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AN ANALYSIS OF THE ENVIRONMENTAL IMPACT OF ELECTRIC VEHICLES

Abstract

Electric cars have the reputation as a possible solution to many modern environmental and economic issues. Electric motors have been an interest of many inventors since the 1830s, but fully electric vehicles were not prevalent until 2008 when Tesla Motors released the Roadster. The looming energy crisis is one of the main motivations for the advancement in renewable and alternative fuel technologies, but since the early 60s, it has been the environmental lobby that has been pushing for this change. The environment suffers from industrialized nations as the amount of greenhouse gas emissions reach new heights every year. Filtration systems and other air detoxifying routes are being explored, but a major reduction in greenhouse gas production will make the most significant climate difference. Fully electric vehicles claim to have zero tailpipe emissions, but that doesn't account for the emissions produced from the energy production used to charge those vehicles. This study evaluates the environmental impact of electric vehicles and the economic policy that is encouraging greater use of this technology.

An Analysis of the Environmental Impact of Fully Electric Vehicles

The electric vehicle market has been rapidly expanding since 2008. This market expansion is partially due to the technology becoming more widely used by car manufactures as well as a significant price decrease. Electric vehicles have also grown in popularity because of the increasing concern for the environmental impact that greenhouse gas emissions cause ("Car Emissions and Global Warming"). Global warming is still questioned, but more people around the world are slowly seeing it as a real concern. Some have suggested that the forests and oceans are soaking up the toxic emissions as fast as they are being produced. However, the United States Environmental Protection Agency released a report in January 2017 proving this argument false. \Others claim that global warming is a natural planetary process, and the EPA (2017) agrees that global warming is the process that keeps Earth at a livable temperature. However, the surplus of emissions that has caused the 1.5° fahrenheit increase in temperature over the last century. This is a great concern considering the ice age was only 5-9 degrees cooler than today's climate. This change in temperature due to greenhouse gasses has the potential to

This increase in emissions is due to the rising population and increased production and consumption of energy and transportation. From the year 1990 to 2012, only 22 years, the amount of greenhouse gas emissions increased by 41% internationally (Samimi & Zarinabadi, 2012). If the rise of emissions continues at this exponential rate, the coming centuries will have to deal with even higher temperature increases and more intense effects of global climate change. The United States makes up 4.5% of the world's population, but uses 19.2% of all the world's energy; it is the second largest energy consumer in the world, just behind China (Aslani & Wong, 2013). Many smaller countries have made efforts to decrease their emissions and to produce energy through renewable technologies, but even if 100% of the energy produced was green, their impact would be much smaller than if the big energy consumers reduced a large

portion of their emissions (Wilson, 2013). The transportation sector of the US accounts for 28% of the nation's greenhouse gas emissions, which means there is a big opportunity for a reduction in tailpipe emissions with greater use of electric vehicles (Jenn, Azevedo, & Michalek, 2016). This technology is reaching higher demands than ever before, which will increase their total impact; by 2020, the number of electric cars on the road is estimated to increase from the 740,000 in 2015, to several million (Patel, 2015). The emissions of fully electric vehicles (FEVs), when taking the energy production emissions into account, will be analyzed to prove that FEVs will make a significant reduction in greenhouse gas emissions.

Methodology

The most relevant scholarly articles from the time period of 2013 to the present were used to analyze the environmental impact of fully electric cars. Interest in the electric car industry spiked after Tesla's Roadster debuted; therefore, relevant articles were not produced until a few years after. Many of the articles used were highly referenced in the field and discussion of electric cars. The main databases used to search for articles were ScienceDirect, Environmental Science and Technology, American Chemical Society Publications, and the United States Department of Energy. I searched using phrases such as "environmental impact of fully electric cars", "power sources in the United States", and "lithium ion batteries in electric cars." As a mechanical engineer, my interest stems from new automotive technology; there were no preconceived notions on this topic and no encouragement from outside sources to produce a bias article.

Power Source

The most important part, and conveniently the most forgotten part, of the electric vehicle discussion is where the energy is coming from to charge these vehicles and the emissions associated with the production of that energy. The United States Department of Energy reported

in 2016 that natural gas and coal make up 64% of America's produced energy. Natural gas produces roughly half of the amount of emissions that coal does, but if two thirds of the country's energy is coming from these non-renewable sources, the amount of emissions is still high. The growth in the renewable energy field is extremely hopeful considering the amount of energy produced in 2012 was only 13.2% (Aslani & Wong, 2013). That increased to 34% in 2016 with the use of nuclear, hydro, wind, biomass, and solar energy (US Department of Energy, "Emissions", 2016). The country has a large potential for even more growth because of the wide open spaces in the west for solar panels and wind turbine farms .

Even with the energy coming from this two thirds non-renewable energy grid, fully electric cars still produced less than half the emissions of gasoline powered cars. Fully electric cars annually produce 4,587 pounds of CO2 while gasoline, hybrid, and plug-in hybrids produce 23,885 pounds of CO2 (US Department of Energy, "Emissions", 2016). This statistic only covers the emissions produced to charge the vehicles; it does not cover the emissions from vehicle manufacturing, power stations, combustion, upstream fuel production, and grid loses. With all those pieces taken into account, the estimated United States average emissions is 202g CO2e/km and the estimate for a gasoline vehicle is about 300g CO2e/km (Wilson, 2013). The more energy that is produced through renewable resources, the greener fully electric cars become and their claim of "zero emissions" becomes closer to the truth.

Batteries

The lithium-ion batteries store the energy for fully electric vehicles. Lithium-ion batteries also allow the vehicle to travel up to 335 miles on one charge; the actual travel mileage depends on the vehicle model(Lambert, 2017). Lithium-ion batteries have come a long way since 1992 when the were first sold to consumers. They now hold double the energy by weight and only cost

300 dollars per kilowatt-hour (Patel, 2015). When Tesla released the Roadster in 2008, the cost of a lithium-ion battery was upwards of 900 dollars. Although still expensive, this decrease has helped drive down the cost of fully electric vehicles. The reason these are the prefered batteries of choice is their "high power-to-weight ratio, high energy efficiency, good high-temperature performance, and low self-discharge" (US Department of Energy, "Batteries", 2016). These factors make lithium-ion batteries the most promising form of on-board energy storage and management devices for fully electric vehicles.

A variety of chemical designs for the lithium-ion battery are currently being tested and produced. The Nissan Leaf and BMW i3 use a lithium nickel manganese cobalt battery which has an energy density of 140-180 Wh/kg (Patel, 2015). The issue is finding a chemical make-up that allows for an increase in energy capacity while still being stable at high-temperatures and repeated charging cycles. The new Tesla Model S uses a lithium nickel cobalt aluminum oxide battery which "boosts the energy density greater than 240 Wh/kg" (Patel, 2015). Researchers are continuing to test new materials for lithium-ion batteries in order to increase their energy density for electric car use; vehicles will be able to go further on a single charge which will make them more practical for car owners who drive 20-50 miles to work every day.

The applications for lithium-ion batteries extend far beyond electric cars. This market grew 73% between 2010 and 2014 (Narins, 2017). This could limit the growth of the electric car industry because of the relatively low supply of high quality lithium for these batteries. In December of 2015, the price of 99% lithium imported into China doubled to 13,000 dollars per ton; with almost half of an electric vehicle's production costs being made up by the cost of their batteries;, this poses a huge threat (Narins, 2017). The price is estimated to fall over time, which could cause another spike in electric vehicle production like what was seen in 2008. The greater

number of electric vehicles on the road, the greater the impact they will make on emissions production.

Economic Policy

The United States realizes that they are the world's second biggest energy consumer and has made efforts in the form of legal policy to reduce the country's emissions. In 1975 the US passed the Corporate Average Fuel Economy policy which enacted greenhouse gas emission standards on the transportation industry (Jenn, Azevedo, & Michalek, 2016). This bill has been revised and added to throughout the years and the EPA estimates that by 2050 it "will lead to reductions of 500 million metric tons of CO2 annually" (Jenn, Azevedo, & Michalek, 2016). This will help the environment eventually, but because of the rapid increase in emissions an immediate solution was necessary. The Energy Policy Act of 2005 offered immediate tax incentives and loan guarantees to companies that researched and produced renewable energy sources such as solar and wind (Aslani & Wong, 2013). These policies also started a pattern among the individual states to implement their own policies regarding emission standards and funding for renewable energy each year.

The economic crash of 2008 made renewable energy a low priority because the unemployment rate and economy state dominated the media. As the economy has recovered, more Americans have fought to see more environmental policy changes.The 2009 Omnibus Public Lands Management Act and the American Reinvestment and Recovery Act which gave 90 billion dollars for green projects (Sheppard, 2014). This push will further renewable energy research therefore making the grid and use of electric vehicles have an even greater impact in the reduction of greenhouse gasses.

Discussion

The use of fully electric vehicles does make a significant impact in reducing greenhouse gas emissions. Even with the energy production in the United States being two thirds non-renewable energy, electric vehicles still produce less than half the amount of CO2 as conventional gasoline cars do annually. The purpose of the study was to bring all the pieces of information together that create a full picture of the potential significance of this technology . While electric vehicles may be making a difference now, their impact could be increased if a substantial effort is made by the government and lobbying parties to encourage more policy change, research, and production of more electric vehicles. One of the limits of this study was the limited research done on cradle-to-grave emissions of the production of lithium-ion batteries. Since this is relatively new field and each battery has its own chemical background, emissions of production were not found. This is an important component of the electric vehicle discussion because the production of these batteries is not only the most expensive part of the car, it may alsobe the most energy consuming part of production. More research needs to be conducted on electric vehicles, renewable energy, and lithium-ion batteries, especially the various chemical make-ups of the batteries on the market . The country is on the right track to start making a significant reduction in greenhouse gasses, and with these reductions the planet should remain livable for centuries to come.

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