ADDRESSING EMISSIONS IN THE TRUCKING INDUSTRY:

Laying the Framework of Alternative Fueling Transportation

By Joshua Stiff

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WASHINGTON INTERNSHIPS for STUDENTS of ENGINEERING

Preface

About WISE

The Washington Internships for Students of Engineering (WISE) program is a program designed to familiarize engineering students with technical aspects of policy, emphasizing the importance of having engineers involved in public policy. During the summer, interns are given the responsibility of conducting their own research for a controversial political topic of their choosing. While researching, interns are provided opportunities to network among local government agencies, non-profit associations, and industry leaders to gain a broader perspective on their chosen issue.

About SAE International

The Society of Automotive Engineers (SAE) International, founded in 1905, is a society dedicated to share knowledge on the subject of mobility, known for its standards development and continuous pursuit of knowledge.

About the Author

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List of Acronyms

B20	20% Biodiesel Fuel
BEV	Battery Electric Vehicle
bhp	brake horsepower
BTS	Bureau of Transportation Statistics
CO_2	Carbon Dioxide
CTI	Cleaner Trucks Initiative
DOE	Department of Energy
DOT	Department of Transportation
DPF	Diesel Particulate Filter
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
FCEV	Fuel Cell Electric Vehicle
g	gram
GHG	Greenhouse Gas
hr	hour
LSD	Low Sulfur Diesel
NOx	Nitrogen Oxides
OEM	Original Equipment Manufacturers
PM	Particulate Matter
ppm	parts-per-million
SCR	Selective Catalytic Reduction
ULSD	Ultra-Low Sulfur Diesel
US	United States
ZE	Zero-Emission
ZEV	Zero-Emission Vehicle

Table of Contents

Executive Summary

The emissions sourced from diesel fuel have been regulated since the 1970s to try and manage the effects of pollutants, toxins, and greenhouse gas emissions. The United States Environmental Protection Agency (EPA) has continued imposing ambitious regulations to meet the demands of the public. The diesel engine's importance in the freight industry has been proved time and time again as it continues to be relied upon for heavy-duty transportation. With the continued imposition of regulations on the diesel engine, many technologies have begun to rise claiming they can tackle the cleanliness problems that diesel engines face. The issue is, there is little space for newer zero-emission technologies to enter. Facing little to no infrastructural support and trying to compete with an industry heavily subsidized by the government, how can the United States usher in the hopes of a zero-emission future?

As costs continue to rise in the diesel trucking industry due to pressure for increased regulatory action, there is still great hope that the zero-emission transportation technologies can be brought to market. While many urban areas face continued smog and respiratory issues in part due to emissions, the onset of climate change is also pressuring communities around the globe to adopt into zero-emission technologies. Being as it is, the heavy-duty commercial industry is already highly regulated, and has adapted to several emission limiting requirements in the past. Industries, fearing the eventual crack down on diesel emissions entirely, have been proactive in the switch from diesel to zero-emission. While the proactive notion of industry leaders is great, the government can assist this movement in a variety of ways, through incentivization, regulation, and a greater partnership programs to promote the future of zero-emission technologies.

While many movements have been made to assist the zero-emission market, the government must continue to provide and expand help in infrastructure programs, research and development programs, fueling programs, and regulatory programs. There needs to be greater enablement for zero-emission vehicles to enter the heavy-duty sector, through subsidization, and the lowering of subsidizations in the fossil fuels industry. The current administration has been detached from the continuous cleansing of automotive emissions in general. However, with great progress that continues to be made in research and development, the private sector has been able to catch on to the dire need of a switch from combustion powertrains to zero-emission powertrains. The end goal of zero-emissions cannot be simply tackled with just one technology, but it will require a pairing of technologies. The available technologies fighting this problem in the automotive market are fuel cell technologies and battery electric technologies. Each respective technology has begun to pave a way into the heavy-duty sector of transportation, offering solutions to the pollutant effects of diesel engines. While many carbon reduction technologies exist, the permanent key to solving the problem at hand is through zero-emission powertrains.

1. Definition of the Problem

Ever since the introduction of the diesel powered engines, they have been the choice of powertrain for a variety of heavy-duty trucking applications. Proving useful, highly efficient, and cost effective for heavy-duty freight transportation, there is not much competition as far as choice of powertrain goes in the motor carrier industry. As new technologies are explored, there are significant barriers that must be overcome as diesel engine technology is so ingrained into society, including fossil fuel subsidization, infrastructural benefits, and familiarity to the public. As the need to reduce carbon emissions becomes more pressing due to pollution concerns and climate change concerns, companies must be persuaded to direct efforts towards new technologies that can get the job done without sacrificing cost effectiveness, safety, and efficiency. A plan that allows for smooth integration of zero-emission (ZE) technologies is desperately needed.

The United States government has been making efforts to include new technologies in the transportation industry, with the Department of Energy (DOE) pursuing research and development (R&D) in arising ZE technologies, such as battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV), two technologies looked upon highly in regards to a ZE future. As much research as the DOE continues to promote, there is still much to be done before these powertrains, the systems which provide power to mobile vehicles, become a normalized, ingrained portion of the industry. Each up and coming technology has its own set of problems, ranging from infrastructure issues, to technological barriers, to issues of regulatory restraint or negligence. If the United States truly hopes to reduce carbon emissions in line with the Paris Agreement, some assistance from the government will be necessary to ensure ZE powertrain technologies can become competitive within the motor carrier market, no matter how ingrained diesel powertrains are into the United States.

The recent strides made in the hydrogen fuel cell industry has driven researchers, companies, and consumers to explore the expansive possibilities of FCEV. Due to the nature of fuel cell technology, most agree that FCEV technology applies wonderfully to the motor carrier industry. The DOE has continued promoting research and development in the feasibility FCEV technology in trucking applications; however, the current state of the diesel dominated freight industry does not easily allow for the diversification of powertrain applications. Recent investments made by automotive industry leaders such as Toyota and Honda have given FCEV technology a helping hand in gaining momentum and attention in the trucking industry. Smaller companies, such as the up and coming Nikola Motors, are hoping to forge the path into the fuel cell powered truck market, providing the public with the hopes of new infrastructure, smooth implementation of new powertrains into the market, and awareness regarding the possibility of this technology.

On the other hand, companies such as Tesla Motors are investing in the BEV market, ensuring the motor carrier industry can rely upon batteries and electric charging to power transportation. As of current, BEV charging stations are struggling to catch on with the

automotive market, due to the difficulties risen from the length of charging, the inability to commercialize stations, and lack of technology in battery swaps. Much industry experimentation and research must be done to find ways in which BEV technology can be effective for the automotive industry, before catching onto the motor carrier industry. The lack of infrastructure capacities and standardization creates several roadblocks in generating the necessary infrastructure. In regard to port and other localized trucking areas, BEV will be useful in kicking off the ZE goals for highly populated areas with more dense pollution and greenhouse gas (GHG) problems.

Several problems have arisen with the importation of oil from the Middle East, causing conflicts and dangerous reliance upon foreign countries. The Canadian oil industry, another external oil source has been enabling oil drilling practices which are destructive to the environment. Subsidies for fossil fuels have created such a large reliance on combustion fuels that ZE technologies have become high risk markets to enter. The United States will continue to rely upon these imports as long as transportation technologies disregard the expanse of alternative powertrains and stifle technological growth. Governmental programs must continue to push the automotive industry, spurring technological advancement and a diversification of fuel reliance, promoting higher energy independence. Compared to previous introductions of alternative powertrains, there is no competitiveness between industries to advance the current technologies beyond agreements within the market.

This policy paper will attempt to dive into the issues facing the alternative powertrain market, and why current regulations or the lack thereof may be hindering the advancement of new technologies in the automotive market. Exploring reasons to continue pursuing a zero emission transportation sector, the focus will be on heavy-duty transportation specifically, yet themes discussed within the paper may pull from issues within the passenger sector or other markets. Due to the nature of the program, and the vast strategies for emission reduction this paper will mainly focus on heavy-heavy duty class 8 vehicles, and ZE technologies. The feasibility and discussion of lowered emission vehicles may be discussed sparingly throughout the paper.

2. Background

Diesel powertrains have had a historic impact on the shaping of America's freight transport industry; however, several issues have begun to arise among the American public, from health concerns to international affairs. While diesel will continue to dominate the heavy-duty industry for at least the next decade, it is time for the US to begin shifting focus into alternative methods of heavy-duty power, specifically, ZE. Concerns of the fast-approaching effects of climate change have begun to come down upon the automotive industry, being one of the major contributors to carbon dioxide emissions. Alongside climate change, there have been proven health benefits to the reduction of diesel emissions, which are commonly known to breed smog hanging over highly populated port cities. Several initiatives and regulations have been highly effective in reducing emissions from diesel engines, yet issues continue to arise while scientific evidence evolves and public awareness advances.

2.1. Problems with Emissions

As reports and warnings continue to be published by leading scientists and organizations, several problems have been brought to light with the continuous emitting of hazardous particles from fuels used in modern power generation. From evidence of climate change, to widespread health effects, several countries around the world continue to pursue cleaner methods of power. Seeing the reliance upon power generation, there is an immediate need to address the situations regarding healthier and more environmentally conscious methods of generating power. Whether it be the transportation sector, the industrial sector, or the power and energy sector, many investments are being made globally to shift into cleaner power sources.

Various respiratory problems, as well as issues with soot and smog hanging over cities, can be blamed on the emissions of particulate matter (PM) and various nitrogen oxides (NOx). The presence of NOx in the atmosphere has been known to assist in the forming of PM, specifically that of lesser than 2.5 microns in width[1]. PM has been known to lodge itself deep inside the lining of lungs; therefore, causing respiratory issues for humans in areas where PM concentrations are higher, who might be at higher risks of asthma[2]. Alongside PM and NOx, sulfur oxides (SOx) have contributed to the respiratory problems facing populations introduced to higher concentrations of diesel emissions. Diesel combustion engines also emit carbon monoxide (CO) and carbon dioxide (CO_2); however, these gases have different implications on human health.

Various gases emitted (naturally and unnaturally) into the atmosphere, termed GHGs, contribute to the atmosphere's heat-trapping abilities. As these gases persistently enter the atmosphere, the risk for increased average temperature of the earth increases. Major GHGs recognized by the Environmental Protection Agency (EPA) include: CO_2, methane, nitrous

[1] University of Washington, "Air Quality Agencies Can Breathe Easier about Current Emissions Regulations."
[2] American Thoracic Society, "Coarse Particulate Matter May Increase Asthma Risk."

oxide, and fluorinated gases[3]. While methane is 30 times more effective at trapping heat within earth's atmosphere, the continued negligence of realizing carbon dioxide's effect on the atmosphere is due to cause several problems for humans around the globe. Observing Figure 1, the projections of average global temperatures show that at this current pace, the lowest temperature change experienced by the end of the century possible is just over 7°F. Current temperature change goals established by the Intergovernmental Panel on Climate Change (IPCC) are challenging the globe to minimize the average temperature change to 1.5°C[4].

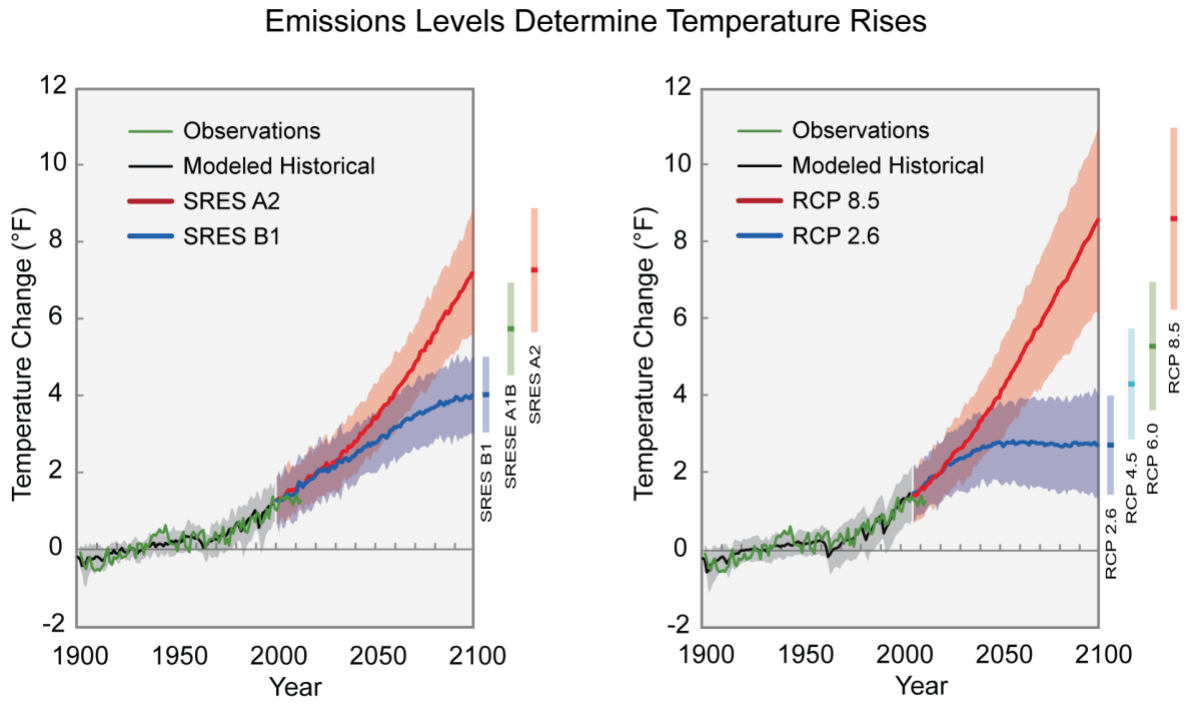

Figure 1: Climate projections given by two different methods of projections: Special Report on Emissions Scenarios (SRES)[5] and Representative Concentration Pathways (RCP)[6,7]. Graphs gathered from the United Nations Framework Convention on Climate Change.

As the globe coalesce around an effort to reduce GHG emissions from all industrial sources, research and development funds are being poured into alternatively fueled and ZE vehicles (ZEVs). Much focus is centered around the passenger vehicle sector; however, according to the EPA, the second largest contributor of GHG emissions in the transportation

[3] U.S. Environmental Protection Agency, "Overview of Greenhouse Gases."
[4] Masson-Delmotte et al., "Summary for Policymakers."
[5] SRES B1 accounted for a strict imposition of GHG regulations, narrowing in on significant reductions starting in 2050; while SRES A2 assumes the current emission levels are continued through 2100.
[6] RCP uses data from current policies that are aimed at reducing GHG emissions, using newer modelling methods than that used in the SRES analysis. RCP 2.6 models a global effort in rapid GHG emission reduction, while RCP 8.5 is based upon the current rate of emission increases, with little to no effort to reduce emissions.
[7] Kunkel and Cooperative Institute for Climate and Satellites - NC, "Figure: Emissions Levels Determine Temperature Rises."

sector is medium and heavy duty trucks. Imposing GHG regulations on the passenger vehicle sector have been sidetracked by the amending of the Corporate Average Fuel Economy standards aimed at addressing affordability issues[8]. The regulation of light-duty vehicles faces difficulties, as the passenger vehicle sector demand is controlled on an individual consumer basis. Heavy-duty engines have historically undergone more regulations, but continue to be a source of the GHG emissions problem. Figure 2 shows the spread of GHG emissions distributed accordingly among the U.S. transportation sector in 2017. The transportation sector accounts for 29% of the total US GHG emissions, of which the trucking industry accounts for 7%[9].

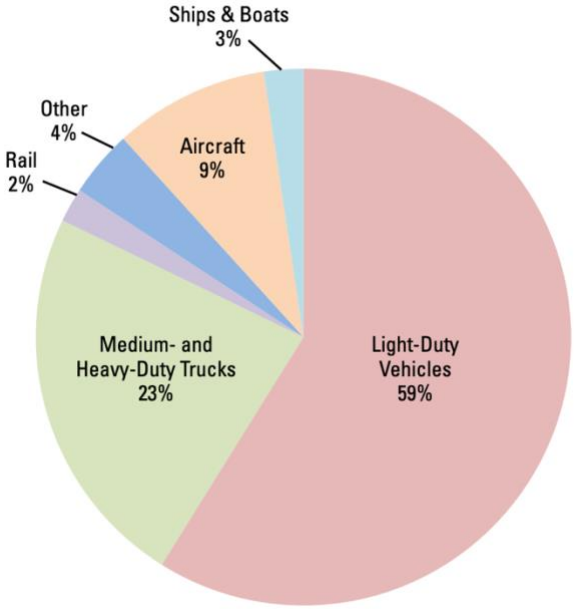

Figure 2: Share of the US Transportation GHG Emissions by Source, 2017[10]. Graph acquired from the US Environmental Protection Agency

2.2. Global Push to Reduce Emissions

Countries around the globe have begun to realize the harmful effects of diesel emissions, creating a movement calling to push combustion engines out of market and replace them with newer, cleaner technologies. In July 2017, the United Kingdom made an announcement that all sales of diesel engines would be halted by 2040, in an effort to reduce NOx emissions[11]. In early 2018, Berlin, Germany, alongside several other German cities began to draw up plans to ban diesel engines due to heavy smog hanging over the city skylines[12]. Studies have shown that reduction in diesel engines have had widespread health benefits. According to a study of Leipzig,

[8] U.S. Department of Transportation, "SAFE: The Safer Affordable Fuel-Efficient 'SAFE' Vehicles Rule."
[9] U.S. Environmental Protection Agency, "Fast Facts: U.S. Transportation Sector Greenhouse Gas Emissions, 1990-2017 (EPA-420-F-19-047, June 2019)."
[10] U.S. Environmental Protection Agency.
[11] Rakotonirina, "New Diesel and Petrol Vehicles to Be Banned from 2040 in UK."
[12] Huggler, "Berlin Becomes Latest German City to Draw up Diesel Ban."

Germany, the implementations of a "Low Emission Zone" allowed for a 60% reduction in "black carbon" concentrations[13].

The United Nations Framework Convention on Climate Change (UNFCCC) is a convention by the United Nations, consisting of about 194 countries, which has the aim of mitigating the effects of humans on the global climate. Of this convention has come the Kyoto Protocol, calling developed nations around the world to lead the efforts in reducing emissions. More recently coming from the UNFCCC, the Paris Agreement has brought 196 parties together to more aggressively fight to minimize the overall temperature change to about 1.5 to 2 °C from pre-industrial temperatures[14]. This effort has begun to prove mildly ineffective, as just about 6 of the 194 countries involved have correctly met the agreed upon standards as of June 2019[15].

With countries around the world calling for reform in efforts to reduce GHG emissions there lies a greater need to allow the room for ZE powertrains to enter the market. The reduction of emissions on both diesel and gasoline engines will have significant effects on public health, the environment, and even national relations. Diversifying powertrain options will allow for more energy security, more technological competition, and greater independence in US power generation methods. Cleaner technologies have become more difficult to bring into major transportation industries because of the widespread availability of combustion fuels, the high infrastructure investments required by alternative fueling stations, and the reliance upon large subsidies within the fossil fuel market.

2.3. Diesel Developments in the United States

Currently, the United States trucking industry is solely powered by diesel driven powertrains. There have been many efforts made to control the amounts of emissions created by these diesel engines; however, with all the efficiency and toxicity improvements, many have realized the difficulty in regulating diesel engines. Several technological improvements have been made to limit the greenhouse gas (GHG) and particulate matter (PM) emissions. Methods of improvement may include improving engine efficiency, ridding fuels of toxins or pollutants, or developing powertrains that run solely on electricity or hydrogen fuel cell technology. It is rare for these powertrains to make it beyond that of a lab environment; however, recent investments made by leading automotive manufacturers have begun to pave the way for alternative powertrains.

In 1970, President Richard Nixon signed the Clean Air Act (CAA), which allowed the EPA to begin monitoring air pollution for the well-being of US populations. Shortly after, the CAA was amended in 1977 and again in 1990 to improve regulatory standards surrounding mobile pollution sources. Beginning in 1974, the EPA began imposing regulations of heavy-duty

[13] Leibniz Institute for Tropospheric Research (TROPOS), "Healthier Air Due to the Low Emission Zone: Significant Decrease of Black Carbon and Ultrafine Particles in Urban Air."
[14] United Nations, "Nationally Determined Contributions."
[15] "Climate Action Tracker."

diesel emissions to improve air quality[16]. Stricter regulations came about in 1988, calling for manufacturers to reduce NOx emissions from 10.7 to 4.0 g/bhp-hr[17], and reduce particulate matter from 0.60 to 0.10 g/bhp-hr[18]. In 2002, EPA began to require exhaust gas recirculation (EGR) for most major diesel engine manufactures, effectively reducing NOx emissions[19]. EGR recycled a majority of exhaust into the intake valve to ensure less dirty exhaust would enter the atmosphere per mile traveled. EGR continued to be a part of diesel engines moving forward but could be altered as newer technologies improved engine efficiency to better the durability of engine components.

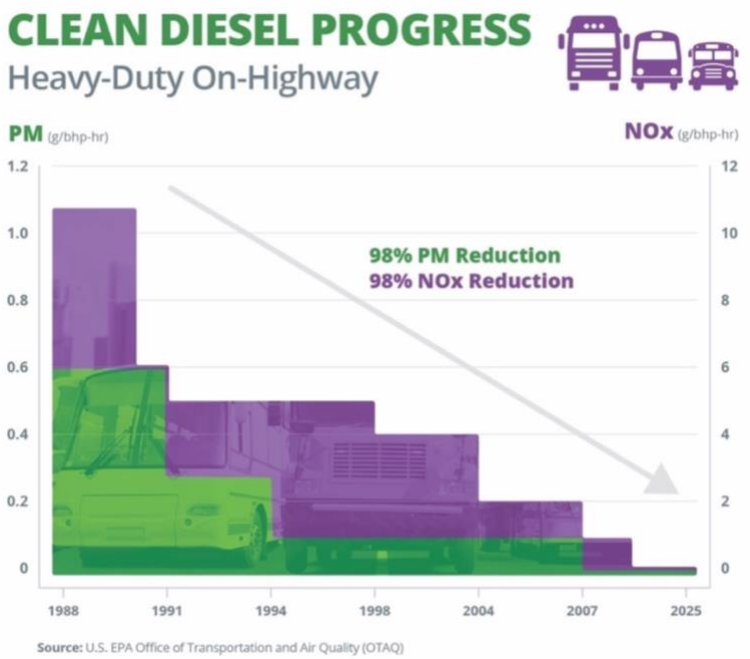

Figure 3: Visualization of NOx and PM reduction[20], graph provided by dieselforum.org

The latest NOx and PM standards were phased in between 2007 and 2010, which was met by manufacturers using diesel particulate filters (DPF) in 2007 and selective catalytic reduction (SCR) in largely 2010 when NOx emissions tightened[21]. DPF acted as a filter for engine exhaust, which frequently requires maintenance to keep the filtration system efficient and effective. SCR allowed for a catalyst to chemically alter the exhaust to break up toxic emissions before entering the atmosphere. These standards required 0.01 g/bhp-hr of PM and 0.20 g/bhp-hr

[16] "US: Heavy-Duty: Emissions."
[17] g/bhp-hr is a unit measuring the mass per unit of energy, gram per brake horsepower-hour
[18] "US: Heavy-Duty: Emissions."
[19] Jääskeläinen and Khair, "Exhuast Gas Recirculation."
[20] Diesel Technology Forum.
[21] "US: Heavy-Duty: Emissions."

of NOx emissions[22]. Figure 3 shows a summary of the EPA's NOx and PM standards from 1988 t.o 2010.

The presence of SOx in diesel fuel allowed for more particulate emissions, therefore requiring that such a device be paired with diesel fuel of lower sulfur content[23]. Due to this predicament, the EPA began to require ultra-low sulfur diesel (ULSD) fuel, emitting 15 parts-per-million (ppm) of sulfur, which is a 97% reduction in sulfur compared to low sulfur diesel (LSD) fuel, to ensure maximum efficiency and cleanliness of diesel powered engines for models after 2007 or later[24]. By 2010, ULSD became the standard diesel fuel for all highway operating diesel vehicles[25]. With the current regulations, the toxic emissions of a 1988 heavy-duty highway diesel vehicle would be about 60 times that of a heavy-duty diesel engine manufactured today[26].

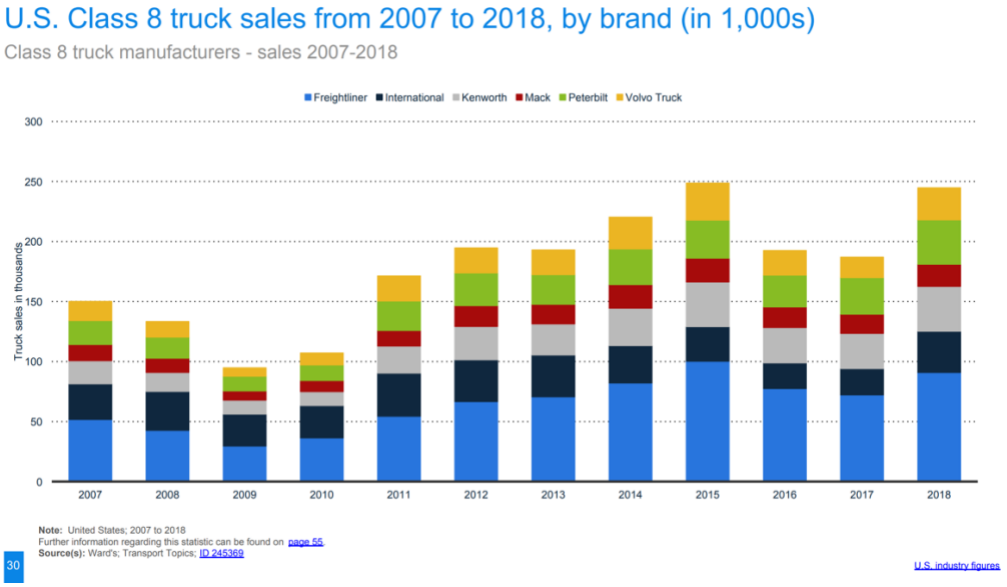

Figure 4: US Class 8 truck sales from 2007 to 2018, by brand[27]. Graph gathered from statista.com

The requirements enforced by the EPA have caused manufactures to drive up truck costs by almost four times that of EPA's compliance cost estimate. From 2002 regulations to the finalized 2010 regulations, the average cost increase per truck was over $21,000[28], while the EPA gave a compliance estimate of about $5,136[29]. Due to the nature of EPA's regulations, there

[22] "US: Heavy-Duty: Emissions."
[23] U.S. Environmental Protection Agency, "40 CFR 86.007–11 - Emission Standards and Supplemental Requirements for 2007 and Later Model Year Diesel Heavy-Duty Engines and Vehicles."
[24] U.S. Department of Energy, "Ultra-Low Sulfur Diesel."
[25] U.S. Department of Energy.
[26] Diesel Technology Forum, "About Clean Diesel, Why It Isn't Dirty."
[27] Statista, "Trucks and Commercial Vehicles (2011 - 2016)."
[28] Calpin, Patrick; Plaza-Jennings, "A Look Back at EPA's Cost and Other Impact Projections for MY 2004-2010 Heavy-Duty Truck Emissions Standards."
[29] U.S. Environmental Protection Agency, "Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements."

was a severe drop in truck sales from 2006 to 2009. From 2006 to 2007, Class 8 truck sales were halved, dropping from almost $300,000 in sales during 2006, and $150,000 in sales during 2007[30]. Noting that the Great Recession began in December 2007[31], there was still a large pitfall in sales the months leading up to the official beginning of the Recession. As illustrated in Figure 4, sales did not begin to recover until 2010. Even beyond 2018, sales have not risen back to the near 300,000 level that was reported in 2006.

The issue with the rise in cost of Class 8 trucks, is that it means many trucking companies most likely tried to make the previous generations of trucks last longer, in order to save on cost. This raises the concern: perhaps EPA's tightening of regulations allowed for an even greater buffer, in which older trucks with less restrictions on emissions were able to stay on the road for a longer of duration of time. Again, observing Figure 4, the lowest truck sales occurred in the years 2009-2010, which were the most up-to-date, compliant engines with SCR NOx reduction features installed. Even in 2019, the number of model year trucks pre-2008 far outweighed model trucks between the years of 2008 and 2010.

In 2018, several petitions from states in the US were dissatisfied with the NOx levels measured around diesel-dense areas, as well as air quality measurements in general. On November 3, due to the petitions across the United States regarding the current NOx standards, the EPA issued the Cleaner Trucks Initiative (CTI)[32]. Over 20 states petitioned for revisions to the current standards, seeing that modern air pollution continued to warrant a call for stricter diesel standards[33]. The CTI will allow the EPA to generate new regulations that will further reduce NOx emissions. The previous standards issued by the EPA in January 2001 have allowed for a 40 percent reduction in NOx emissions within the past decade[34]. NOx and PM emissions are expected to continue decreasing, especially as model year trucks older than 2010 begin retiring from regular use[35].

Currently, with EPA's round of GHG emission reduction, manufactured truck standards for Class 8 Trucks are scheduled out until 2027, in an effort to combat CO_2 emissions[36]. According to Table 1 below, there is about an 11% reduction in CO_2 gasses emitted by model year 2027 compared to 2014 model years. This is a significant reduction in contributions to GHG emissions; however, original equipment manufacturers (OEM) are concerned they will be unable to implement any further GHG reduction to engines if the EPA decides to continue imposing GHG requirements beyond 2027, because of the economic burden it could impose on OEMs. Regardless, progress is being made in ZE powertrain sectors, and there are improvements being made in diesel fuels which may allow for greater reductions in GHG emissions, which will be

[30] Statista, "Trucks and Commercial Vehicles (2011 - 2016)."
[31] Rich, "The Great Recession."
[32] U.S. Environmental Protection Agency, "Cleaner Trucks Initiative."
[33] U.S. Environmental Protection Agency.
[34] U.S. Environmental Protection Agency.
[35] U.S. Environmental Protection Agency, "Our Nation's Air."
[36] "United States: Heavy-Duty Vehicles: GHG Emissions & Fuel Economy."

discussed further in section 3.1. The urgent need to reduce CO_2 emissions poses the question: are continued emission regulations enough to combat toxicity and climate change results?

Table 1: Heavy-Heavy Duty CO_2 Standards from 2014 to 2027[37].

Year	2014	2017	2021	2024	2027
CO_2 Emissions (g/bhp-hr)	567	555	513	506	503

Data provided by dieselnet.com

Ideally, the trucking industry should be slowly guided to look into zero-emission vehicle (ZEV) technologies, which will be the most effective method and technology at curving GHG emission increases. As the EPA continues to enforce emission policies, they must be aware of the severe lag that comes between the policy and the impact it has[38]. Just like the emission standards set between 2007 and 2010, the effects have not become apparent until recently, when the market regrew to initial levels almost a whole decade after the standards. If market delays are to be expected when new regulations are imposed, regulatory ambitions must be able to address the delay that will take effect.

Legislative action currently being taken within the US has consisted of the Green New Deal, sponsored by Representative Alexandria Ocasio-Cortez, which fosters an initiative over the next 10 years for the US to reduce carbon emissions by 40-60% by 2030, alongside reaching net-zero emissions by 2050[39]. This bill is paired with an effort to create several jobs within the push to reduce emissions and promote sustainability. Article 1 section A specifically addresses the need to meet net-zero emissions, putting the labor and community needs at the forefront of the initiative. Article 2 section H specifically addresses the transportation sector, calling for ZEV manufacturing and infrastructure. The Green Real Deal proposed by Representative Matt Gaetz has also been introduced to the House, and specifically mentions spurring innovation towards cleaner power generation technologies[40]. Notably, there is a great push in Congress to move the American Society toward cleaner power solutions.

2.4. Reliance upon Foreign Oil

In 2018, according to the US Energy Information Administration (EIA), 20% of petroleum use was used for producing diesel power; this includes diesel used for trains, boats, buses, and even heavy-duty trucks[41]. As the US has become more independent in sourcing its oil, there is still a big reliance on foreign petroleum imports. The large reliance upon diesel fuels have become an economic burden on the US, with approximately $5.2 billion spent on fossil fuel

[37] "United States: Heavy-Duty Vehicles: GHG Emissions & Fuel Economy."
[38] Robert W. Hahn, "The Impact of Economics on Environmental Policy."
[39] 116. U.S. Congress, Recognizing the duty of the Federal Government to create a Green New Deal.
[40] 116. U.S. Congress, Recognizing the duty of the Federal Government to create a Green Real Deal.
[41] U.S. Energy Information Administration, "Diesel Fuel Explained: Use of Diesel."

subsidies in 2017[42]. This dependence has allowed the US to become unhealthily attached to foreign countries, specifically in the Middle East, creating skirmishes and trade wars. This conflicts may easily be avoided as long as the US begins to shift its energy reliance into a more secure strategy of energy independence. According to the US Energy Information Administration, approximately 11% of oil is imported[43], a significant decrease in reliance since the peak in 2005, where oil imports where approximately 60% of US oil stock[44]. Although the US has seen significant decreases in dependency upon foreign oil, the political rivalries and conflicts have continued.

Throughout the months of June and July 2019, several events have led to heightened tensions between the west and Iran, in the Strait of Hormuz, a high traffic area for oil imports and exports. While much interaction has been between the UK and Iran, the US has fallen into some conflicts with Iran. After two US oil tankers had allegedly been attacked by Iranian forces on June 13 and a US Navy drone downing by Iran on June 20, the US retaliated by downing an Iranian drone on July 18[45]. This rise in tensions has been due to President Donald Trump pulling out of the 2015 nuclear deal, hence re-imposing sanctions on Iran until a new deal is agreed upon. Although tensions have been rising, the conflicts on Iran and their oil exports have existed since the 1970s. With the heavy-duty trucking industry relying so heavily on these oil imports, the US should begin looking to alternative methods of powering the freight infrastructure.

On the note of the US's dependence on oil subsidies, this creates a market that is unfairly protected by the federal government. This can hinder technological advancement, as well as entrance into the market from alternative power sources, such as hydrogen or electric power relating to the transportation market. Legislation, which reduces the societal reliance on fossil fuel subsidies can usher in speedier advancements in ZE power generation, not just in the transportation sectors, but among electricity generation and industrial power generation as well.

[42] Coady et al., "Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates IMF."
[43] U.S. Energy Information Administration, "Oil: Crude and Petroleum Products Explained: Oil Imports and Exports."
[44] Nerurkar, "CRS Report for Congress U.S. Oil Imports and Exports."
[45] James and Murtaugh, "How a Persian Gulf Conflict Could Impact Commodities Markets."

3. Alternative Powertrains

As alternative powertrains have been backed by decades of research, many shifts within the automotive market must take place before they become a viable choice of transportation. Besides market shifts, many infrastructure changes will be expected, and with each new technology, comes a unique set of challenges specific to each technology. The infrastructure framework will need a great number of updates to accommodate for technologies on the rise. As logistic issues are sorted out by the industry to best market new technological products, the government can play a huge role in forging the path for these new technologies, as well as removing barriers which might hinder the progress of new forms of powertrain.

3.1. Reduced Emission Fuels

While ZE powertrains are highly effective at reducing emissions, the R&D efforts of reduced emission fuels and powertrains have been a topic of conversation in the heavy duty and passenger sector. These reduced emission fuels and powertrain technologies will be widely beneficial in the time leading up to a ZE future, but will not offer the permanent solution. Government entities must not be satisfied with simple reductions in CO_2 emissions. Rather, there must be continuous strife towards ZE powertrains. The developments in areas of reduced carbon emission fuels can be used for the intermediate periods between now and the rise of a greater ZEV market, especially in the heavy-duty sector.

Many recent developments in the global initiatives to convert to cleaner heavy-duty fuels have led researchers and industries to look into the feasibility of biodiesel and renewable diesel. These are two diesel fuels that are said to have cleaner methods of refining alongside a significant reduction in carbon emissions. With the many pros of biodiesel and renewable diesel, there are still plenty of solutions that must be worked out before becoming a viable option for fueling the US's vast heavy-duty transportation system. Many manufacturers have begun to oppose the implementation of biofuels, all the while biofuel refineries continue to advocate for the biofuel, calling it cleaner, more sustainable, and just as trustworthy as standard diesel fuels today.

Biodiesel is a fuel created by refining oils from inedible crops, such as soy, corn, and various other crops around the US. It has been said that biodiesel produces carbon emissions when combusted, as well as less PM. A downside of this is that biodiesel could produce a slightly greater amount of NOx emissions, which creates difficulties for biodiesel advocates when the EPA's NOx emissions are so stringent[46]. The switch from petroleum diesel to biodiesel is tough on engines, because petroleum diesel fuel will form deposits within the engine, while biodiesel will release these deposits[47]. Biodiesel fuels are typically mixed with petroleum diesel fuels to clean up the emissions of diesel engines. They are measured based on the percentage of

[46] U.S. Energy Information Administration, "Biofuels: Ethanol and Biodiesel Explained: Biodiesel and the Environment."
[47] Radich, "Biodiesel Performance, Costs, and Use."

biodiesel added, whereas B20 fuel is 20% biodiesel and the rest is petroleum diesel. Common biodiesel concentrations on the market today are B5 and B20. The US has done much already to promote the use of biodiesel fuels, such as a tax incentive for biodiesel producers per every gallon that is used or produced[48].

Developments in the research of natural gas combustion for powering heavy-duty engines have great benefits as far as emission reductions go. With the regulations instituted by the EPA, diesel engines have been able to meet similar standards to that of natural gas engines. The benefits of natural gas engines are that they do not have to require the number of components which diesel engines require[49]. Having been known to benefit smaller applications, such as that of forklifts, ZE technologies are quickly becoming a more popular alternative because of recent strides to reduce emissions. Alongside researching alternative fueling technologies, engine manufacturers as well as the US government have explored hybridizing heavy-duty engines, completely stepping away from the usual, more common diesel engine.

Hybridization has become largely popular among consumers in the passenger vehicle sector. Studies have shown that hybridization can improve fuel efficiencies in Class 8 trucks by 28-50%[50]. Researchers at Massachusetts Institute of Technology have developed a plug-in hybrid engine which might be run on pure gasoline or alcohol, said to be highly effective at reducing both GHG emissions and pollution[51]. While this is still early in the developmental stages, hybridization of heavy-duty vehicles might very well be an option for OEMs and government standardization in the near future.

The SuperTruck, an initiative started by the DOE in 2014 is a diesel vehicle which reaches mile-per-gallon (mpg) efficiencies close to that of a 70% improvement from the average heavy-duty trucks on the road[52]. The possibilities of reducing GHG emissions as well as toxic emission with an engine this efficient should pave the way for manufacturers to seek emission reduction technologies such as those used in the SuperTruck. The current EPA standards do not push the technological advancements of diesel engine technologies far enough, in regard to efficiency and emission reduction. The advancements made example by the SuperTruck should spur more ambitious GHG regulations to better address the problems at hand.

3.2. Battery Electric Technology

With the first developments of an electric car existing since 1828, it has almost taken over two centuries for the electric car powertrain to become a viable option in the transportation market[53]. Ever since 1912, where the electric starter was invented for gasoline engines, and Ford effectively began assembly line manufacturing for the Model T, BEV technology has failed to compete with the ease of combustion-fired powertrains. In regard to the heavy-duty trucking

[48] U.S. Department of Energy, "Biodiesel Production and Blending Tax Credit."
[49] U.S. Department of Energy, "Natural Gas Vehicle Emissions."
[50] Zhao, Burke, and Miller, "Analysis of Class 8 Truck Technologies for Their Fuel Savings and Economics."
[51] Chandler, "Engineers Develop Concept for Hybrid Heavy-Duty Trucks."
[52] U.S. Department of Energy, "SuperTruck Making Leaps in Fuel Efficiency."
[53] U.S. Department of Energy, "Timeline: History of the Electric Car."

industry, BEV technology has failed to produce the power, endurance, and ease of use to meet the needs of freight hauling. President Barack Obama highly backed BEV research, and even signed the federal incentive of giving hybrid and BEV owners a tax credit of $7,500 through the American Recovery and Reinvestment Act[54]. Recently, major industry leaders have taken investments into battery-powered heavy-duty truck manufacturing. Battery electric vehicles have begun to shift into the trucking market in order to assist in the reduction of CO_2 emissions as well as other pollutants, especially in area of high-density heavy-duty freight transportation, like ports[55]. With rumors of Tesla's new freightliner model, Semi, to begin production in 2019[56], emission-free freight transport lies in the near future. Even the longtime manufacturer of heavy-duty diesel engines, Daimler, has made commitments to convert a Portland, Oregon plant to produce all electric trucks by 2021[57]. There is great positivity surrounding the outlook of BEV technology usage in heavy-duty applications.

Even then, compared to diesel fueling, BEV stations are far from efficient, as AC charging provides just about 5 or 20 miles per hour of charging for Level 1 and Level 2 charging, respectively[58]. DC charging, on the other hand, has plans on competing with the current charging stations, allowing for 60 to 80 miles of range per 20 minutes of charging[59]. It is difficult to understand how this will translate to heavy-duty trucking, where loads are much heavier and require a greater amount of power. According to Tesla's website, the Semi is expected to have offered ranges of either 300 or 500 miles per full charge[60]. Full charge has been expected to be reached within thirty minutes, but much speculation surrounds the methods of charging, as the power delivery requirements are near impossible with current technologies and charging stations[61]. As more companies continue to invest in the BEV applications of trucking, much work must be done in order for freight markets to shift from cheaper and reliable diesel engines to BEV powertrains which are highly experimental with an unsure future.

Battery swaps have also been a discussed solution for the long charging times that will be experienced by long-haul truck drivers. With a machine patented by Tesla Motors, battery swaps could be possible within 15 minutes[62]. This method argues that battery swap machines could be placed along high-traffic truck routes. However, this would require major investments, mainly in infrastructure, but also largely in machine operators and supervisors. Major grid improvements must be made in order to deliver power sufficient to keep resting batteries charging at these stations in order to support the volume of trucks along major routes. Experts, such as Rick Mihelic, the president of Mihelic Vehicle Consulting, project that diesel will be the ideal choice

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[54] U.S. Department of Energy, "President Obama Announces $2.4 Billion in Funding to Support Next Generation Electric Vehicles."
[55] Other pollutants could refer to nitrogen oxides, sulfur, or methane gases/particles.
[56] Tesla, "Tesla Press Information."
[57] Dzikiy, "Daimler to Make All-Electric Freightliner Trucks at Converted Portland Factory."
[58] U.S. Department of Energy, "Developing Infrastructure to Charge Plug-In Electric Vehicles."
[59] U.S. Department of Energy.
[60] "Tesla Semi."
[61] Turpen, "Tesla Semi Truck's Battery Pack and Overall Weight Explored."
[62] Roberts, "Could Tesla Solve EV Range Issues With Battery Swapping System?"

of heavy-duty freight leaders for the next several years[63]. This can easily change if the BEV market is given a fair advantage to compete amongst fossil fuel powered diesel engines.

The continued support of government entities will be highly necessary for the rise of BEV technologies in both the passenger and freight sectors. Much research and development must be pursued in areas of updating battery technologies and charging solutions. The onset of revolutionizing transportation to utilize ZE technologies will surely contribute to the R&D efforts of battery infrastructure and improvements.

3.3. Hydrogen Fuel Cell Technology

In the 1970s, people became worried about the US's dependence upon foreign oil imports, and since then, alternative fuels have become a big topic of discussion in the political realm. Hydrogen FCEVs have been a big topic of research since 2003, when President George W. Bush announced a $1.2 billion fuel cell initiative to promote zero emission power and reduce the US's dependence upon foreign oil imports[64]. Spurring research in the feasibility of FCEV technology, the DOE has made strides addressing issues within the fuel cell industry, as well as promoting and assisting companies in utilizing this technology for transportation. As research continues, several within the fuel cell community are beginning to realize the potential for FCEV applications in heavy-duty and off-road applications. Most recently, in March of 2019, the DOE announced a $51.5 million budget for heavy-duty applications with hydrogen fuel cell technology[65]. In the rural parts of the US, this is exciting news, where heavy-duty and off-road vehicles share a large portion of the automotive market, where these vehicles have integrated within the communities because of their usefulness in farming, transporting, and many other labor applications. Heavy duty engines have become a necessity for rural communities, even regarding the cultural impact of these vehicles.

Fuel cell technology has proven itself in heavy duty applications, providing more power and more range for heavier loads. The Department of Energy has launched the program H2@Scale to visualize the deployment of widespread hydrogen use as a means for power. This program has made great improvements and agreements with companies looking to capitalize on cleaner energies, gaining a head start in creating a newer, cleaner energy framework. The California Fuel Cell Partnership has announced goals of having one million FCEVs and one thousand hydrogen stations by 2030, which is a great head start on laying the foundation for alternative fueling technologies. With the launch of hydrogen vehicles by companies such as Toyota, Hyundai, and Honda, this creates a pathway for hydrogen fueling infrastructure to grow, where companies can begin to profit from hydrogen fueling stations to ultimately become self-sustaining. The majority of the FCEV market is concentrated in California, because of the ambitious direction of emission reduction policies by the state government.

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[63] Roberts, "Will Future Tech Have a Domino Effect on Fleets?"
[64] The White House, "Fact Sheet: Hydrogen Fuel: A Clean and Secure Energy Future."
[65] U.S. Department of Energy, "Department of Energy Announces $50 Million for Commercial Truck, Off-Road Vehicle, and Gaseous Fuels Research."

Fuel cell technology has already made itself cost effective and operationally efficient within the forklift industry[66]. As more warehouses continue to invest in hydrogen fuel cell forklifts, many industries have begun to explore industries to which fuel cell can expand next. According to the DOE, there is a great argument for implementing fuel cell into warehouses which are looking to become ZE yet remain economically conscious. The quick refueling allowing for near constant operation of forklift equipment paired with a central fueling station continues to triumph over current rechargeable electric forklifts. The visual shown in Figure 5 explains how FCEV becomes more effective for continuous loads and heavier loads, while BEV makes a good case for short, intracity trips in urban and suburban areas.

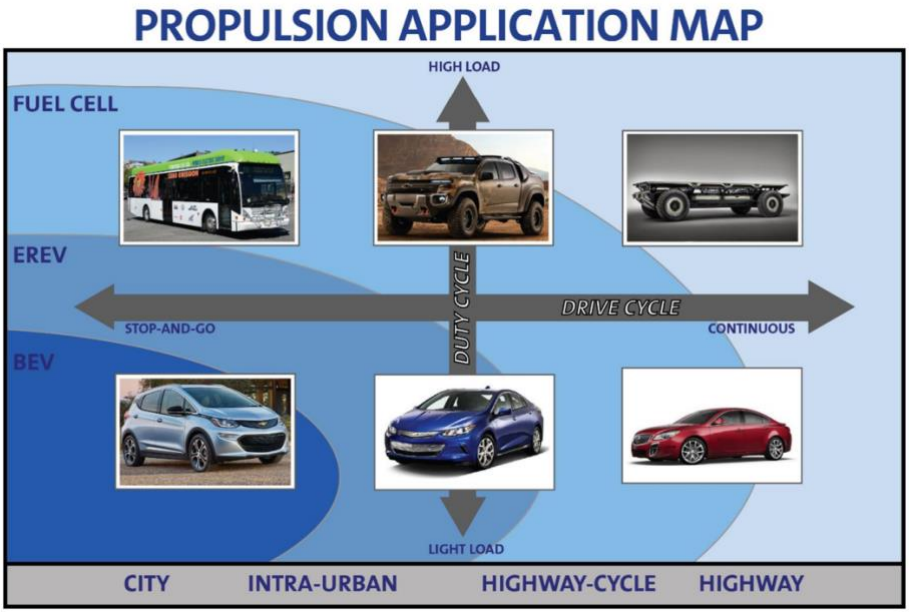

Figure 5: Applicability of ZEV technologies based on load and range[67]. Figure acquired from the US Department of Energy

The question is now up in the air as to whether the cost benefit analysis will translate to other industries. A great similarity between trucking industries and forklift industries is the ability to be centrally fueled. At least in port cities, such as Los Angeles, New Orleans, or Boston, there is a short distance travelled by the average heavy-duty truck when hauling freight from cargo ship dock to local warehouses or port yards. According to the Bureau of Transportation Statistics (BTS), about two-thirds of the freight moved (by weight) is carried a distance of less than 250 miles[68]. So, in highly populated port-cities, there is a higher density of heavy-duty trucks that only go as far as 250 miles away from the port location, and then may even return the same day. The Nikola Two offers a range anywhere from 500 miles to 750

[66] U.S Department of Energy, "Early Markets: Fuel Cells for Material Handling Equipment."
[67] Rivkin, "National Codes and Standards Deployment and Outreach."
[68] U.S. Department of Transportation, "Freight Facts and Figures 2017."

miles[69], which will easily meet the demands of over two-thirds of freight transport needs. For as long as these jobs are occupied by diesel emitting trucks, there will always be a higher concentration of NOx and PM than locations beyond 250 miles from the port area. A great case can be built for FCEV applications for jobs under 250 miles from central locations. Just like forklift stations must be centrally located, so could fueling station for heavy-duty port transportation.

While FCEV technologies have great advantages for heavy-duty applications, much development must be done to standardize a market for vehicles of this type. Infrastructure, as previously mentioned, is still in the early stages, and will not be widely available until beyond 2030. For now, heavy-duty FCEV will continue to be most effective in centralized fueling locations. Public education is also a great issue among new technologies, while there is great benefit to convince the public to invest into cleaner technologies, there is also a need for familiarity. This will happen naturally, as the FCEV market continues to grow, people will begin to warm up to the thought of hydrogen power and the safety measures taken to ensure compatibility with road applications. As of July 2019, the DOE has announced $50 million towards fuel cell research in commercial trucking, off-road, and gaseous fuels research.

[69] Nikola Corperation, “Nikola Two.”

4. Concerns Relating to Current Heavy-Duty Dynamics

With the rise of the ZEVs market, there is a current global concern over the following issues presented. While many are concerned about the impending shifts of climate change, there must be further measurements taken to ensure all automotive markets are given a fair chance to enter the market. Several million jobs depend on that of the diesel industry, afraid of the power the government could use to push them out of work. ZEV industries will have to become adaptable, as the government will surely address issues relative to job losses experienced in the fossil fuels industry. Much of the alternative fueling market depends on the wishes of the consumer; however, there must be an eventual shift in the market to ensure consumers begin investing in alternatively fueled cars if GHG emissions are to be reduced.

4.1. Emission Reductions

With the controversy of the US pulling out of the Paris Climate Agreement at the beginning of 2019, the question arises as to whether the US is doing enough to reduce emissions. Figure 1 illustrates top experts' analysis on where the surface temperature of the earth could be headed. Trusting in the wide range of scientists who agree immediate action must be taken to reduce GHG emissions, the heavy-duty transport sector can be a nationwide leader in this area. While climate goals may seem ambiguous and difficult to reach without stringent governmental control over diesel-powertrain-producing industries, there are several ways to give industry greater expanse of freedom through emission reduction. Technology is increasingly updated, which will significantly improve the affordability and ease of use for cleaner technologies.

The health issues associated with ozone risks, NOx emissions, and PM emissions are also a concern as mentioned in section 2.1. The great benefits that have been seen from reducing NOx and PM emissions should spur policy makers to continue the switch from diesel over to ZEV technologies. The sooner harmful gases stop being emitted into the air, the healthier high traffic communities will continue to be. The continuation of smog in large port cities and its effect on persons at risk for asthma will not be hindered unless larger scale action is taken, which allows for cleaner trucks to be turned over as quickly as possible.

As ZEVs grow, passenger vehicles might then be able to rely on the infrastructure that has paved the way, in turn growing the market of ZEVs. The relationship that exists between the passenger vehicle sector and the freight delivery sector will need to be heavily utilized for the conversion from combustion-fired powertrains to ZE powertrains. These advancements in the US transportation sector as a whole will be highly beneficial not only to the US's technological leadership, but to the environment and several countries around the globe. The largescale improvement of cleaner infrastructure will enable a greater push towards an emission-free transportation sector.

4.2. Foreign Reliance

The reliance upon foreign countries for oil imports has put several Americans at risk for the unpredictable rising and falling of fuel prices. While costs associated with fuel might seem minimal, their reliance upon foreign imports will never be 100% safe for national security. The US has had significant improvement in regards to lessening reliance upon foreign oil, as discussed in section 2.4. The current oil reserve allows for less of an impact on citizens when national relations falter; however, greater energy independence will allow for greater centralization of energy, as well as diversification of energy sources. This will allow for continued technological improvement, which will be discussed further in section 4.3.

As US relations with the Iranian government continue to escalate into the near future, oil imports could greatly be affected; although, there has been a great shift in reliance upon countries with whom international relations are more secure. Future problems with international relations may be observed with the US dependence upon rare minerals from China. Rare minerals are a significant contribution to today's BEVs; hence, even cleaner technologies can be affected by insecure international relationships. The great dependence of the US automotive market on foreign counties is bound to cause problems in the future.

4.3. Technological Hinderance

The dominance of the combustion fired-engines in the US transportation sector had completely pushed the thought of ZEVs out of the market for several years. This form of powertrain has been challenged in issues of emissions. Now there is a competition to see which technology can fit American's needs as well as address the CO_2 crisis. For years, because of combustion engine dominance, the efficiencies and fuel compositions have not had to measure up to much challenge. With the pursuit of cleaner engine technologies, there must be greater allowance for societal transition to newer, cleaner technologies. The US infrastructure is not yet prepared to handle the demands of a transportation sector powered solely on alternative fuels.

The possibility for future fueling methods to compete with one another will allow for great technological advancements to be made, where FCEV technologies currently have to prove they can meet the advances of BEV technologies, BEV may have to improve to do the same in the future. The possibility of this industrial competition's existence should create a push from all sides of government to enable this possibility of advancement.

5. Recommendations

While the EPA and several global partners have taken responses to the issues involved with the emissions from diesel-fired powertrains, there is still a long way to go. As industry leaders seem to be moving in more positive directions to reduce emissions, it can be shown that if careful consideration is taken, a balance between industry regulations and industry freedom is possible and will be effective if correctly implemented. Pursuing a ZE future will require not just the EPA's guidance, but cooperation throughout governmental entities as a whole. To minimize compliance costs and industry restrictions, the following considerations should be kept in mind or acted upon.

5.1. Recommendation 1: Enable EPA Action Towards GHG Reduction

For any progress to be made allowing alternatively fueled vehicles (ZEV)s into the transportation market, several more initiatives must come from the federal level. While simultaneously sustaining a market free enough for two technologies to compete, there must be persuasion away from heavy-duty diesel powertrains into heavy duty ZEV powertrains. The reason diesel continues to dominate the market today is due to the lack of push towards cleaner powertrains, and the continued ease of manufacturing combustion-fired powertrains, while making slight improvements at too slow a pace. If the US ever plans to cut carbon emissions, regulations instituted by the EPA must be strategically be designed to streamline the implementation of new technologies and phasing the old out. This ensures that emissions regulations are unable to over-burden industry leaders, while guiding them in the correct directions, allowing them to make their own choices.

As a part of President Trump's Executive Order on Reducing Regulation and Controlling Regulatory Costs plan of reducing non-defense spending, there is a great risk of the ZEV tax credit being disabled. This could greatly reduce the push for consumers to purchase ZEV vehicles, especially while the same tax credit structure could be beneficial to generating a larger market for heavy-duty transportation. Congress needs to address this situation, observing the need for greater regulations on emissions, as well as looking into the benefits which could be cultivated from a greater need for technological diversity.

While the EPA's CTI has great intentions of reducing NOx and PM emissions from heavy-duty diesel exhaust, this need is almost obsolete. Studies have continued to show that a majority of the smog forming over west coast cities comes from Asia's lack of enforcement on emission standards[70]. While the health concerns sourced from NOx and PM emissions are noteworthy, much of the west coast's emission reduction is dependent upon Asian countries. Several heavy-duty vehicles occupy the roads which are model years before the ambitious EPA reductions; therefore, NOx reductions can be expected for at least the next decade, by which then 2007-2010 model year vehicles can be expected to retire.

[70] Chappell, "Smog In Western U.S. Starts Out As Pollution In Asia, Researchers Say."

If the US hopes to effectively reduce NOx and PM levels, the 2% of vehicles which cause these emissions must be removed from the road. Simply outlawing vehicles which are pre-2002 will have a great impact on yearly NOx emissions. Even small reimbursements for parties affected by this outlaw will ensure a smooth transition into powertrains which comply with more updated EPA regulations. While this pertains more to the CTI, these regulations might be better imposed in locations more heavily effected by smog. Being proactive on this issue will prevent future challenges, keeping cities from having to instigate a diesel ban entirely, as Germany had to do in early 2019, outraging citizens who had good intentions of buying diesel to reduce GHG emissions.

EPA's efforts would be better spent trying to curb GHG emissions, addressing the issue of climate change, all the while promoting ZEVs. It is important to balance the GHG initiatives, because any hasty decision might easily overburden the entire freight industry, which in turn could damage the economies of markets all around the US. To avoid a drop in output like that of the years between 2007 and 2010, careful cost considerations must be made, which can openly convey a realistic cost of compliance for industries effected by new GHG regulations. A gradual shift from one type of powertrain to another will be best for the success of the freight industry. This recommendation will be explored in section 5.4.

Implementing stricter regulations may require waiting until there is a greater grasp around ZEV markets, to confirm the establishment of newer technologies. Surely if there is a greater presence of infrastructure and market for newer technologies, there will not be a severe hindrance in shipping and freight transportation, as was seen in 2007 with the addition of harder PM and NOx regulations by the EPA. ZEV technology is nationally possible by 2050 if the right considerations are taken with regards to regulating emissions or vehicle technology. In depth research must be taken to ensure the market does not reject ZEVs or hold on to older vehicles for longer periods of time than necessary or effective.

5.2. Recommendation 2: Formulate Alternative-Fueling Infrastructure Solutions Through the DOT

Currently, it is up to the states to invest in infrastructure, and their choice on how to raise money off of drivers on the road. Recently, several issues have arisen at the state level which hinder the growing market of ZEV technologies. While many states are at varying level of ZEV infrastructure readiness, it is largely up to the states to support these vehicles and their entrance into the market. To reach ZEV capabilities, there must be a unionized push towards this effort, whether it comes in the form of federal taxes, or agreements between bordering states to provide the support for cleaner heavy-duty vehicles. The Department of Transportation (DOT) has a great opportunity to contribute to the infrastructure development of ZEV needs.

Cleaner fueling infrastructure will more easily allow networks of cleaner heavy duty transportation to grow. By addressing ports and industrial cities initially, cleaner fueling networks will continue to expand beyond that of just cities. While large cities are the most effected by diesel emissions, the issue of climate change will have an eventual impact on all

parts of the country. There needs to be established strategies which allow self-sustaining stations to grow beyond the reaches of the port. Seeing as two-third of freight is carried within 250 miles, the other third of freight must still be addressed. Requiring that a greater expanse of cleaner fueling technologies is a necessity for a ZE future.

ZEVs have a hard time gaining market support for many reasons, the main two being the cost, and the fueling infrastructure rarity or unreliability. Studies show that current ZEVs are driven by more affluent persons, who have the money to invest in the equipment required to take care of and power these vehicles. Shifting the heavy-duty sector to become subject to ZE regulations will allow for this infrastructure to take off, within a higher public access to stimulate ZEV technology practicability.

While BEV infrastructure support has begun to rise successfully in the past decade, there are still greater needs that must be addressed. A greater grid capacity will allow for the implementation of newer charging technologies, such as DC Fast Charging, allowing for charging capacities that reach miles per fueling minute rates closer to that of gasoline or diesel engines. A great amount of power is required for charging stations such as these to exist, and the grid capabilities within the US are not up to standards to meet these power requirements. Methods of battery replacement have been mentioned in regard to powering the electric heavy-duty sector; however, much of the technology for this method is still in development stages, because this method also takes 15 to 20 minutes minimum, leaving several freight companies skeptical of a ZE future.

Hydrogen fueling infrastructure requires a lot of time to expand over the nation, and much technological advancement must be taken to allow centrally located fueling stations to become effective and profitable. Transportation of hydrogen has proven to be difficult, and the generation methods of hydrogen must be streamlined and further researched to become both cost-effective and 100% ZE processes. Several states require lengthy permit processes which have good intentions of being safe, yet hinder the rapid expanse of hydrogen fueling stations. There are several hydrogen storage codes that must be addressed and loosened to become widely available for ZEV market growth.

Because combustion fired powertrains have great infrastructural advantages over ZEVs, there is a great economic barrier that must be overcome through government investment in ZEV infrastructure. If the US is truly to become a leader in technological advancements and the reduction in emissions, government intervention will be a necessity to spur alternate fueling structures which can convince the public to buy cleaner powered cars and trucks. This necessity remains true for both light duty vehicles and heavy-duty. Creating a framework for cleaner freight transportation will surely trickle down into the passenger vehicle sector, and eventually all sectors.

5.3. Recommendation 3: Federally Provide Consumer Incentives for Zero-Emission Vehicle Freight Fleets

As industry leaders fear the possibility of being pushed out of the automotive market by governmental regulations, they have started to oppose incentives given for ZEVs. As BEV technology grows, states have begun to fear they will have no source of income when fuel powered vehicles begin to decrease in number. The need of gas taxes is highly important for the states to fund and upgrade infrastructure; however, state governments fear BEVs might begin freeriding off of gasoline vehicles without having a share in helping costs of infrastructure improvements and maintenance.

While it is necessary for the government to continue to tax transportation systems to generate funds for infrastructure improvements, a balance must be found between the incentivization of ZEVs and the generation of revenue off ZEVs. Recently, states have opted to give BEVs fees while driving to make up for the revenue lost through gas taxes. Currently, there are federal incentives under the American Recovery and Reinvestment Act signed in 2009 by President Barack Obama is contributed to ending the Great Recession, also promotes hybrid and ZE powertrains through a tax credit of $417 plus $417 for every kilowatt-hour beyond 5 kilowatt-hours depending on the attribution to emissions[71]. These incentives have greatly grown the prospects of ZEV passenger markets; introducing an amendment to the American Reinvestment and Recovery Act to provide specific for the magnitude of a ZE heavy-duty engine. This might encompass a tax credit on the order of $20,000-$30,000 dollars due to the greater power required for these engines.

Along the lines of federal incentives, this act has a limit of 200,000 sales, which means the incentive is halved once the engine manufacturer reaches this amount. Current lobbying battles are ensuing due to the request of a larger sale threshold. Combustion fuels are lobbying for a fair playing field; however, there is already a great amount of subsidization within the fossil fuels industry itself. Just like passenger vehicle consumers are receiving tax credits for the purchase of a certain amount of electric vehicles, so should heavy-duty vehicles to build a greater market for these vehicles, specific to the needs of the industry, ideal around a threshold of 200,000 sales.

With the growth in ZEVs, several of the states are beginning to tax these vehicles, manufactures as well as the general public are afraid that consumers may become discouraged from purchasing ZEVs. The likelihood of consumers being discouraged from these purchases are extremely low, as the federal tax incentive far outweighs that of what drivers must pay at the state level. Even California, which highly encourages ZEV purchases, has state tax on BEVs. Even so, many economists say that states are losing infrastructure funds because the tax is not comparable enough. Governmental authority must ensure needs for infrastructure are met, all the while continuing the promotion of ZEVs.

[71] 111. U.S. Congress, American Recovery and Reinvestment Act of 2009.

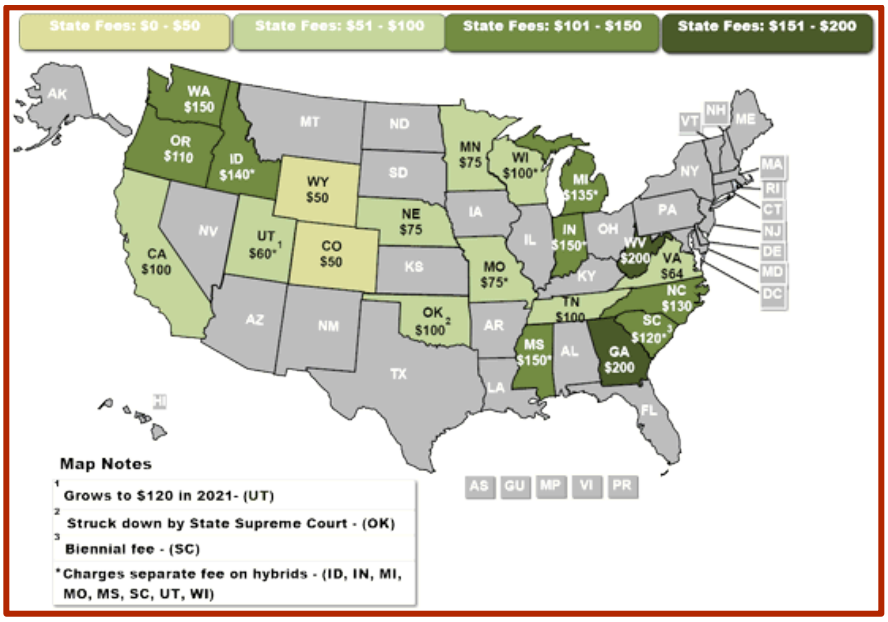

Figure 6: States charging annual BEV fees[72]. Chart provided by ncsl.org.

While combustion engine leaders are lobbying for a fair playing field, discouraging incentives upon ZEVs, there must be an industry wide agreement which allows for leaders to come to a consensus. There is a desperate need for transportation leaders to look into ZEVs, while seeking to reduce industry reliance upon oil and other carbon emitting fuels. Subindustries within the heavy-duty trucking industry can lead this initiative by accepting governmental incentives to have their truck fleets invest in ZEVs. Before allowing this to happen, infrastructure needs must be met, as mentioned in section 5.2. Trucking fleets will not be convinced into purchasing ZEVs until the proper infrastructure is in place for drivers' needs to be fairly and efficiently met.

When governments are considering these incentives, there must be insurance that each ZE technology is being fairly treated under regulatory standards. The governments' decision to incentivize one ZEV technology over the other could be costly. Not only would one technology be completely phased out of the market, but the goal of reaching a ZE transportation sector could be prolonged. If choosing BEV, the US will have to greatly increase the capacity of its grid for effective charging stations. If FCEV technology is chosen, a long developmental process must take place before the entirety of trucking fleets can convert over from diesel to hydrogen. This recommendation will be further explored in section 5.5, but the general concept of equal treatment between technologies must be kept in mind when producing ZEV incentives.

A balance must be made which allows for states to continue generating infrastructure funds off of all vehicles on the road, while still promoting ZEVs. The best way to equally tax all vehicles on the road is by utilizing toll booths. Unfortunately, this means that more traffic congestion problems must be dealt with; however, with the rise of cashless tolling, congestion is

[72] Hartman and Pula, "New Fees on Hybrid and Electric Vehicles."

becoming less of a problem. Cashless tolling makes for a great case to treat each vehicle with equal consideration in regard to the infrastructure. The challenge of balancing tax incentives and tax fees will continue to be an issue government must confront until a ZE future is reached.

5.4. Recommendation 4: Propose Alternatively Fueled Vehicle Manufacturing Agreements with Original Equipment Manufacturers of Heavy-Duty Engines

Since there is a great need for larger numbers of OEMs to produce cleaner powertrains, this can boost the heavy-duty powertrain market to begin efforts of investing into manufacturing processes which produce those powertrains. The ZEV market is a high-risk industry to enter into for businesses, mainly because it will be years until a profit is made. As with Tesla in the passenger vehicle sector, the company has yet to have a profitable year[73], relying on the faith of investors to anticipate the company's growth. If carbon emissions are to be truly pursued, there must be protections in place, as well as benefits in place, for investors to continue supporting ZEV markets.

Luckily, several more companies are producing ZEVs, allowing profits to be made via combustion engine cars, and suffering small losses with the marketing of ZEVs. While these companies will continue to pursue minimal emission technologies, they will slowly grow the ZEV market. This slow growth due to market shift will not be enough to meet goals recommended by leading scientists. The International Panel on Climate Change's (IPCC) report on a 1.5 °C rise from pre-industrial levels calls for major shifts in carbon emitting industries[74]. Policy makers have the power to speed this shift through engine manufacturers especially. While this requires diplomatic agreements between large industry players, governmental leaders have the power to make deals with companies that avoid putting truck sales in a downturn.

An ideal bill to promote this sort of manufacturing would be a percentage-based requirement, where an industry is required to manufacture and sell a certain percentage of ZE powertrain technology to bring slight growth into the ZEV market. In the past, most regulations have been most impactful to individual consumers, raising the truck prices and implementing more equipment requiring more frequent maintenance and supervision. Dispersing the cost of heavy-duty ZEVs among the sales of diesel engines can better allow for private sector research, as well as reduced costs in heavy-duty ZEVs. This will allow the consumers to make more strategic decisions in whether to purchase ZE or not. For example, if a freight industry business is more concentrated with states that have stricter emission regulations or ZE incentives, then they can be better supported in purchases of ZEVs from the manufacturer.

Effectively requiring OEMs to begin manufacturing ZE powertrains for heavy-duty vehicles will work best for the safety of the current industry leaders as well as create an environment which generates the advancement of heavy-duty ZEVs. The expertise of current heavy-duty powertrain manufacturers can then be applied to a different set of needs that may need to be met with ZEVs. This transition will allow for OEMs to stay in business, and not

[73] "Tesla Net Income 2009-2019 | TSLA."
[74] Masson-Delmotte et al., "Summary for Policymakers."

become victims of governmental regulations which might push several companies out of business. Companies like Daimler have already started this push out of its own motive, with the intention to supply California's demand of electric trucks[75]. As Daimler has begun to prove the possibility of a paced conversion from diesel to electric due to California's governmental demand, many other companies will be able to follow along if regulations are taken into consideration which allow companies to increase ZEV engines at a given pace.

5.5. Recommendation 5: Keep All Zero-Emission Vehicle Technologies Equal Under New Regulations and Benefits

To foster greater competition between ZEV technologies, it is important that the US government avoids giving too much assistance to one side of the market. Just like in 2010 when FCEV manufactures feared the DOE would no longer provide assistance towards their side of the market due to advocation for BEV transportation and cut research funds for FCEV technology, administrations should try their best to avoid choosing one ZE market over the other. If the entire US transportation sector is to be converted to ZE powertrains, the quickest and most effective way to address the problem at hand is to allow both technologies to grow on their own, competing against one another.

As manufacturers begin to forge paths down the ZEVs sector, they must take great risks; not only that, but ZEVs are very difficult to sell to customers who will not have the guaranteed infrastructure in place until many years later. Putting it in perspective, there are about 111,000 retail fueling stations[76] while 55% offer diesel fueling pumps[77]. As of July 2018, in California, there were 35 hydrogen stations, with a planned 1,000 by 2030[78]. As far as B20+ biodiesel goes, there are only about 200 stations nationwide[79]. BEV stations, by far the most established, have over 22,000 nationwide locations[80]. The current technological and grid limitations mentioned in the Battery Electric Technology section make this form of clean transportation undesirable for longer and heavier hauls, which will require a lot more power for longer amounts of time.

The infrastructure is growing for all ZEV markets, however, no one technology will be able to sustain the US transportation sector itself. As it will take years to establish a hydrogen fueling infrastructure, and the capacity of the electric grid must be doubled to sustain a majority BEV market, ZEV markets must unite to more quickly achieve emission reduction goals. This unity requires that at least the federal government treats ZE technologies without discretion in the early stages of growth. This could include requiring a FCEV incentive for every BEV incentive, widening the options of ZE technology and applications. The government must be

[75] Dzikiy, "Daimler to Make All-Electric Freightliner Trucks at Converted Portland Factory."
[76] US Census Bureau and ProQuest, "Number of Gasoline Station Establishments in the United States from 2013 to 2016 (in 1,000s)."
[77] Diesel Technology Forum, "Diesel Drivers Fuel Locator."
[78] California Fuel Cell Partnership, "CaFCP Vision 2030."
[79] U.S. Department of Energy, "Biodiesel Fueling Station Locations."
[80] U.S. Department of Energy, "Electric Vehicle Charging Station Locations."

careful not to select or overly favor one technology over the other, if the two become highly established in the ZEV market.

The weaknesses between the current ZEV technologies allow for greater market competition and does allow for the emergence of new, less so established technologies. Each technology will play great roles in the path to a ZE future, but the governmental involvement of choosing technologies over another must be discouraged. In legal conversations, regulations, and announcements, it is important to use neutral terms encompassing all technologies which avoid implying one ZE technology is greater than the other.

Conclusions

While many R&D challenges must be overcome to further reduce costs and increase the cleanliness of production, regulations must begin gearing more focus towards aggressive yet feasible and attractive emission regulations. With the great initial increase in cost that will come with ZEV compliance regulations, and infrastructural funding, the economic benefits will drastically allow for greater competition among powertrains as well as higher improvements in technology and emission rates. The rapid approach of climate change effects should push for a greater contribution towards ZEV technologies in any sector of transportation, which will be the most effective way of converting to ZEV technologies. Now that the ZEV technology has begun to prove itself in the market, it is up to the government to address the issues at hand by promoting all ZEV technologies and addressing the challenges faced by ZEVs.

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