3690: A Journal of First-Year Student Research Writing

Volume 2021 Article 6

2021

Help Reverse Global Warming: Drive an All-Electric Vehicle

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Abstract

Overview: Global warming is one of the biggest challenges facing humanity today, so I wrote this paper primarily to determine what technologies could possibly impact the trend of this global threat enough to help reverse it. Since transportation contributes 29 percent of all greenhouse gas emissions in the United States I chose to focus on this economic sector, and more specifically, light use vehicle alternative fuel technologies. I further narrowed my scope to a discussion of ethanol, bio-diesel, hydrogen and electric fuel technologies because each represents one of the four alternative fuel categories. I evaluated the fuels on the following criteria: a complete or major percentage reduction in greenhouse emissions, a reasonably fast nationwide implementation, economic viability and the technology must be a sustainable solution. My paper begins with a tweet from Elon Musk stating, "We will not stop until every car on the road is electric." I conclude my paper in agreement with this statement.

Author's reflection: I am currently a sophomore marketing major at St. John Fisher and I chose Climate Change as my Researched Based Writing class because the topic interested me. Prior to college, my knowledge of global warming primarily consisted of the basic science behind the problem and some of its more common causes and effects. Reading *The Story of More,* by Hope Jahren, at the beginning of our class opened my mind to this problem's complex nature of intertwined environmental, economic, political and social issues. Her narrative and jaw-dropping statistics comprising the chapter devoted to transportation truly caught my attention, which provided the impetus to focus my research on alternative fuels. Writing and researching this paper provided many challenges like deciding how to evaluate the chosen fuel technologies. Perhaps the biggest challenge stemmed from the need to decide what evidence or data to include in order to support my hypothesis, as my research continuously provided new, relevant and sometimes better evidence. Nonetheless, I enjoyed the process of putting this conundrum together. I invite you to read my paper and also encourage you to make your next car purchase an electric one.

This article is available in 3690: A Journal of First-Year Student Research Writing: https://fisherpub.sjf.edu/journal3690/vol2021/iss1/6

Help Reverse Global Warming: Drive an All-Electric Vehicle

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April 29, 2021

Introduction

"We will not stop until every car on the road is electric," tweeted tech icon Elon Musk (Musk, 2017). Despite being a rather controversial figure, Musk's technological genius and passionate drive to transform the automobile industry cannot be questioned. His tweet speaks to the urgent need to decarbonize the world's economy, because two possible but inevitable outcomes exist on the near historical horizon. First, the global supply of petroleum will be exhausted in about 50 years, based on British Petroleum's respected annual publication, the Statistical Review of Energy (Perkins, 2019, para. 6). Or, the global consumption of petroleum and other fossil fuels will lead to a catastrophic ecological disaster. Currently, 67% of adults in the United States believe that global warming presents a real threat, and the federal government needs to do more to reduce greenhouse gases. (Funk & Hefferon, 2019, para. 4). Further, 77% believe alternative energy development should be the priority over further fossil fuel development (Funk & Hefferon, 2019, para. 8).

Why focus on alternative automobile fuels to reduce greenhouse gases? According to the United States Environmental Protection Agency (2021, para. 4), transportation emissions from cars, planes, trains, ships and trucks contributed 29% of the greenhouse gases produced by the United States in 2019. Nearly half of that, or 14%, originated from light use vehicles (passenger automobiles and small trucks). The agency further reported that petroleum-based fuels powered more than 90% of all vehicles in the transportation sector. Alternative fuels definitely provide substitutes that will reverse global warming emissions contributed by light use vehicles.

Elon Musk owns and runs the largest all-electric car company in the world, but is his very biased tweet noted above actually correct? Are all-electric cars indeed the best alternative in the United States to the petroleum-based gasoline powered combustion engine? This research inquiry seeks a partial answer to this question by investigating four alternative fuels including ethanol, biodiesel, hydrogen and electricity. Several other alternative fuels could be included, but these four were selected to limit the research scope, and to represent each of the four major alternative fuel categories. The categories include alcohols (ethanol), gases (hydrogen), biologically sourced (biodiesel) and electricity. These four alternative fuels will be evaluated on the following criteria: a complete or major percentage reduction in greenhouse emissions, a reasonably fast nationwide implementation, economic viability (widely available to most of the population and a developed market) and the solution must be permanent (not sourced from finite resources). The discussion of these four alternative fuels proceeds in the following manner: how each alternative fuel technology works, the advantages and disadvantages of each alternative, economic considerations of all-electric vehicles and the social and institutional barriers to implementing all-electric vehicles. The research concludes with a discussion of the reasoning behind the choice of electricity as the best of the four alternative fuels.

Four Alternative Fuel Technologies

Ethanol, an alcohol distilled primarily from corn, is already widely used and blended with gasoline. In fact, 98% of all gasoline contains at least 10% ethanol. The three classifications of ethanol-blended gasoline include E10, containing 10% ethanol, E15, containing 10.5%–15% ethanol, and E85, containing between 51%–83% ethanol (United States Department of Energy, n.d.-e, para. 1). The two blends, E10 and E15, fuel any conventional light use vehicle with any internal combustion engine manufactured since 2001. The E85 blend can only be used in specially designed Flexible Fuel Vehicles (FFVs) able to run on any blend of ethanol and gasoline up to 83% ethanol. FFVs utilize internal combustion engines, however they require modifications to certain components, primarily the fuel pump and fuel injection systems, to accommodate ethanol's chemical properties and energy content (United States Department of Energy, n.d.-g, para. 1). Cold weather affects the reliability of ethanol, so the proportion of ethanol to gasoline in E85 varies by region, climate, season and terrain.

Biodiesel provides an alternative to petroleum-based diesel fuel for any vehicle with an internal combustion diesel engine. One of the primary differences between a diesel and traditional engines stems from the ignition process. Traditional combustion engines ignite the fuel employing sparkplugs, while diesel engines rely on high levels of compression to ignite. Biodiesel is made from vegetable oils, used cooking oils, yellow grease or animal fat. The production involves reacting 100 pounds of oil or fat with an alcohol (typically methanol) and sodium hydroxide or potassium hydroxide. This process results in 100 pounds of biodiesel and ten pounds of a co-product called glycerol (United States Department of Energy, n.d.-a para.1). Similar to ethanol, biodiesel is blended with diesel fuel, with B20, containing 6%–20% biodiesel, and B95, containing 5% biodiesel, being the most common. Blends containing more than 20% biodiesel require engine modifications (United States Department of Energy, n.d.-c, para.1).

Hydrogen fuel is a very different technology than ethanol or biodiesel. In a Fuel Cell Electric Vehicle (FCEV) a fuel cell converts the stored energy in Hydrogen into electricity, which powers the electric motor to turn the wheels. There are several types of fuel cells and the way a fuel cell works is complex, however they basically produce energy by passing hydrogen through an anode and oxygen through a cathode. A catalyst produces a reaction at the anode and splits the hydrogen into protons and electrons to release the energy (Manoharan et al., 2019, p. 4). Fuel cells are not batteries and do not need replacement. They can be refilled with hydrogen much like filling an automobile tank at a gas station, and they will continue to work provided fuel is supplied. Just as gasoline must be refined from crude oil, hydrogen must be produced.

Ninety-five percent of commercially produced hydrogen uses steam-methane reforming, which employs high temperature steam and a catalyst to react with methane. The process results in hydrogen, carbon monoxide and carbon dioxide. One alternate method to produce hydrogen uses electrolysis to split water into its two components, hydrogen and oxygen (United States Energy Information Center, 2021-b, paras. 2-4). It is important to note that hybrid fuel cell vehicles exist, but the scope of this inquiry includes vehicles powered solely by hydrogen.

Similar to hydrogen, this research will focus only on all-electric vehicles also referred to as battery electric vehicles (BEVs). BEVs have an electric motor instead of an internal combustion engine. A large rechargeable battery pack stores electricity simply by plugging it into a wall outlet or by using electric vehicle supply equipment. The stored electricity in the battery runs the electric motor. A BEV contains fewer moving parts than fuel combustion engines primarily because no complicated fuel system is required, and it emits no exhaust. (United States Department of Energy, n.d.-f para.1). Regenerative braking is a technology found on BEVs, which captures and stores electricity when applying the breaks.

BEVs use three different charging technologies. A level 1 charger is simply a 120V AC plug, like those used to plug in household appliances. No special equipment is needed to charge a BEV in this manner, and the charge rate is between 2–5 miles of range per hour. A level 2 charger use a 240 V residential plug or a 208 V commercial plug. Again, this type of charger does not need additional equipment, but BEVs charge at a faster rate of 10–60 miles of range per hour. They are used at home and most public charging stations. DC Fast Chargers use 480 V AC input and require highly specialized, high-powered equipment in addition to special equipment in the vehicle itself. These chargers can produce a range of 60–100 miles after charging for 20 minutes. Approximately 15% of all public charging stations in the United States offer DC fast charging (United States Department of Energy, n.d.-d, para. 5). Solar panels can be adapted into BEV designs to allow charging while operating.

Advantages and Disadvantages of Each Alternative Fuel

The E85 blend is the only ethanol-blended fuel considered alternative by the Energy Policy Act of 1992, and on the surface ethanol appears to have many advantages over gasoline. First, it provides a large boost to the farm economy since 94% of ethanol is produced from corn (United States Department of Energy, n.d.-e, para. 1). Second, ethanol improves energy security by lowering fossil fuel dependence. Third, it utilizes the current infrastructure from production to delivery. Fourth, the cost of a FFV remains comparable to traditional vehicles. Finally, ethanol burns cleaner than gasoline and reduces harmful emissions by 19%–48% (Chillrud, 2016, para.1). The process to grow the crops and produce the ethanol results in carbon emissions and non-point source pollution. Ethanol is considered a renewable fuel, however this is a shortsighted view. It is not a sustainable solution as there is a finite amount of land to grow crops. If demand for E85 fuel should drastically increase along with population growth, there is a tradeoff point between corn for food and corn for fuel, and eventually there will not be enough for both. As just discussed, ethanol fails to meet two evaluation criteria for this research, a significant reduction in greenhouse gas emissions, and it provides no permanent sustainable solution.

Biodiesel reduces harmful greenhouse emissions over petroleum diesel by 74% (United States Department of Energy, n.d.-b, para. 5). Unfortunately, pure biodiesel is not sold commercially, so this potentially large reduction in greenhouse emissions never materializes. Like ethanol, it boosts the farm economy and energy security. However, the same unsustainable land use problem plaguing ethanol prevents biodiesel from being a permanent widely used solution. Further, no potential exists for zero emissions from the vehicle itself making hydrogen and electricity more attractive solutions. The failure to satisfy two of this inquiry's evaluation criteria eliminates both ethanol and biodiesel from the remaining discussion.

Hydrogen fuel's biggest advantage is that it burns completely emission free producing only water vapor and warm air. High price tags for FCEVs and a small declining market share are hydrogen's largest disadvantages. The 2021 Toyota Mirai costs $50,455 after a $9,000 drop from the 2020 price. The high-end trim level still costs $66, 955 (Baldwin, 2020, para. 5). FCEV sales in the United States dropped to 937 vehicles after being slightly above 2,000 during the period 2017–2019. Cumulatively, only 8,931 FCEVs have been sold in the United States during the past nine years (Kane, 2021, para, 3-5). The FCEV market does not appear ready to expand rapidly. FCEVs match the equivalent of gasoline with the capability to refuel in about four minutes. The price of hydrogen remains high with a gallon of hydrogen fuel being the equivalent of $5.6 per gallon of gasoline (National Association for Convenience and Fuel Retailing, 2020, para. 5). However, the price is expected to fall and be competitive with gasoline. Hydrogen fuel is an emerging technology that shows great promise to reduce greenhouse emissions. Its applications as a fuel in all transportation sectors are being explored. Unfortunately, in the light vehicle market Americans adopted BEVs as their zero emission vehicle of choice. For this reason, the remainder of this discussion focuses on BEVs.

Like FCEVs, BEVs biggest advantage is that they produce zero harmful greenhouse emissions during operation. However, they increase the demand for electricity, which currently produces 27% of the United States' greenhouse gases (United States Environmental Protection Agency, 2021, para. 5). Only 20% of the United States' electricity production comes from renewable sources (United States Energy Information Administration 2021-a, para. 3), so any expansion of the electric grid should incorporate renewable technologies. BEVs would reduce the need for oil production and ultimately has the potential to eliminate the need to refine gasoline.

Most of the criticisms aimed at BEVs are simply not accurate, or at the very least exaggerated. Several of the criticisms include: low mileage range, relatively unsafe, expensive to operate, pollute just as mush as conventional cars, lack of speed, short battery life, too expensive, inconvenient charging, and the power grid will not be able to accommodate the surge in the number of BEVs on the road. Each of these supposed disadvantages will be addressed using arguments and statistics from Gorzelany (2019, paras. 3-16). Regarding a low mileage range, BEVs supposedly cannot go very far on a full battery charge. The facts are the average person drives 40 miles per day, well within the range of any BEV. The vast majority of charging happens at home over night, so routine driving is unaffected by range even though home charging is a fairly slow process. Further, the range of BEVs is improving, as some models currently possess the ability to cover 280–320 miles with a full charge. Conversely, long trips do provide the need to plan carefully, as quick charging stations across the country are not plentiful in much of the United States. Another criticism is that BEVs are not safe. Since BEVs are considered low volume vehicles they are not always crash tested. However, when tested they receive good ratings. They do not explode any more than traditional vehicles in an accident. Regarding the cost to maintain and repair, they are actually less expensive over the life of the vehicle. BEVs do not need oil changes, tune-ups, spark plugs, belts and gaskets. They possess fewer moving parts than fuel combustion engines that eventually need replacement. The actual cost of maintaining a BEV will be discussed under economic feasibility later in this inquiry. Some try to argue that BEVs pollute just as much as regular automobiles due to the increased production of electricity. This argument is unjustifiable as BEVs produce oxygen and water vapor as emissions. Further, increased electric demand would be offset by less oil extraction and gasoline production, as well as growing renewable electricity sources. Are BEVs indeed slow? No. Because the torque of an EV is 100% available instantly, it accelerates faster than conventional automobiles. The Tesla Model S possesses the capability to accelerate from 0 to 60 mph in 2.5 seconds. Short battery life is also a baseless claim. Federal mandates require that batteries carry a separate warranty for eight years or 100,000 miles. The Nissan Leaf retained 75% of charging power after 120,000 miles and a Tesla owner reported 90% after 200,000 miles. The fact that EVs are currently more expensive than conventional automobiles currently remains a legitimate disadvantage. Government incentives in the form of tax breaks make them more affordable, but they are temporary and may or may not be renewed. The demand for BEVs is increasing and more models are being introduced creating more competition. Competition generally results in lower prices. Further, the price of BEV batteries is expected to come down significantly in the short run adding to affordability. Regarding the lack of infrastructure to charge vehicles is a temporary but valid concern. However, BEV charging is typically done overnight when the rates and demand are lower. Extended trips produce the inconvenience factor. The shortage of quick charge stations and a 20 minute required charge time make long trips even longer.

BEV Economic Considerations

General Motors recently launched their initiative to become an all BEV company by 2035. This aggressive and bold strategy is backed by a 27 billion dollar investment and includes the introduction of 35 new BEV models by 2025. In addition, they plan to build 2,700 level 2 charging stations around the United States (Root, 2021, para 4). This investment in infrastructure increases the convenience to consumers, while offering GM part of the future revenue stream form operating BEVs. Also, the company plans to build a 2.8 million square foot battery production facility in Tennessee. The investment is $2.3 billion and will create 1,300 jobs. Investors appear to be all in on this move by GM as the stock has risen 40% in 2021 (Root, 2021, para. 5). If GM's plan proves to be successful, companies like Fiat Chrysler and Ford will be forced to invest heavily in the United States BEV market as well. Amazon is another large company investing heavily in BEV technology. They designed a delivery van with the BEV manufacturer Rivian, and committed to buy 100,000 of these electric delivery vehicles. The vans delivered 20 million packages in Europe and North America in 2020, and that number will increase this year as the changes needed to accommodate these vehicles occur in more warehouse facilities. The new vans help realize the company's commitment to net zero carbon by 2040 (Amazon, 2021, para. 7).

In 2018, BEVs reached a milestone of one million cars on the road in the United States. The number is expected to reach nearly 19 million in 2030, which represents roughly 7% of total vehicles on the road. (Edison Institute, 2018, paras. 1-6). Though BEV's market share will increase significantly in the short run, the long-range picture remains unclear. An examination of 20 sources on this subject revealed no agreement on the projections, with predictions ranging from 7%–70%. However, a majority of sources predict around 60%.

There are many benefits for consumers and society when a BEV is purchased. Quantifying social costs and benefits is always difficult, but Malmgren (2016, p.8) estimated the societal benefit of driving a BEV over ten years and 100,000 miles to be $12,403. This figure includes fuel and maintenance savings, reduced carbon dioxide emissions, health benefits, national security cost reductions and economic development benefits. When applying her categories comparing a Nissan Leaf (BEV) to a Honda Civic (gas powered) the societal cost of ownership was $25,375 and $33,908 respectively. Even if the $7,500 purchase tax incentive is added back to the Nissan Leaf, the cost of ownership remains lower despite the approximate $10,000 purchase price difference (Malmgren, 2016, p. 9). Perhaps the largest direct benefit to consumers driving BEVs is the fuel cost savings. Both electricity and gasoline prices vary across the country making this difficult to quantify for an individual. Also, charging level options vary in cost as well. However, an extensive study of this subject by Borlaug et al. (2020, p. 1476) computed a levelized cost savings national average equal to $7,500 compared to gasoline vehicles over the life of the BEV. Routine maintenance provides another cost savings opportunity for consumers. The Union of Concerned Scientists (2017, p. 16) reported the routine maintenance costs of the Chevy Bolt (BEV) and the Chevy Sonic (gas powered) to be $983 and $2,529 respectively. These figures covered 150,000 vehicle miles and excluded unexpected maintenance. Fuel combustion engines and their exhaust systems inevitably require some non-routine maintenance prior to reaching 150,000 miles driven.

Social and Institutional Barriers to BEV Implementation

Transforming the automobile industry to BEVs on a large scale involves several social and institutional barriers that warrant discussion. The few discussed below offer only a glimpse into the many barriers contributing to the complexity of switching to BEVs.

In a study conducted by Pettifor et al. (2017, p. 254), a social psychological phenomenon known as the “neighborhood affect” emerged to have a strong affect on vehicle choice. It basically means that cars driven by neighbors greatly influence a person’s automobile purchase choice. This is motivated by a desire to be like everyone else, be accepted and ensure your perceived status equals that of your peers. The neighborhood affect presents both a problem and an opportunity for BEVs. On the one hand it can hold back change, but on the other it can serve to accelerate change if a critical mass gets behind BEVs.

Another social barrier stems from American's reluctance to change and hold steadfastly to traditions. A long history of affinity between Americans and their cars has reached a point where the car a person drives becomes part of their identity. Whether one drives a Ferrari, a Mercedes, a powerful "muscle" car or a BEV, the idea that it makes a statement about who you are is pervasive. Also, what about racing traditions like NASCAR and INDY? As mentioned earlier, BEVs have plenty of speed and acceleration to design a racecar, but imagine a race where refueling stops require 20 minutes. In a future world if BEVs rule the market, exceptions could be made for certain cars and organizations. However, owners should somehow pay the true social cost of operating carbon-polluting vehicles, perhaps through a usage tax.

According to Browne et al. (2012, p. 18), the convenience aspect of driving a car cannot be underestimated. Americans fuel their automobiles at gas stations that are always close by at predictable prices that do not vary widely across the country, and service their cars with their chosen trusted mechanic. BEVs offer the convenience of charging at home to fuel the car at a price less than gasoline, however the charging infrastructure over a long trip could not be relied upon. Also, a lack of faster than 20 minute charging times will be a barrier to many thinking about entering the BEV market.

Oil companies and most of the automobile industry are the biggest corporate institutions posing a barrier to the expansion of alternative fuels. The reason stems primarily from the enormous sunk costs in the infrastructure for these corporations surrounding the automobile industry (Browne et al. 2012, p. 17). In the case of the oil companies, 44% of the United States' consumption of oil comes from gasoline (United States Energy Information Administration, 2021-c, para. 4). They are certainly not going to allow the alternative fuel markets to replace nearly half of their business without mounting a serious effort against it. One of their strategies thus far has been to control the narrative about their polluting actions, by spending $3.6 billion over the past five years to portray themselves as part of the solution to global warming while slowly investing in renewable energy technologies (Holden, 2020, para. 13).

Another institutional barrier is the government itself. Politicians represent states with incredibly diverse interests in the automobile and oil industries. One could never imagine politicians from Texas supporting a bill to rapidly expand the BEV market and infrastructure. Suppose a bill of this nature passed. Then the debate over how a project like this should be financed and regulated would result in years of debate by many government and industry officials with a myriad of opposing interests.

Conclusion

Based on the evidence researched and presented in this paper, electricity is the recommended solution to mitigate and potentially eliminate greenhouse emission in the light vehicle industry. It successfully meets this inquiry’s four evaluation criteria. Implementation is already well underway with more BEV models being introduced annually. The conversion could proceed faster with a commitment to expand the industry infrastructure by building additional charging stations and expanding the electricity supply through renewable sources. Regarding economic viability, the demand for BEVs is increasing rapidly. With BEVs in many price points, the technology will be available to nearly everyone. In terms of reducing harmful greenhouse emissions, BEVs produce none. That alone would have a major impact on reducing global warming. However, BEVs also reduce pollution and carbon emissions in complimentary industries such as gasoline production, oil drilling and oil refinement. Finally, the solution is a permanent one. Electricity production offers renewable solutions and eventually can transform into a net zero carbon industry as well. The idea of converting the light use vehicle market to one technology might be challenged by individuals believing others are equally viable. Perhaps this is true. However, no other zero emission technology is developed and advanced enough to be implemented as rapidly as needed. Further, Americans accepted one technology, the internal combustion engine fueled with gasoline for over a century. By committing to one technology as GM has done, BEV and battery manufacturers will compete to improve and capture a greater market share. It turns out Elon Musk is correct. Everyone should drive an electric car.

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