Combating Climate Change on a Local and Global Scale

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

John Saunders

Spring, 2021

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature _____ **Date 4/26/2021**

John Saunders

Approved _____ **Date** _____

STS Advisor, Richard D. Jacques

Introduction

Climate change is arguably the most pressing issue worldwide, and this project and paper focuses on actions taken to combat this issue. The technical project focused on increasing recycling in the Charlottesville community. A resource website was created that shows the most useful information about recycling, such as locations and what items are accepted. The website is hosted publicly and available for residents and college students to reference if they have questions about ways to recycle in the area or are curious to learn about more ways to recycle. The research paper topic is focused on electric vehicles and what exactly their adoption into mainstream usage means. Electric cars have many benefits for the environment over internal combustion engines, and when used with a power grid depending on renewable energies, they produce no emissions. A major focus is on Tesla and how the company and CEO have changed the vehicle marketplace. The ethics of the new technologies that accompany electric vehicles, such as self-driving technology, are also evaluated. A technical project focused on recycling and a research project focused on electric vehicles identify and investigate two main ways to combat climate change.

Technical Project

The goal of the website, cvillerecycles.com, is to be an educational resource aiding college student and the overall Charlottesville community better understand the options available for recycling. The hope is to indirectly increase the amount of recycling done in the community by making a tool available that can be used as a guide to answer any questions that people may have about recycling. The website was built using the framework Angular 10, styled using PrimeNG, a web framework, and hosted using the tools provided by Amazon Web Services. It includes deliberate design choices to make the site as useful, concise, and intuitive as possible. It

also conforms to different screen sizes and therefore any device, making it accessible to any user. Additionally, to be compatible to as many users as possible, UI best practices of styling and accessibility were referenced and followed.

The website was made to fill the need of have a website that shows information on how to recycle in Charlottesville. Although is not the only site which does this, similar sites are poorly designed, contain irrelevant information, or are difficult to navigate. The website solves these problems by having a UI which is well organized, has concise information, and contains any information one would need to know about recycling. This website could replace the many scattered pages that Rivanna Authority, the organization that handles recycling in Charlottesville, hosts displaying information on recycling. Beta testing, although conducted with a small sample size, already indicates that cvillerecycles.com is a preferred site by Charlottesville residents for recycling information. Given that the website will be hosted for years to come, as it gains traction and the number of users increase, ideally the knowledge of recycling in Charlottesville will also increase, leading to more recycling in the area. The site has been running for a few months now and has already been viewed by over 60 people, most of whom are from Charlottesville or neighboring areas. The site is already the sixth result when 'Charlottesville recycling' is searched on Google. These are results to be proud of because they show that the concept works and is making recycling in Charlottesville more accessible.

Research project

Electric vehicles (EVs) are causing disruption in the automotive industry. Companies such as Tesla and Nio have sprang up and gained much attention. In the past twelve months, Tesla has tripled in valuation despite controlling less than one percent of the car market. It is valued higher than Toyota, Volkswagen, Daimler, GM, BMW, Honda, Hyundai, Fiat Chrysler

and Ford combined. Nio, the largest Chinese electric car manufacturer, is similar to Tesla in that it has only a small percentage of the Chinese market but has grown to a larger market cap than Ford and General Motors. This is staggering for companies that are producing few cars, and investors must see something special in electric vehicles. The existing car manufacturers and big players have been forced to respond while watching their own company evaluations plummet. General Motors said it will stop selling gasoline-powered cars by 2035 and Volvo by 2030, and Ford announced in February that it plans to invest 29 billion in electrical vehicles over the next four years. Other car manufacturers have announced similar plans, and therefore whether through new or existing car manufacturers, in a few decades most new cars on the road will be electric.

Although it seems like mass-produced EVs are a recent development by newer companies, General Motors produced the first mass-produced EV over two decades ago. GM created the first mass produced electric vehicle called the EV1 in 1996. The EV1 was fully electric and delivered to thousands of customers with widely positive reviews. However, within two years, the car was cited as being unprofitable and discontinued, and with it, GM lost the potential for a head start on becoming the leader in the EV market - instead it is now forced to play catch up. What has changed and why do car manufacturers and investors now see EVs as the future?

The main reason is that the cars can now be made at a lower cost. Battery technology has advanced tremendously, competition has increased, government subsidies have been created, and the electric car has become cool. Tesla and Elon Musk, Tesla's CEO (or as he filed with the SEC the "Technoking of Tesla"), have led most of these changes. The battery is by far the costliest component of producing an electric car. 42% of the cost to produce a Tesla comes from

producing the battery. Therefore, innovation in battery technology is a major focus for Tesla as they try to make electric cars more affordable and therefore more accessible. Although Tesla previously outsourced battery production to other companies, such as Panasonic, Tesla plans to produce the batteries for their cars themselves going forward. The company is building a 'gigafactory' in Nevada, which will be the largest building in the world, for this purpose (Hayes, 2020). During its 'Battery Day' in September 2020, Tesla announced the creation of an in-house 'tabless' battery that promises to be six times more powerful and increase range by sixteen percent (Lyons, 2020). 'Tabless' batteries provide many advantages to battery design, including a smaller distance for electrons to travel, causing less heat and degradation (Arar, 2020). For Nio, a similar story exists with their success also being attributed to advancements in battery technology. Again, batteries are extremely important to these EV manufacturers' success, and the recent innovation in them is one of the main reasons investors see so much potential.

Another reason for the reduction in the cost of producing EVs is the creation of government subsidies and an increase in competition. A $7,500 tax credit for individuals who purchase an electric vehicle exists, and under the Biden administration, more incentives are expected to be created with the promise of $400 billion in investments into clean energy, which includes EVs (Wayland, 2020). Recently, US Senate majority leader Chuck Shumer has discussed his plans about adding even more EV incentives. Specifically, he wants to increase the tax credit, create incentives for auto manufacturers, and give incentives to local districts for adding charging stations (Hawkins, 2021). As the United States continues to have Democratic leadership in Congress and the Presidency, these incentives will continue to be implemented in the coming years.

Tesla was the only serious manufacturer of EVs for years, but competition has increased and led to lower EV prices. Some of these contenders include Li Auto, a Chinese manufacturer rivaling Nio, Nikola, a truck manufacturer that has received buzz for potential plans with GM, and Lucid Motors, a manufacturer who plans to begin manufacturing very soon. Tesla has a multiyear head start in the design and production of EVs, but another company will likely be a serious competitor soon, which would lead to lower prices in the EV market.

Public perception of the EV has radically changed in recently too causing the demand for electric vehicles to increase. For years, cars that were good for the environment such as Priuses and the Chevy Volt were not seen as luxury or sporty cars. Most people care about the environment and realize the negative effects of fossil fuels, however, the options available to fight the problem were not as appealing in terms of style and status. However, Tesla made all the difference. When Tesla released the Roadster in 2011, it was the first time that electric cars were seen as trendy, sporty, and fast. This has continued with subsequent models - electric cars are now seen as cool to modern consumers mainly due to the sleek design and incredible features. Having a Tesla is now seen in a similar view as having the latest iPhone, and in many ways, the company has been compared to the early days at Apple with the CEO being compared to Elon Musk. Elon Musk has single handedly given life to the electric car market and made consumers excited for electric vehicles, a product never before seen as "cool." This is exactly what Steve Jobs did with products like the iPod and iPhone, and I believe Elon Musks will be viewed as one of the most innovative persons of this century.

Given the clear disruption of the auto industry, what this means for the future should be addressed. A proactive assessment of the impact our environment and morals is needed if we are to actively prepare for the changes that electric cars will cause. The more positive one of the

impacts to the environment will be discussed first, followed by a discussion of the morals of some features included in these cars.

Electric cars do not consume any fossil fuels nor do they have a tailpipe. However, it is still important to acknowledge the emissions that EVs do create. One of the more impactful ones is the emissions from the creation of the energy needed to power the cars. The amount of emissions created by charging the car is completely dependent on the means of creating the power. For regions with power grids that depend on fossil fuels like coal, the benefit is not as drastic as an area where the electricity supply comes from a cleaner energy source. Another main criticism is the emission created when building the cars, especially batteries. It is difficult to quantify exactly how much emissions are created from the development of the batteries because it mostly varies on how the electricity of the factory where it was made. A study found that the amount of emissions created is similar to that of creating an internal combustion engine vehicle (Hall, 2018).

With the two main criticisms of electric car emissions addressed, it is important to emphasize how much better electric cars are to internal combustion vehicles and how the Earth will benefit during its widespread adoption. The transportation industry accounts for roughly 30% of the greenhouse gas emissions in the United States with research showing that the number of cars is only growing. With the climate deteriorating exponentially, it is an area where innovation and widespread adoption is needed. As mentioned before, many variables go into figuring out the emissions created by electric cars. In terms of air quality related emissions, EV's accounted for approximately 84% reduction in emissions compared to internal combustion vehicles (Ahmadi, 2019, p. 1216). Another source found that the electric car produces approximately 50% less emissions than internal combustion vehicles (Hall, 2018). Producing

half as much emissions is a figure cited more often, but any way it is viewed, evidence has shown significant emission advantages. This paper mainly discusses fully electric cars, but hybrid cars are also shown to be advantageous to the environment with a study showing that the emissions from hybrids cut emissions by 60% (Ahmadi, 2019, p. 1216). One of the most notable differences in the efficiency of the electric car is its ability to convert energy into movement. The electric car converts 77% of the electricity from the power grid to movement, while internal combustion engines only convert 12%-30% (U.S. Department of Energy and the U.S. Environmental Protection Agency, n.d.). As shown through many sources and statistics, it is pretty clear the environmental advantage that electric vehicles have will be a positive change as they become more widely used.

A feature that is associated with electric vehicles, especially Tesla, is self-driving technology. Tesla is the pioneer in autonomous driving technology with Teslas on the road already capable of 'Autonomous' driving. According to their website, autopilot is built using a deep neural network, which is the most innovative machine learning technology that is currently heavily researched. A deep neural network can become extremely optimized and accurate. For common machine learning applications like identifying an image, getting some error is not that bad, and having a machine learning model that performs perfectly is nearly impossible. The problem is that when it comes to driving, consumers expect the car to perform perfectly. A machine learning model that drives a vehicle and makes a mistake can literally cost lives, which is one of the main criticisms of self-driving technology. The technology right now can handle simple conditions such as interstate traffic, single lane roads, and shifting lanes very well. The problem is that more complicated unique circumstances exist that the machine learning model could have less experience with such as construction zones and parking lots that leave the

algorithms vulnerable. For example, during a test drive at night, Uber's self-driving car hit a woman who died while walking across the road in Arizona (BBC News, 2020). When accidents like this happen, they make big news and cause people to lose trust in autonomous technology. However, the reality is that self-driving technology is much more dependable than human driving. The National Highway Traffic and Safety Administration estimates states that 94% of crashes are caused by human error and that fully autonomous driving will eliminate this factor (NHTSA, 2021). They also cite other benefits to autonomous driving including economic benefits and less traffic. It is also predicted that by 2025 fully autonomous vehicles will be a reality, and with 36,560 people dying in car crashes each year, it cannot come soon enough. The difference is simply that humans get distracted, drive while tired, or are not properly trained in driving, and it makes much more sense for a computer to perform this mundane task.

Another ethical dilemma common to the conversation around self-driving technology is the decisions that are made by the car in rare but unfortunate circumstances. One of the most common of these is the question of whether or not to save the driver or the pedestrian. The reality is that with modern braking this situation is extremely unlikely to occur, however it is still a situation that could happen and a discussion on it must occur. A large project by a group of MIT researchers created a platform called Moral Machine that compiled over 40 million responses about how to respond in these types of situations. Some of the interesting trends they found include people from richer countries choosing to save business people over the homeless and people with strict government institutions choosing to kill the jaywalker over the driver in more cases. Overall though it was found that it is an even split consensus between killing the jaywalker and driver (Nature Editorial, 2018). This poses an incredibly hard problem for the individual and programmer who must make this decision, because they cannot simply cite that

most people think a certain way to make their decision. Therefore, in this case, personal bias will have to come into play on how the car will react. Interestingly enough, many of the same people who said they would choose to save the pedestrian also stated that they would not buy the car that made that decision, and because companies are driven by sales, this fact will motivate their decision-making process. Society's morals and what is seen as acceptable is changing constantly and rapidly, so hopefully the people and companies making these decisions will continue to listen to consumers. Tech companies tend to move quickly and learn from mistakes rather than be slow and methodical, but because driverless technology can be so impactful hopefully the engineers working on this technology are weighing moral decisions as they develop and realize the importance of doing so.

Most of an engineer's job will be technical work that requires math and critical thinking, and it will be easy to get lost in this work and forget that the decisions we make affect people's lives. The programming of choosing who lives in a car crash is an extreme example, but there will be times where choices will be made that are potentially discriminatory, biased, or disenfranchising. In these times, we engineers must be unafraid to step up and take the path that aligns with our positive morals and values.

Conclusion

The environment was discussed on a local and global scale. A technical project was discussed where an interactive, intuitive website was created, focusing on increasing recycling in Charlottesville. The project has seen some quantitative positive results from beta testing with site users in the local area and the site's high position on Google's search results. Next, research on the impact of electric vehicles on our society through the lens of the environment and features that are controversial was discussed. As shown through many sources, electrical vehicles are

significantly more sustainable than the internal combustion engine, and as more renewable sources of consumer power are implemented, they will only become more sustainable. With the waste from cars making up a large percentage of greenhouse gas emissions, the inevitable adoption of electrical vehicles is one of many steps necessary to combat climate change. The morals of the features coming with EVs was discussed mainly related to self-driving technology. The main question comes down to if we will allow mistakes to come from human error or errors from a machine learning algorithm. Given how common human error is, in contrast with the fact that machine learning is continuing to improve over time, it seems clear that machines should take the wheel. However, with that comes questions of how a car should react in situations like the one discussed of whether to save the driver or the pedestrian. This answer is unclear and there is no consensus on it. This question and ones similar to it must continue to be researched. Through the technical project increasing recycling on a local level and electric vehicles making transportation more sustainable and safer, innovation from engineers has proven to finally begin steering the world toward addressing and combating climate change.

References

Ahmadi, P. (2019). Environmental impacts and behavioral drivers of deep decarbonization for transportation through electric vehicles. *Journal of Cleaner Production*, *225*, 1209–1219. https://doi.org/10.1016/j.jclepro.2019.03.334

Arar, S. (2020, October 10). *Just How Much of a "Breakthrough" is Tesla's Tabless Battery Cell?* News. https://www.allaboutcircuits.com/news/just-how-much-breakthrough-teslas-tabless-battery-cell/

BBC News. (2020, September 16). *Uber's self-driving operator charged over fatal crash*. https://www.bbc.com/news/technology-54175359

Hall, D. (2018, February 9). *Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions | International Council on Clean Transportation*. The International Council on Clean Transportation. https://theicct.org/publications/EV-battery-manufacturing-emissions

Hawkins, A. J. (2021, March 17). *Chuck Schumer wants to replace every gas car in America with an electric vehicle*. The Verge. https://www.theverge.com/2021/3/17/22334634/schumer-electric-vehicle-swap-discount-infrastructure-interview

HAYES, A. H. (2020, May 29). *Will Tesla Cars Ever Be Affordable?* Investopedia. https://www.investopedia.com/articles/personal-finance/042415/will-tesla-cars-ever-be-affordable.asp

Lyons, K. (2020, September 23). *Tesla Battery Day: biggest announcements*. The Verge. https://www.theverge.com/2020/9/22/21450840/tesla-battery-day-production-elon-musk-tabless-range-cathode-cobalt-plaid

Nature Editorial. (2018, October 24). *Self-driving car dilemmas reveal that moral choices are not universal*. Nature. https://www.nature.com/articles/d41586-018-07135-0?error=cookies_not_supported&code=3d7b8a44-ea3f-4e23-a534-d5d77f967c63

NHTSA. (2021, March 18). *Automated Vehicles for Safety*. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

U.S. Department of Energy and the U.S. Environmental Protection Agency. (n.d.). *All-Electric Vehicles*. Fueleconomy. Retrieved March 22, 2021, from https://www.fueleconomy.gov/feg/evtech.shtml

Wayland, M. (2020, December 15). *Auto industry wants more government support for electric vehicles*. CNBC. https://www.cnbc.com/2020/12/15/auto-industry-wants-more-government-support-for-electric-vehicles.html

Ahmadi, P. (2019). Environmental impacts and behavioral drivers of deep decarbonization for transportation through electric vehicles. *Journal of Cleaner Production*, *225*, 1209–1219. https://doi.org/10.1016/j.jclepro.2019.03.334

Arar, S. (2020, October 10). *Just How Much of a "Breakthrough" is Tesla's Tabless Battery Cell?* News. https://www.allaboutcircuits.com/news/just-how-much-breakthrough-teslas-tabless-battery-cell/