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Analysis of the Tesla electric long haul truck: batteries, performance, and economics

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Research Question

- **Is the 500 mile battery-electric long-haul class 8 truck viable, and cost effective?**
- In this research, the performance and costs of a 500 mile class 8 battery-electric truck, similar to that proposed by Tesla, are analyzed in detail based on ADVISOR simulations and associated cost calculations.
- We consider both the economics of such a truck and the required specifications, to assess its technical feasibility

Methods and Data

- **We have analyzed the design and operation of a battery-electric long-haul truck using our Advisor simulation model, based on published information from Tesla.**
- We then estimated the kWh and weight of batteries needed, the truck's acceleration and gradeability characteristics under that configuration, and the truck's economics compared to a diesel truck.
- We have also considered the difficulty in accommodating the weight and volume of the batteries on the tractor of the truck.
- Tesla has provided the following information for its Class 8 truck:
  - Acceleration 0-60 mph with 80K lbs load – 20 sec
  - Speed up a 5% Grade – 65 mph
  - Mile Range – 300 or 500 miles
  - Powertrain – 4 Independent Motors on Rear Axles
  - Energy Consumption – Less than 2 kWh / mile
  - Fuel Savings – $200,000+
  - Expected Base Price (300 mile range) – $150,000
  - Expected Base Price (500 mile range) – $180,000
  - Base Reservation – $20,000
  - Expected Founders Series Price – $200,000

Our approach does not account for steep grades, which can require big increases in energy to climb (kWh/mi)

Driving cycle	0.0 Grade	½ % grade	1% grade
WVintercity	1.97	2.84	3.78
Interstate Highway Up to 75 mph	2.42	3.36	4.36
Constant speed 65 mph	1.78	2.69	3.89

- We have modeled an electric long haul truck with inputs aligned to the technical specs provided by Tesla. We used our ADVISOR vehicle simulation program to determine the energy consumption, range, acceleration, and gradeability of the truck. Using the ADVISOR simulation results, we determined the characteristics (kWh, weight, and volume) of the battery pack and estimated the initial purchase and ownership costs of the truck and compared them to a base future diesel truck in 2030. The methods used in this analysis of the 500 mile electric truck are discussed in detail in [3]

Technical Inputs and Results

- The key inputs were the following:

CD =.36, AF =9.5 m2, fr =.005, Wt. =39500 kg, electric motor 750 kW 95% max eff, accessory load =1.5 kW

- The batteries have an energy density of 250 Wk/kg for the cells and a packaging efficiency of 1.35 (wt pack/wt. cells =1.35).
- Based on the simulation results for energy consumption for highway driving (60-65 mph) on a highway with no grade, the truck would need 1134 kWh of batteries to achieve about 500 mile range.
- The battery pack would weigh 6075 kg and have volume of about 3400 L.
- As indicated by the energy consumption values in the table above, the range in the real world would likely be significantly less than 500 miles due to the truck encountering some operation on grades and traveling at speeds of 65 mph or higher. For short hill grades, part of the increased energy consumption will be recovered by regenerative braking during down grades.

Broader Results

- It was found that the performance claims (energy consumption, range and acceleration times) made by Tesla for their truck are generally confirmed by the simulations.
- We estimate that the required battery pack in the 500 mile electric truck stores 1134 kWh of electrical energy. This battery will weigh about 6 tons, reducing a 20 ton payload by 30%.
- If all the batteries were placed on the tractor, the tractor weight would be doubled compared to today's typical tractor weights. It is not clear if this poses any problem.
- As would be expected, the economics of the truck operation are dependent primarily on the unit cost ($/kWh) of the batteries and their cycle life in long haul truck applications.
- The cost calculations indicate that for battery pack costs close to $100/kWh, the higher price of the 500 mile electric truck compared to a diesel truck can be recovered from fuel/electricity cost savings in about 5 years if the trucks are operated 125,000 miles per year.
- The average per-mile cost of the electric truck over 5 years is (therefore) similar to that of the diesel truck, around $0.50/mile. These results depend heavily on fuel price assumptions (we assume $3.50/gallon diesel and $0.15/kWh electricity) as well as the battery costs. Further, they assume a battery that can last 5 years and sustain 1500 charging cycles in the process.
- This seems reasonable for future batteries, though any need for early battery replacement would severely worsen the BEV truck economics.
- Our base case cost results are shown in the table below. The bottom line of about $0.50 per mile over 5 years of truck operation, for both truck types, can be seen:

	Diesel truck	Battery-electric truck
Glider cost	$93,000	$93,000
Engine and related components	$39,000	
Batteries @ 1176 kW, $200/kWh ($100/kWh)		$226,800 ($113,400)
Electric motor and balance of system		$33,750
Total truck cost	$132,000	$354,000 ($240,000 with cheaper batteries)
Energy cost	$3.50 / gallon	$0.15 / kWh
Vehicle efficiency	8.7 MPG	2 kWh/mile
Energy cost per mile	$0.40	$0.30
Miles driven in 5 years of operation	625,000	625,000
Used capital cost after 5 years (50%)	$66,000	$177,000 (@$200/kWh), $120,000 (@$100/kWh)
Resutls: Capital cost per mile	$0.11	$0.28 ($0.19)
Energy cost per mile	$0.40	$0.30
Total cost per mile	$0.51	$0.58 ($0.49 with cheaper batteries)

Conclusions

- The battery requirements for a 500 mile Class 8 truck would be considerable, over 1000 kWh and over 6 tons. This significantly lowers payload capacity and increases tractor weight.
- The cost of this truck over 5 years appears to be competitive with diesel trucks, at least with the set of data and assumptions used here. Sensitivity analysis is needed (and underway) to test the effects of varying these assumptions.

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