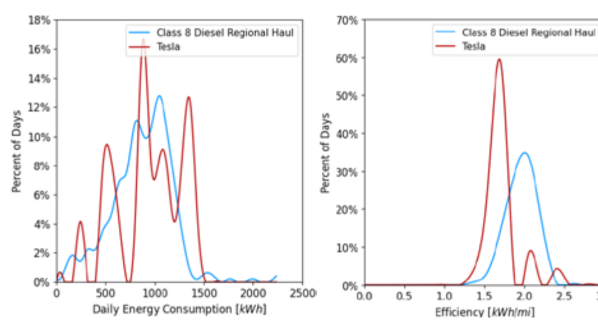

Figure 3. Distributions over daily energy consumption (left) and efficiency (right)

Vehicle Modeling

NREL used Tesla's Class 8 tractor specifications and measured data from PepsiCo to calibrate the FASTSim model to accurately simulate energy usage on Class 8 diesel regional-haul drive cycles from FleetREDI. To account for significant weight variations during trips and their effect on factors such as efficiency, required propulsion energy, and regenerative braking energy, NREL applied a model-based mass estimation method to the diesel data.

Using a Nelder-Mead-based optimization method, NREL estimated the vehicle mass for each microtrip—driving instances between periods where the vehicle is off or idling for at least 5 minutes, assuming weight changes during these windows due to unloading or loading. The optimization aims to minimize the difference between the simulated fuel rate and measured fuel rate recorded for each microtrip to estimate the mass.

NREL applied these mass estimates to the electric vehicle (EV) model to refine predictions when running on the respective diesel drive cycles. Results are shown in Figure 4.

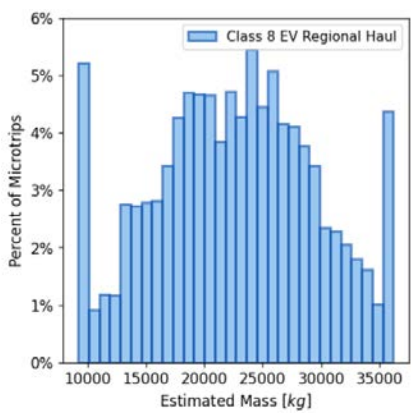

Figure 4. Estimated mass for all microtrips

Results

Figure 5 includes the results from running the EV model on FleetREDI's diesel drive cycles. The simulated results from the model show efficiencies such as the PepsiCo Tesla fleet averaging 1.8 kWh/mi, with a daily energy consumption of approximately 820 kWh.

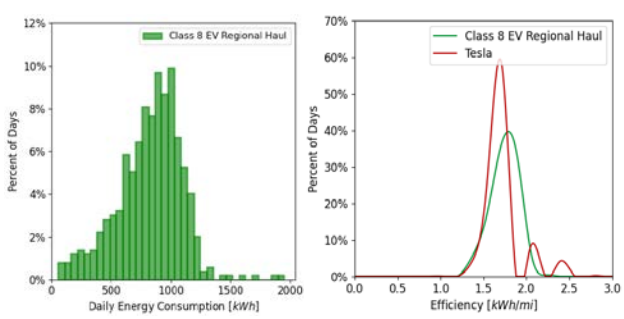

Figure 5. Distributions over the simulated daily energy consumption (left) and efficiency (right)

Using the simulated battery power, Figure 6 identifies how many vehicles can complete their routes with various battery sizes and charging rates, assuming vehicles charge only when stopped for 50 minutes or longer. For a 900-kWh battery—such as the battery used by the surveyed Tesla trucks—and a 750-kW charge rate, only 12.2% of the simulated electric trucks can complete the required duty cycle.

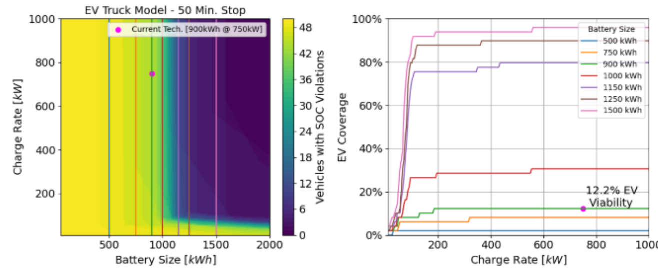

Figure 6. Class 8 EV route success given various battery sizes and charging rates (charges if stopped ≥50 min)

However, in the extreme case, if the modeled tractors charge when stopped for at least 5 minutes, 100% electrification is possible (Figure 7).

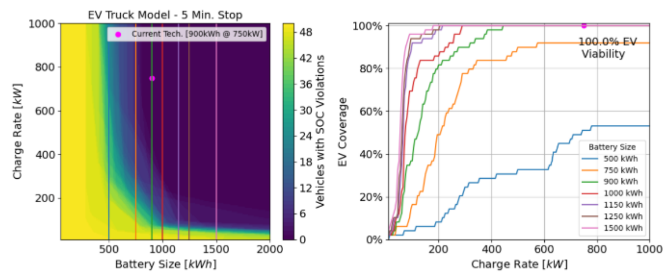

Figure 7. Class 8 EV route success for various battery sizes and charging rates (charges if stopped ≥5 min)

Conclusion

Analysis reveals that the modeled Tesla trucks, with an average efficiency of 1.78 kWh/mi, struggle to achieve full operational coverage using current battery and charging configurations assuming operations remain unchanged. However, in an extreme case where ubiquitous charging exists, 100% EV coverage is possible for the given drive cycles. These findings highlight the trade-off between battery size and charge rate in electrification potential and emphasize the need for advancements in charging infrastructure to enable electric trucks for regional-haul operations.

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