Big E-Trucks & E-Buses

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1. Introduction

By the time this is posted, it will be about 10-months since my last post about heavy Highway Vehicles. That post is summarized and linked below.

Really Big Electric Trucks: *There will be two subjects in this paper. Both of them are flavors of the title, but one I've written about before, and the other, not so much. The first is definitely a clean-sheet design, and the latter looks (and mostly is) derivative of earlier generations. Both need to ramp production very quickly to help my home state (California) make the transition to non-diesel big rigs.*

Starting in 2036, no new fossil-fueled medium-duty and heavy-duty trucks will be sold in the state. Large trucking companies also must convert to electric or hydrogen models by 2042. The California Air Resources Board (CARB) decided to review progress and obstacles in meeting the deadlines two and a half years from now.

https://energycentral.com/c/ec/really-big-electric-trucks

This post will focus on the largest (motor-coach) electric buses, and the largest (class 8) electric Semi Trucks, specifically focusing on the Tesla Semi. Currently, viable battery sizing for each of the vehicle-classes limits their trip distance to around 200 miles. However, this distance allows them to address large sub-markets in each of their overall markets.

2. Interregional Express Bus Service

An interregional express bus service can use a currently available battery capacity option (676 kWh) at a charge rate of 125 kW to immediately electrify part of its fleet for routes up to 200 miles in moderate climates.[1]

Ace Express Coaches is an All Aboard America Holdings Inc. portfolio company that offers interregional public transportation bus services across Colorado through its Bustang-branded fleet of motorcoaches in partnership with the Colorado Department of Transportation. The National Renewable Energy Laboratory collected operational data on nine 45-foot Bustang motorcoaches from May through August 2022. The deployment statistics are summarized in Table 1.

Table 1. Deployment Overview

Location	Number of Vehicles	Type	Vocation	Duration	Miles
Colorado	9	Motorcoaches	Intrastate bus	May–Aug. 2022	33,942

[1] Cory Sigler, Polina Alexeenko, Alicia Birky, Andrew Kotz, Jason Lustbader, Matt Jeffers, and Mike Lammert, National Renewable Energy Laboratory (NREL), "Electrification Analysis: All Aboard America!" November 2024, https://www.nrel.gov/docs/fy25osti/91370.pdf

2.1. Duty Cycle Analysis

Full electrification of Bustang fleet operations is not achievable today; however, partial electrification may be feasible with commercially available electrified motorcoach options. Figure 2 shows distributions of the daily distance and engine output energy observed from the fleet. The distributions are separated based on which corridor the vehicle primarily traveled (i.e., Interstate 25 vs. I-70).

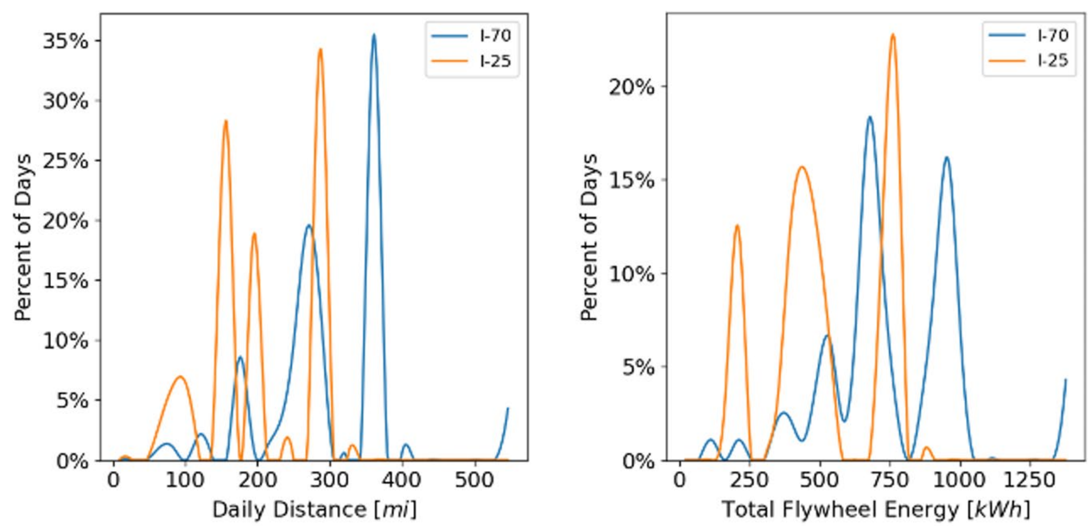

Figure 2: Distributions of daily distance (left) and energy (right disaggregated across primary travel corridors

Energy and distance requirements are lower on average for I-25 vehicles with significantly lower maximum requirements than the I-70 group, especially considering that midday dwell times for I-25 vehicles allow for additional charging opportunities. Furthermore, 21 of the 32 vehicle-days in the I-25 group were less than 200 miles and 600 kWh of energy, suggesting electrifying travel on the I-25 routes may be feasible with only minor operational changes.

Consistent overnight dwells are present in the operating probability plot; however, the duration, start, and end times of these dwells vary between bus and day, indicating higher depot charging rates may be necessary some days.

None of the combinations of battery size and charge rate presented in the electrification viability plot can satisfy the travel needs of every vehicle observed in the fleet. However, a battery capacity equivalent to an available market option (676 kWh) at a charge rate of 125 kW may be sufficient for seven of the nine buses. Additionally, the electrification viability is shown to be far more sensitive to battery size than charge rate.

Midday charging would be required to meet these electrification targets. Figure 4 (next page) shows a heat map highlighting locations where the buses were stopped for 1 hour or more, showing the opportunity for midday charging along routes.

The Bustang fleet faces significant challenges to electrification given current market options resulting from demanding range requirements and relatively limited charging opportunities. The primary limiting factor for electrification is battery capacity, but vehicles operating on the shorter routes with a lower grade along the I-25 corridor show more immediate electrification potential.

Increases in available battery capacity and the availability of fast charging locations along I-70 routes are both critical for electrifying the full fleet.

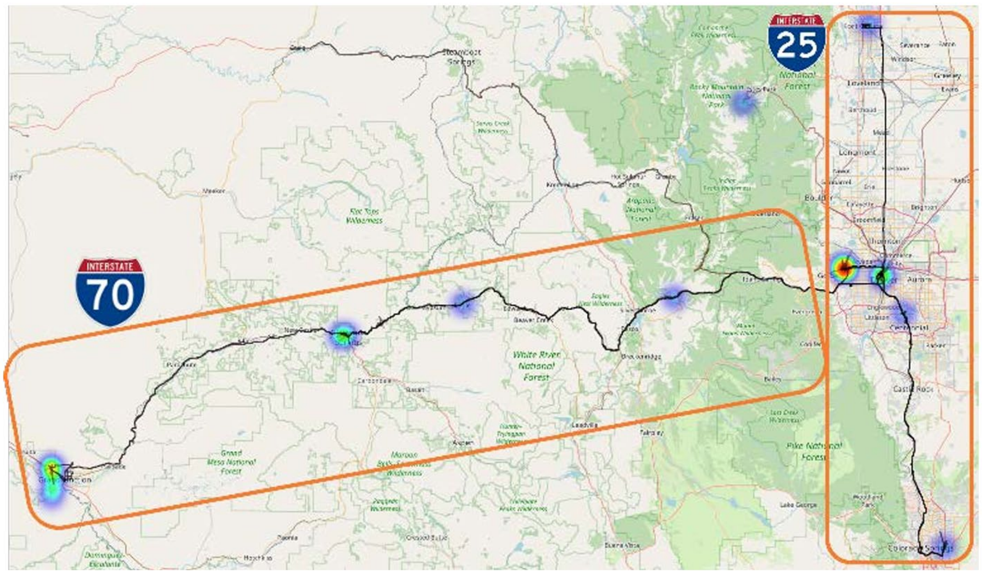

Figure 4: Routes and stop locations of 1 hour or more.

3. Electrification Potential for Regional Haul Trucks

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.[2]

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 2: 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

[2] Andrew Kotz, Setayesh Fakhimi, Catherine Ledna, and Jason Lustbader, NREL, "Estimating Electrification Potential for Class 8 Regional Haul Trucks, Nov 2024, https://www.nrel.gov/docs/fy25osti/91369.pdf

3.1. 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 (next page) 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.

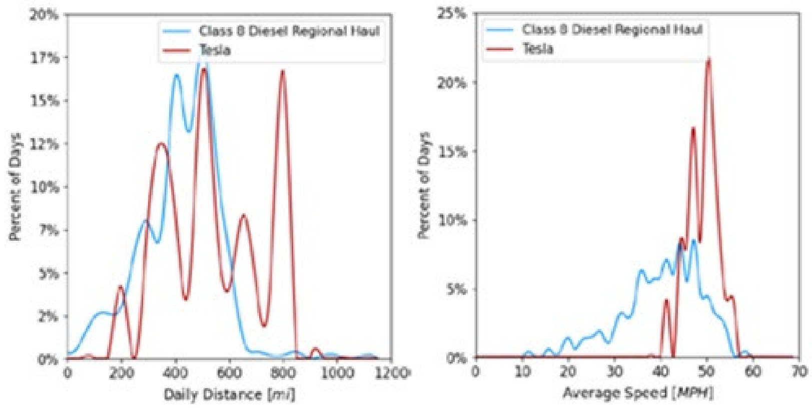

Figure 5: Distributions over daily distance (left) and average speed (right)

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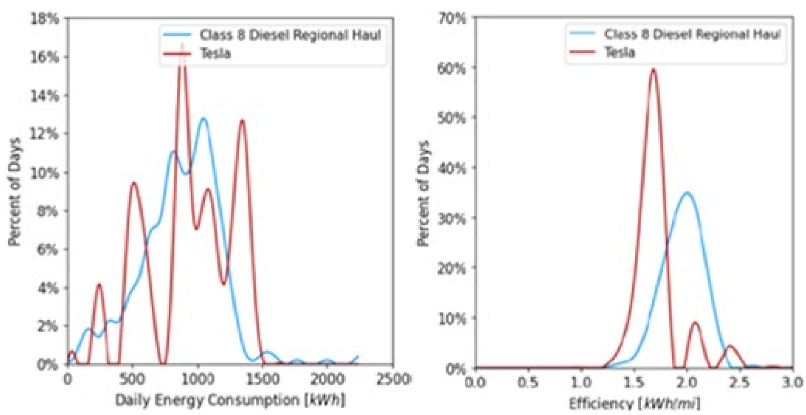

Figure 6: Distributions over energy consumption (left) and efficiency (right)

Figure 6 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.

3.2. 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 7.

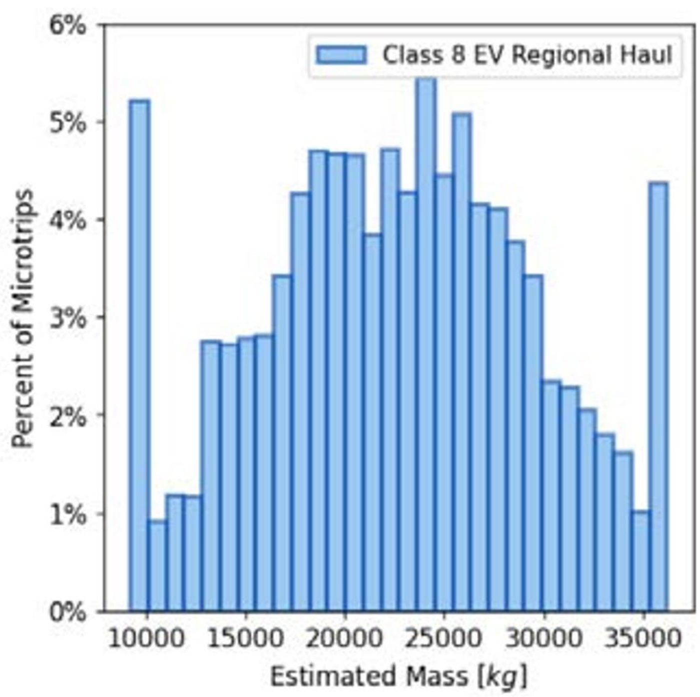

Figure 7: Estimated mass for all micro-trips

3.3. Results

Figure 8 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.

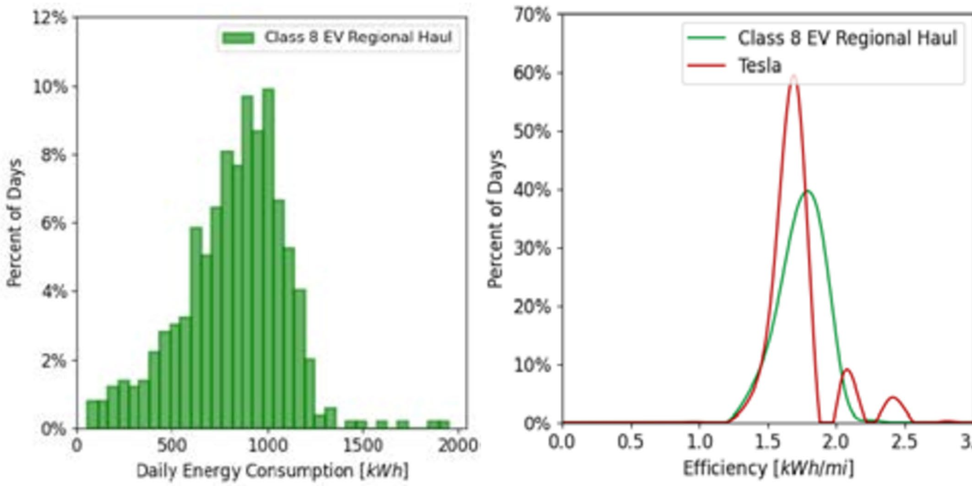

Figure 8: Distributions over the simulated daily energy consumption (left) and efficiency (right)

Using the simulated battery power, Figure 9 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.

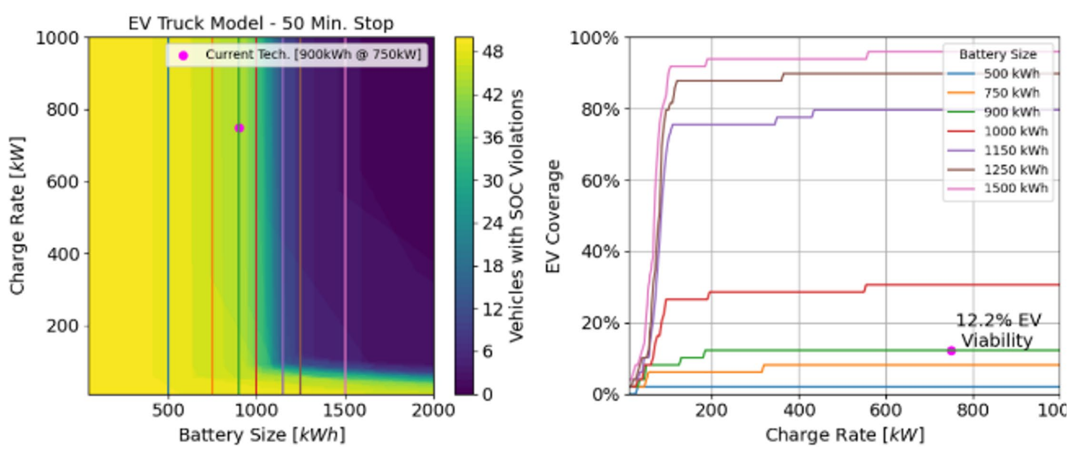

Figure 9: Class 8 EV route success given various battery sizes and charging rates (charges if stopped 50 min or more)

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

3.4. 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.

4. Final Author Comments

The above paper focuses on short-haul routes – 200 miles and under. There is a more advanced solution for electric class-8 semi-trucks than batteries that enable a range of over 500 miles.[3] See the related earlier post summarized and linked below.

Efficient Hydrogen Storage for Big Rigs: *One class of likely mobile users of hydrogen are large road vehicles, ESPECIALLY if the space required for storage of the hydrogen could fit into current big rig tractor designs and provide a non-stop range comparable to existing diesel-fueled tractors. Although there are quite a few details to work out, this goal appears to be much closer to reality.*

https://energycentral.com/c/ec/efficient-hydrogen-storage-big-rigs

[3] Hydrogen Central, "Verne and Lawrence Livermore National Laboratory achieve cryo-compressed hydrogen storage record, demonstrating first system suitable for heavy-duty transportation," Dec 17, 2023, https://hydrogen-central.com/verne-and-lawrence-livermore-national-laboratory-achieve-cryo-compressed-hydrogen-storage-record-demonstrating-first-system-suitable-for-heavy-duty-transportation/