Analysis of Fuel Cells for Trucks

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Overall Objectives

Fuel cell electric trucks (FCETs) have the potential to be a cleaner and sustainable alternative to diesel-powered trucks. Because the fuel cell technology targets set for light-duty vehicles are inadequate for heavy-duty FCETs, the objective of the project is to inform heavy-duty-specific technology goals for fuel cells, hydrogen storage, and refueling infrastructure.

Fiscal Year (FY) 2019 Objectives

- Develop a baseline truck to represent the best-in-class conventional Class 8 sleeper truck.
- Validate the model against information available from actual vehicle tests.
- Develop a model for a fuel-cell-powered Class 8 sleeper truck with current cargo and performance capabilities.
- Use the vehicle model to inform target-setting activities of the Fuel Cell Technologies Office (FCTO).

Technical Barriers

This project addresses the following technical barriers from the Systems Integration and Systems Analysis sections of the FCTO Multi-Year Research, Development, and Demonstration Plan[1]:

- Unpredictability of competing technologies' future performance
- Inconsistent data, assumptions, and guidelines
- Insufficient suite of models and tools.

Contribution to Achievement of DOE Milestones

This project will contribute to achievement of the following DOE milestones from the Systems Analysis and Systems Integration sections of the FCTO Multi-Year Research, Development, and Demonstration Plan:

- 2.2: Annual model update and validation
- 4.2: Independent reviews of progress on technical targets.

FY 2019 Accomplishments

This project uses Autonomie [1], a simulation tool developed at Argonne to simulate conventional and fuel-cell-powered trucks. Diesel trucks are also expected to improve over the coming years, as demonstrated by DOE's super truck project. The FCETs of the future will compete against such advanced diesel trucks. This work informs the fuel-cell target-setting activities for heavy-duty sleeper trucks.

INTRODUCTION

Over a thousand different truck models are available in Autonomie, spanning multiple classes, vocations, powertrains, component technologies, and fuels. This project uses Class 8 sleeper trucks with conventional and fuel-cell powertrains. This work focused on FCETs with fuel-cell-dominant designs, as explained in prior work [2].

Under real-world driving conditions, Class 8 sleeper trucks typically have a fuel economy under 6 mpg [3]. However, several recent real-world driving experiments show that these trucks can achieve higher mileage

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

through better driving habits and some aftermarket devices (tires, aerodynamics, etc.). Instead of choosing an average truck as a reference, this work used the best-in-class conventional truck as a reference. The specifications for such a truck were validated against reports published by the North American Council for Freight Efficiency (NACFE) and Navistar [4, 5].

This work estimates the fuel consumption of conventional and fuel-cell-powered trucks in the present day, as well as interim and ultimate scenarios envisioned by DOE.

APPROACH

Validation of Baseline Model

While we do not know the specific drive cycles or the coefficients of drag, tire specifications, or specific axle configurations used by NACFE and Navistar, the overall test parameters such as average speed, type of road, grade, and test weight are available. This work included multiple driving cycles from Autonomie to provide a range of driving characteristics used to compare fuel consumption. The results of these comparisons are shown in Figure 1.

The green bar on the far left shows the average fuel economy reported by trucks that participated in the Run On Less program. This event focused on obtaining better fuel economy. NACFE published the average speed (54 mph), test weight (55,000 lb), and road conditions for this project. Autonomie evaluated a Class 8 truck with a similar weight and aerodynamic modifications on 55 mph runs, using both steady speed and U.S. Environmental Protection Agency (EPA)-specified grade profiles, and predicted fuel economy values that are quite close to the 10.1 mpg observed in Run On Less. Navistar conducted tests on several vehicles to benchmark their new truck against its competitors. The test weight (66,000 lb) and the route used for these tests are known. The posted speed limit for this route is approximately 62 mph. If we interpolate the fuel economy observed in the EPA55 and EPA65 cycles, the test data and simulated results match well.

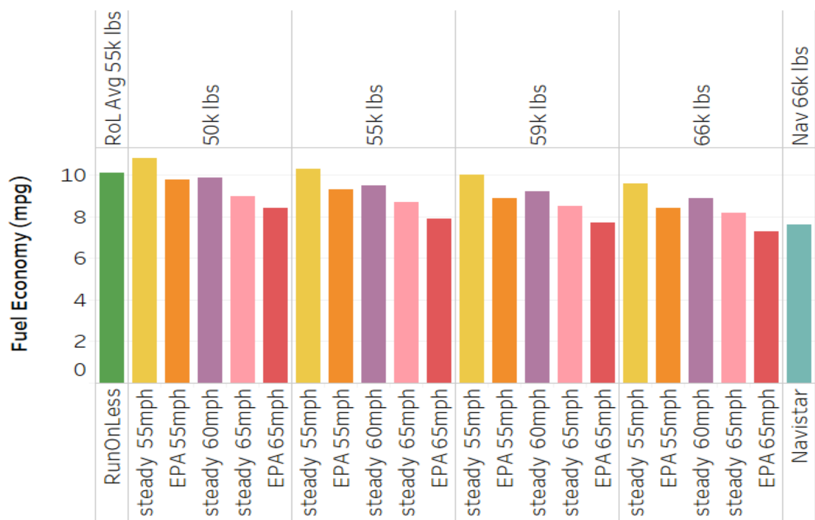

Figure 1. Fuel economy reported from Class 8 line haul trucks tested by Navistar and NACFE correlate well with the values predicted by Autonomie

Interim and Ultimate Scenarios

If SuperTruck demonstrations indicate the direction of technology improvement in Class 8 trucks, we will likely see lighter, more aerodynamic vehicles with efficient and smaller engines. Based on other DOE-funded activities that monitor such technology changes [6], we expect the trucks in the baseline, interim, and ultimate scenarios to have the characteristics shown in Table 1. The high and low values for each parameter show different expected levels of technology progress. Even without DOE's efforts, some improvement will be achieved in all technologies, as shown by the low values. The high values are the goals DOE is striving to achieve through various research and technology demonstration projects.

Table 1. Vehicle Properties for Class 8 Sleeper Modeled in Autonomie

Class 8 Sleeper High Roof	Baseline	Interim	Ultimate
Coefficient of Drag (Low)	0.49	0.43	0.41
Coefficient of Drag (High)	0.49	0.34	0.30
Rolling Resistance—Low (kg/tonne)	5.4	4.9	4.8
Rolling Resistance—High (kg/tonne)	5.4	4.2	3.6
Diesel Peak Efficiency Low	49%	53%	55%
Diesel Peak Efficiency High	49%	55%	59%
Electric Machine Peak Efficiency	96%	96%	96%
Accessory Load (W) Low	3,400	2,600	2,000
Accessory Load (W) High	3,400	1,900	1,000
Glider Weight Reduction Low	0	5%	9%
Glider Weight Reduction High	0	8%	15%

This work looks at the efficiency levels needed from fuel cells in order to make FCETs an economically viable alternative to diesel-powered Class 8 sleeper trucks. The process used for this analysis is shown in Figure 2.

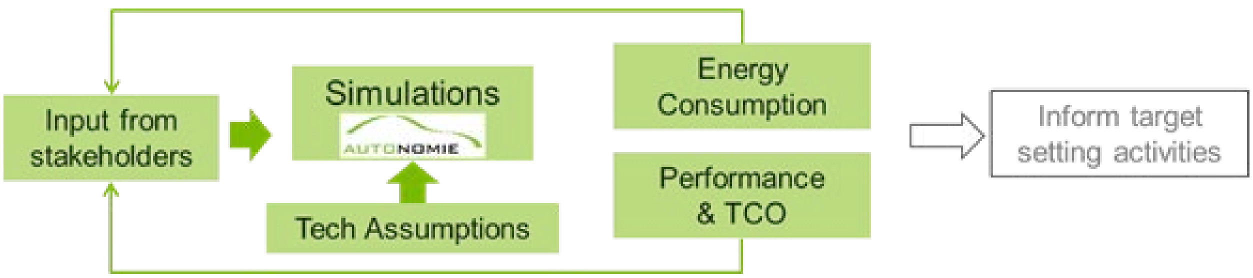

Figure 2. Process of estimating the fuel consumption and cost of ownership for vehicles

RESULTS

FCETs are sized to meet or exceed the performance of their conventional truck counterparts. This process provides us with component size estimates, as well as fuel consumption expected in both trucks. This information can be used to compute a relevant cost of ownership (RCO) value for the trucks. This is different from the total cost of ownership, as several factors such as wages, maintenance, and taxes are not considered in this estimate. Assuming all those values are comparable, RCO can be used to determine the economic feasibility of the new vehicle design.

Figure 3 summarizes the results obtained from this study. It shows that although FCETs are not commercially attractive now, they are likely to become economically competitive if DOE targets are met for cost and technological improvements. In the ultimate scenario, the cost of owning and operating a FCET will be similar to that of a conventional truck. This analysis does not consider other incentives that could come from environmental benefits or compliance with stricter regulatory requirements.

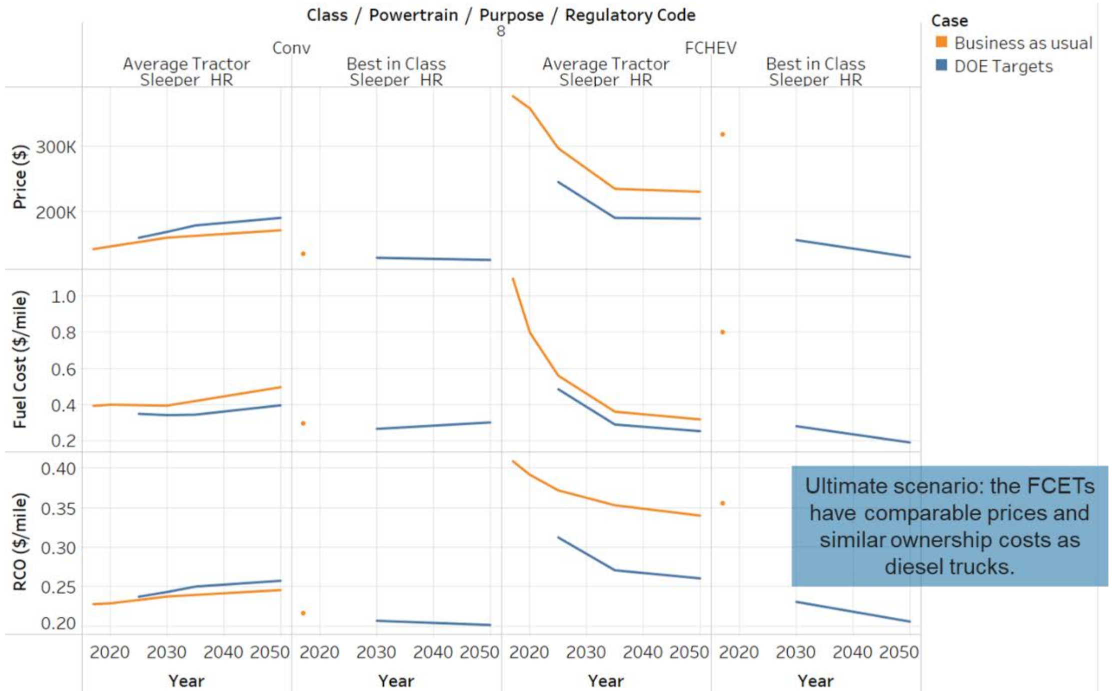

Figure 3. Estimate of vehicle purchase price, fuel cost, and cost of ownership for conventional and fuel-cell trucks

CONCLUSIONS AND UPCOMING ACTIVITIES

This work supported FCTO target-setting activities for the Class 8 sleeper truck. Heavy trucks that spend more time in stop-and-go driving have a lower barrier to be economically feasible. Vocation-specific targets might help prioritize the types of trucks where fuel cells can be introduced without delay.

FY 2019 PUBLICATIONS/PRESENTATIONS

1. K. Sim, R. Vijayagopal, N. Kim, and A. Rousseau, "Optimization of Component Sizing for a Fuel Cell-Powered Truck to Minimize Ownership Cost," *Energies* 12 (2019): 1125.

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6. "Medium and Heavy Duty Benefit Analysis Report," submitted to DOE for final review.