

Feasibility of Electric Hybrid Class 8 Semi Trucks

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HSA 10-5 The Economics of Oil and Energy

I. Background

The growing United States economy has developed a dependency on transportation, whether this is residential or commercial, it is clear that transportation will continue to be a main part of our lives¹. As seen in figure 1, the US Energy Information Administration (EIA) predicts that the transportation sector of the Americas will continue to increase beyond 2040. Also note that of the America's transportation sector, the majority comes directly from the United States.

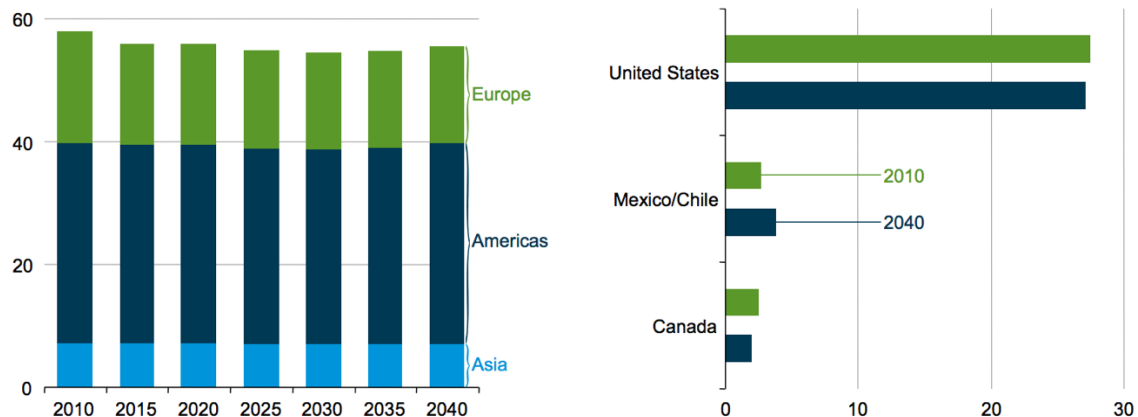


Figure 1 Transportation sector delivered energy consumption by region, 2010-2040 (quadrillion Btu)

The heavy duty trucking industry has remained untouched over the past few years; however, their industry is making a significant environmental impact on the United States. Since the birth of the trucking industry, larger and larger trucks have been manufactured, the downside is that these trucks have greater emissions compared to vehicles that we drive on a daily basis. Currently, the majority of the large semi trucks as seen on the roads are Class 8 trucks, in which its gross vehicle weight rating is greater than 33,001². Additionally, these trucks also include combination trucks, in which the truck has two trailers hitched onto it. In this paper, I will be analyzing Class 8 diesel engine trucks and analyzing the feasibility of using hybrid electric trucks instead.

II. Efficiency of Current Semi Trucks

The United States commercial transportation industry relies on trucking, and it ranges from long distance to short distance travel. Often times, truckers will either focus on city or interstate deliveries. I will be noting both types of these deliveries in this essay to avoid over generalizations of different statistics of the vehicles' miles per gallon ratings.

¹ [http://www.eia.gov/forecasts/ieo/pdf/0484\(2013\).pdf](http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf)

² <https://www.freightlinertrucks.com/About-Us/Truck-classes/Class-8/>

I will first highlight some of the key facts about the United States trucking industry. This data is provided by the American trucking association, and is not updated to our current year. However, note that since the trucking industry will only continue to grow, these facts may appear to be much greater in 2016. In 2010, there was an average of 2.3 million Class 8 trucks that were registered for commercial usage. Because trucking is often paid by the mile, truckers must log their number of miles driven; there was around 397.8 billion miles logged in 2010, which represents 13.4% of all motor vehicles miles traveled in the United States. While 13.4% may not seem a significant amount of the total vehicle mileage driven per year,

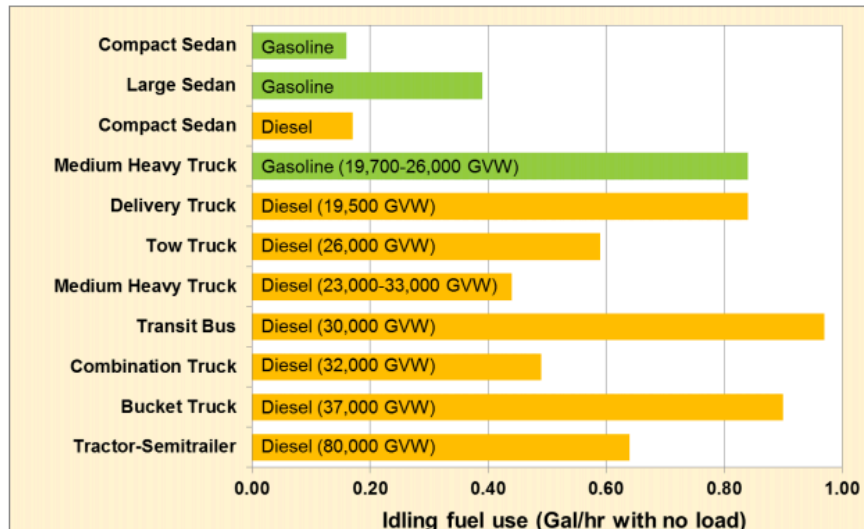


Figure 2 Fuel Consumption at Idle for Selected Gasoline and Diesel Vehicles

figure 2 emphasizes this percentage since even during idling, the heavy duty trucks with a high gross vehicle weight rating had a higher gallon per hour usage³. Keep in mind that the green bars represent gasoline and the orange bars represent diesel, both have their advantages and disadvantages, which will not be

discussed in this essay, as it is beyond the scope of the topic.

In order to translate the number of miles and price per gallon to a more relatable unit, I will convert the miles per gallon of the diesel semi trucks to a price per mile unit. To avoid comparing miles per gallon that was measured differently, I will be using a study conducted by the US Department of Energy on Coca-Cola vehicles and its electric hybrid semi truck. First, the conditions of the test trucks were predetermined by analyzing the routes of various Coca Cola semi trucks. Three distinct cycles were then created: WVU City, CILCC, and CARB HHDDT. The WVU City cycle represents city driving with many stops, where the truck can only reach up to a certain speed and slow down. The CILCC represents a truck where it will maintain a certain speed for a few seconds occasionally, and slow down. Lastly, the CARB HHDDT cycle represents mainly highway driving.

Using these parameters, I can now use the data obtained in Figure 3 to calculate the price per mile. I have chosen to omit the CARB HHDDT data because it turns out the MPG

³ http://cta.ornl.gov/vtmarketreport/pdf/chapter3_heavy_trucks.pdf

compared to the hybrid electric semi truck is very similar, thus the hybrid is not a reliable source for highway driving. According to the EIA, the average price of diesel fuel is

Drive Cycle	HEV Fuel Economy (mpg)	Conventional Diesel Fuel Economy (mpg)	HEV Percent Increase (%)	P Value
WVU City	5.79	4.44	30.3%	0.0003
CILCC	7.55	6.18	22.2%	0.0001
CARB HHDDT	6.17	6.18	-0.13%*	0.69

Table 1 Miles per gallon ratings of diesel fuel and hybrid electric semi trucks.

approximately \$1.989 per gallon⁴. Using this value, I can now calculate the price per mile of the diesel trucks.

$$1.989 \frac{\text{dollars}}{\text{gallon}} * \frac{1 \text{ gallon}}{4.44 \text{ miles}} = 0.448 \frac{\text{dollars}}{\text{mile}}$$

$$1.989 \frac{\text{dollars}}{\text{gallon}} * \frac{1 \text{ gallon}}{6.18 \text{ miles}} = 0.322 \frac{\text{dollars}}{\text{mile}}$$

The price per gallon of diesel may not seem like a large number; however, semi truck drivers will often drive well over 66,000 miles per year⁵. Utilizing this number of miles, I can calculate the amount of gasoline an average truck driver will use.

$$66,000 \text{ miles} * 0.448 \frac{\text{dollars}}{\text{mile}} = 29,568 \text{ dollars}$$

$$66,000 \text{ miles} * 0.322 \frac{\text{dollars}}{\text{mile}} = 21,252 \text{ dollars}$$

As a result, we can see that the average semi truck driver, especially that of the Coca Cola enterprises, spends a great deal of money on transportation alone. This value is even further emphasized if we assume that the average trucker also gets a similar price per mile rating, since I noted before that there are approximately 2.3 million Class 8 vehicles in the US. As a result, we can now see the importance of the trucking industry and the need for an improved price per mile rating of the vehicles.

⁴ <https://www.eia.gov/petroleum/gasdiesel/>

⁵ http://cta.ornl.gov/vtmarketreport/pdf/chapter3_heavy_trucks.pdf

III. Diesel semi truck engines

Before I discuss an alternative to the currently dominating diesel engine, I would like to explain the mechanics behind the traditional semi-truck and why it is inefficient. The current diesel truck that is often seen on the truck is powered by a different technology compared to the gasoline engine; rather than igniting the fuel through a spark ignition system, diesel compresses the fuel until it reaches its optimum temperature. As a result, diesel engines do not require periodic engine tune-ups as gasoline engines require. This is also the reason I will not be proposing a gasoline alternative, as diesel engines are very efficient in comparison.

In recent developments in technology, we see that trucks are increasingly outfitted with selective catalytic reduction technology to reduce the NOx emissions⁶. While this does reduce the NOx emissions to a ridiculously small amount as seen in Figure 3, selective

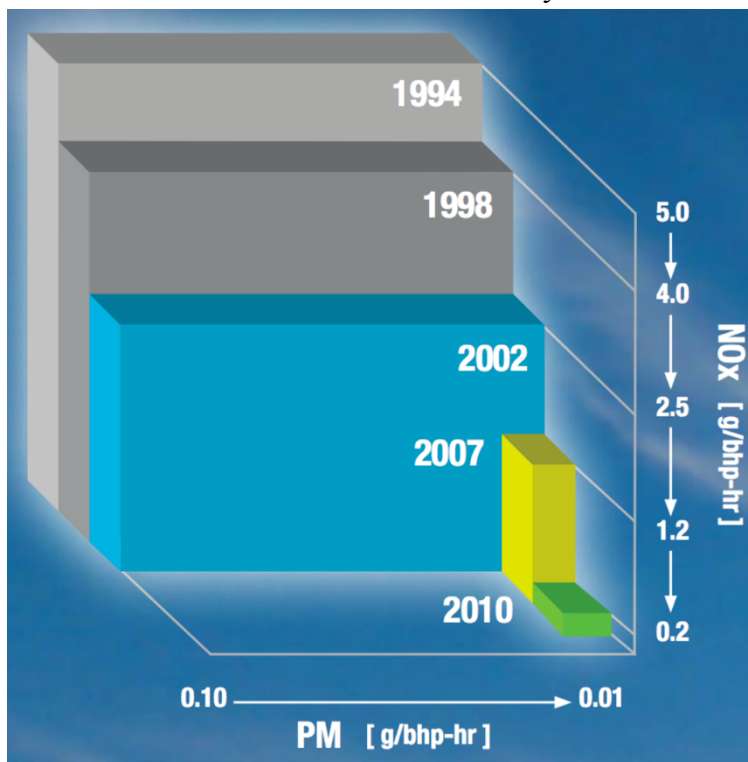


Figure 3 Graph of NOx emissions of Freightliner trucks over the course of 16 years.

attempts to achieve near zero emissions.

catalytic reduction technology also has its disadvantages. First, it uses diesel exhaust fluid (DEF), which is a mixture of urea and water, in order to convert NOx into various byproducts. Although DEF is non-toxic, it must be replaced almost every year. Secondly, the technology releases carbon dioxide as a byproduct, which is not necessarily the type of gas that we want in our environment. As a result of the increasing improvements of diesel engines, it may seem as though there is no need for a change in technology; however, diesel engine trucks still release harmful green house gasses despite the industry's

But what exactly causes the semi trucks to be nowhere near their maximum efficiency, and also why do these trucks have such low miles? There are two main factors that causes the low miles per gallon rating of semi-truck, these include: air resistance and drag, and also a topic that is less spoken of, heat released from the semi-trucks. In this paper, I will be

⁶ https://www.freightlinertrucks.com/content/media/assets/9136_SCRMediumDuty.pdf

focusing on the heat of diesel semi-trucks, and the how hybrid electric trucks are able to harness this energy and convert it into valuable miles per gallon.

IV. Hybrid electric semi-truck background

The use of more advanced hybrid electric semi-trucks is not a very popular subject matter because of the lack of technology to build these trucks; however, many different companies have released various claims of miles per gallon rating, and also different methods of building the hybrid electric semi trucks. Because there has not been any major production line of the more recent hybrid electric trucks, I will be utilizing data from both Coca Cola enterprises, and also data that the trucking companies claim to have achieved.

V. Efficiency of Current Electric Hybrid Semi-Trucks

According to Table 1 from a previous source, I can utilize the data taken of the electric hybrid vehicles and calculate the price per mile to compare with the traditional diesel engine.

$$1.989 \frac{\text{dollars}}{\text{gallon}} * \frac{1 \text{ gallon}}{5.79 \text{ miles}} = 0.343 \frac{\text{dollars}}{\text{mile}}$$

$$1.989 \frac{\text{dollars}}{\text{gallon}} * \frac{1 \text{ gallon}}{7.55 \text{ miles}} = 0.263 \frac{\text{dollars}}{\text{mile}}$$

Using the same idea as before, I can calculate the amount of money an average trucker will spend per year.

$$66,000 \text{ miles} * 0.343 \frac{\text{dollars}}{\text{mile}} = 22,638 \text{ dollars}$$

$$66,000 \text{ miles} * 0.263 \frac{\text{dollars}}{\text{mile}} = 17,358 \text{ dollars}$$

Looking at this data, I can compare these values to the efficiency of the purely diesel semi trucks and determine which truck is more efficient. As a result, I notice that a hybrid electric semi-truck will save 4 – 7,000 dollars per year in comparison to the diesel semi-truck. However, I must admit that this is based off Coca Cola's older technology.

VI. Newer technologies in hybrid electric semi-trucks

According to Peterbilt Trucking Company, a massive research project partnered with Cummins, a diesel engine company, was aimed towards improving the efficiency of diesel engine trucks. The idea was to target multiple parts of the semi-truck including aerodynamics, heat recovery, braking, weight shedding, idling etc. The partnership was extremely successful as the companies together built what's now known as the Cummins

SuperTruck. The newly built truck was able to achieve a mile per gallon rating of 10.7 miles per gallon⁷.

A notable improvement in its technology is the implementation of a waste heat recovery system⁸. The system captures the heat from the exhaust gasses using a pressurized refrigerant. This is so that the refrigerant can expand, which ultimately causes a turbine to spin. The turbine is then able to transfer its power directly to the engine and help relieve the engine, thus less diesel fuel would be necessary to travel.

Given this new mile per gallon rating, I will be generalizing this value to 10 miles per gallon because the circumstances of the rating measured by the SuperTruck may not be very accurate.

$$1.989 \frac{\text{dollars}}{\text{gallon}} * \frac{1 \text{ gallon}}{10 \text{ miles}} = 0.199 \frac{\text{dollars}}{\text{mile}}$$

$$66,000 \text{ miles} * 0.186 \frac{\text{dollars}}{\text{mile}} = 13,128 \text{ dollars}$$

Although this is only a prototype of the SuperTruck, Cummins and Peterbilt are not the only companies investing millions of dollars in new technology. The supermarket giant Walmart has also partnered up with Freightliner and Peterbilt to build a concept truck of their own⁹. Additionally, I recognize while this calculation saves between \$8 - 15,000 compared to the traditional diesel, I can safely assume that this technology is very well possible due to Coca Cola's electric hybrid. While the company's fleet of hybrid electrics do not achieve a MPG rating of the SuperTruck, the companies fleet is based off old technology, where aerodynamics has not been improved as much.

VII. Hybrid Electric Semi-Trucks

Although these semi-trucks are not mass produced currently, it seems very likely that in the near future, companies will invest in this technology considering the relative cheapness and the ability to save so much money from using less mileage. This is especially important to massive companies, as they can easily own thousands of Class 8 trucks in their fleet.

⁷ http://energy.gov/sites/prod/files/2014/07/f17/ace057_koeberlein_2014_o.pdf

⁸ <http://social.cummins.com/supertruck-project-ready/>

⁹ http://corporate.walmart.com/_news_/news-archive/2014/03/26/walmart-debuts-futuristic-truck