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Electric Vehicles are Here to Stay

It's no secret that the earth is warming at an alarming rate. If the world hopes to maintain the temperature increase to no more than 2 degrees Celsius above pre-industrial levels, we have a lot of changes to make and should start with resource consumption and energy production. Our current economic system does not emphasize recycling or using materials sustainably, and the majority of our energy comes from fossil fuels. One necessary change is to electrify the world's fleet of personal vehicles and ultimately all forms of transportation. The United States is pushing these measures, with bills like the Build Back Better Act and Infrastructure Bill in hopes of making 50% of cars on the road electric, hybrid, or hydrogen-powered by 2030 (The White House). This ambitious goal is being achieved with the help of American car manufacturers and government funding that is assisting in expanding the availability of chargers while decreasing the cost of electric vehicles. Not only does this play an essential role in decreasing carbon emissions, but its crucial for energy security. The transportation sector in the United States accounts for 30% of all energy needs and 70% of all petroleum usage (U.S Department of Energy). Clearly, adding electric vehicles to the road would have a significant impact on reducing carbon dioxide emissions. By using electricity as an energy source, we can localize where our energy is coming from and simultaneously build more renewable energy infrastructure to minimize the impact of electricity generation on the planet.

Transforming the United States transportation sector will ultimately come down to consumer decisions. Electric vehicles will only start to take over when they become the economical and affordable choice. To offset the higher upfront cost for electric vehicles, governments offer rebates and other discount credits for certain electric vehicles and charging equipment. In the U.S, credits can be as much as 7,500 dollars for an electric or hybrid car and consumers can potentially claim more based on their state’s electric transportation standards (IRS). California, home to the majority of electric vehicles and charging stations within the United States, is leading this electrification. The state offers many tax credits for various renewable energy ventures and plans to outlaw the sale of gasoline-powered cars by 2035 (U.S Department of Energy). Many states have also started investing in renewable public transportation like New York City, which has their own fleet of government electric vehicles (NRDC). Interestingly, the city reported that these cars cost five times less to maintain year over year compared to traditional gasoline-powered cars. Considering electricity costs are significantly cheaper than gasoline, the advantages certainly add up.

Although there are benefits to using electricity as a source of energy, we also need to account for the total cost of production on the environment. A graphic by the Wall Street Journal compared the carbon dioxide emitted by the creation of a Toyota RAV 4 versus a Tesla Model 3. The Street estimates that before either

car is driven, the Tesla has emitted 12.2 tons of C02 while the Toyota has emitted 7.4 tons. This is mostly due to the environmental impacts of using a lithium-ion battery, which all current electric vehicles use to store energy. However, the tide begins to shift quickly as "for every mile driven, generating the electricity for the Tesla emits 34% of the emissions" of the Toyota. This calculation is done using the national average electricity standard and reveals that the Tesla becomes more environmentally friendly when both cars have driven more than 20,600 miles. The cleanliness of electricity heavily depends on where you are located, but more states are putting funds towards clean energy generation which will continue to decrease the environmental and monetary cost of electricity. Regardless, this calculation shows that there are clear long-term benefits to driving an electric vehicle.

Despite the social benefits, electric vehicles must become the clear economical choice for all consumers if they are to be adopted nationwide. Although prices have been declining for the last 10 years, the average electric vehicle still costs more than a traditional car and they offer uncertainty to unfamiliar consumers (Electrek). In general, most skeptics are worried about driving range, reliability, charger availability, charging time, and charging cost. Addressing these concerns, the average consumer does not travel hundreds of miles a day, however newer electric vehicles, like Tesla, offer a variety of models that range from 200 to 350 miles. Reliability, on the other hand, has been a concern for electric vehicles as people worry about the young age of the technology and artificial intelligence misuse. Nevertheless, reliability has been on an upward trend each year and artificial intelligence continues to improve the safety of personal vehicle users. Furthermore, charger availability largely depends on location and the state's decision to implement chargers. Regardless, all owners can take advantage of the basic level one charger that comes with their vehicle and many homes can upgrade to level 2 charging since it requires the same configuration needed for a dryer (California Air Resources Board). The charger one decides to use is correlational to the time it takes to add more miles.

Level	ChargeHub Markers	Power (kW)	Approximate Charging Time (Empty Battery)
1		1	200 km (124 miles): +/- **20 hours** 400 km (249 miles): +/- **43 hours**
2		3 to 20, typically 6	200 km (124 miles): +/- **5 hours** 400 km (249 miles): +/- **11 hours**
3 (DCFC)		Typically 50, occasionaly 20	80% of 200 km (124 miles): +/- **30 min** 80% of 400 km (249 miles): +/- **1 hour**

The above graphic from ChargeHub illustrates the differences between charging types. The current best option for a household is a level 2 charger, but that will cost about a thousand dollars to purchase. Using direct-current charging, or level 3, can "add up to 10 miles of range per minute of charging time" and is suited for public chargers, although some vehicles do not support it (California Air Resources Board). Meanwhile, the cost of electricity heavily depends on where you live and what time you choose to charge your vehicle. The price of electricity can fluctuate throughout the day and is most expensive during peak hours around noon while prices are decreased at night. Therefore it is most cost-effective to charge your car at your home at night, but some owners also choose to charge their car during the day while they are at work or doing errands. Consumers can utilize public chargers during their day-to-day life that range from being free to requiring a fee or subscription. The type depends on your car model and the charging station manufacturer. For example, some Tesla owners do not have to pay to use Tesla charging stations but all consumers with a different car have to pay a fee (Electrek). Although electric vehicles have their flaws, their infrastructure will continue to advance as chargers become more accessible and the cost of electricity decreases.

How can we quantify the costs of owning an electric vehicle versus using traditional gas-guzzling methods of transportation? Going back to the Tesla 2021

Model 3 and 2021 Toyota RAV 4 comparison, we should look at the monetary cost of operating both vehicles. The standard version of the Model 3 starts at $39,490, while the RAV 4 costs $26,050. From there we can calculate the total average cost of the Tesla by deducting half the standard electric vehicle rebate price since only some consumers will be able to claim this. Rounding up, the Tesla uses 30 kWh (kilowatt hours) for every 200 miles it travels (Electric Vehicle Database). If the current nationwide average cost per kWh is $0.11, then the Model 3 costs about $6.60 per 200 miles or $0.033 per mile. Meanwhile, the RAV 4 gets about 27 mpg (miles per gallon) on the highway but 35 mph in a city. This comes out to an average of 31 mph which means it takes about 6.45 gallons of gas to travel the equivalent of 200 miles. If the national current average cost of gas is $4.12, then it costs $26.58 to give the RAV 4 enough gas for 200 miles, or $0.1329 per mile. If the average person in the United States drives 13,474 miles per year, and we subtract $3,750 from the starting Tesla price, then after 96,967 miles or about seven years, the Tesla becomes the economical choice. However, these calculations do not include the cost of insurance, maintenance costs, or the cost of an additional charger. It also assumes that the price of electricity and gas will remain static over that period of time, which is highly unlikely. The cost of insurance for electric vehicles tends to be more expensive because they cost more upfront and are often more expensive to repair but at the same time, their maintenance costs are also significantly less (although this might not apply to Tesla specifically). This can be explained by gas-powered vehicles' need for an oil change, smog check, and the numerous parts of a car engine that can break down over time. However, looking in the long term, most people extract the full value of their car by either reselling it or driving it into the ground. Using this measure, the average lifespan of a standard Tesla Model 3 is estimated to be 300,000 miles, while a Toyota RAV 4 is expected to last somewhere between 200,000 to 250,000 miles. In addition, the longer-range Tesla model is said to have a 500,000-mile capacity, and battery technology is only continuing to improve. This is significant as the longer you can use a car, the more value you can get from that vehicle. It's also a likely bet that the price of gasoline will continue to rise as we burn through our oil reserves while the price of electricity should decline as we begin to use more solar and wind energy. In the end and in the long term, the winner appears to be the Tesla, especially considering that some of the costs used in my calculation are likely to decline in the future. But what happens to the Tesla battery after it runs its course?

Lithium is the key to our future battery-centric economy. All of our portable electronics contain lithium and so will all electric vehicles due to its favorable characteristics. The majority of mined lithium comes from the salt flats in Argentina and Chile. However, the mining process takes a significant amount of water and energy (Nature). There is a finite amount of lithium in the world and massive amounts will be required to electrify the world's transportation vehicles. There are a few programs that focus on recycling lithium batteries however they are inefficient and only manage to repurpose about 3% of the original lithium (C&EN). This is mainly because it's very difficult to dismantle and separate the other parts of the battery like cathodes, anodes, copper, and wires from the actual lithium. Consequently, most companies export their used batteries to China for recycling because of these challenges and the extreme energy requirement to melt the components of the battery. China’s energy regulations are less strict which allows the country to execute the recycling process easier than in other places, even though it’s not great for the environment. Newer methods for recovering these materials include using water and heat but if the batteries are designed with the purpose of being reused or recycled, this could greatly increase the feasibility of recycling lithium and other essential materials. Manufacturers like Nio are also looking to repurpose whole batteries by simply switching out the spent material and keeping everything else the same (National Geographic). Closing the loop and catering to recycling methods is imperative in preventing excessive mining and lowering material costs. In addition, batteries that are buried in landfills often leak from their casings and infect nearby ecosystems with metals and other chemicals

(C&EN). Although current methods of recycling lithium batteries are not economically motivating, if new adaptive battery designs are made for disassembling, it could lead the way to more sustainable means of recycling.

Car manufacturing companies are competing to satisfy the rising demand for sustainable vehicles— this competition acts as a driving factor to advance electric vehicle technology. Tesla was the first to demonstrate the capabilities of electric vehicles by offering a fully electric luxury sedan and SUV. However, in its wake, nearly every car manufacturer has plans of their own to release an electric, hybrid, or hydrogen vehicle. Volkswagen, Chevy, Nissan, and Toyota all have their foot in the door, offering a range of vehicles and price ranges. The Nissan Leaf and Chevy Bolt are great cheap sedan options while Volkswagen and Toyota offer hybrid and electric SUV options. Toyota is unique in that it is the only car manufacturer that offers a hydrogen-powered vehicle that utilizes fuel cells (Toyota). The infrastructure for this technology is years behind electricity, but it will be interesting to see if its popularity increases in the future. Back to electric vehicles, even American favorites Ford and General Motors are getting in on the action. Ford has been quite successful with its Mustang Mache-E and plans to release the Ford F-150 Lightning this spring. The truck is supposed to be its most powerful one yet and has the ability to power your house for 3 days (Ford). Meanwhile, General Motors has plans for an electric Chevy Silverado and Cadillac for 2023, an electric GMC Sierra and Denali for 2024, and has already released its first versions of an electrified Hummer (GMC). The luxury brands have also stepped into the space as Audi and Porsche already offer pricy versions of their respective keynote cars.

There are also some new kids on the block by the names of Nio, Rivian, and Lucid. These all-electric brands each address a particular type of car. Chinese manufacturer Nio offers a Sedan, SUV, and sports model, but the price difference is mostly due to battery choice. Nio wants its batteries to be easily exchangeable and offers a service that switches your old battery out for a charged one in as little as three minutes (Nio). This allows consumers to have greater choice over the battery range they want and reduces the need to sit and wait for your car's battery to charge. California startup, Rivian is a company that recently went public via SPAC and offers an outdoor sports truck and SUV. Rivian hopes to address consumer demand for an electric vehicle that is suited for camping and four-wheeling. Their car has a range of 315 miles and contains numerous handy gadgets for outdoor use, like a gear tunnel and portable kitchen (Rivian). The company also has a deal with Amazon for 100,000 electric delivery vans and both Amazon and Ford own significant shares of Rivian (Fortune). Finally, Lucid Motors aims to address luxury demand with its sleek-looking Sedan. The company recently began selling vehicles and plans to launch an SUV model in 2023 (Electrive). There are many other electric vehicle startups like Workhorse and Nikola but the expected demand for electric vehicles has clearly already caught the attention of many established brands so it will be difficult for such companies to get off the ground. It's important to note that many of these new brands face production concerns and decide to go public quite early on as a way to generate capital. These companies can then drum up news in order to boost their stock price like Nikola Motors who faked a video showing a shell of a car rolling downhill to play it off as if it was functional (New York Times). While there is a lot of potential for companies to grow exponentially in this industry, investors should be cautious about correctly valuing a company and spotting scams. Rivian has a lot of room to grow however that doesn't explain why it was valued at 127.3 billion when it came to market, while Ford's market cap was only 78 billion. At the time, Rivian had yet to make a sale while Ford had 38 billion in revenue in quarter four alone (Investopedia). Rivian's market cap has since decreased significantly, which demonstrates why investors must consider a company's financials to determine expected value. Regardless, there are numerous automobile companies that are addressing the demand for electric vehicles and the competition between these companies perpetuates the creation of better technology for a lower cost.

The time to invest in the future of electric vehicles is now. With governments pushing to meet pollution standards and spending money on developing key infrastructure, soon the United States, and ultimately the world, will fully transition to electric cars. The cost of batteries and therefore electric vehicles will decrease, we will generate more of our electricity from renewable sources, and countries will finally achieve energy security. States like California are setting a precedent for the future and using government aid to incentivize sustainable vehicles. Lithium recycling will become easier as engineers design batteries that are fit to be reused and we will finally move away from fossil fuels with help from other renewable energy production. Investor money will aid companies in ramping up production, allowing the victorious electric vehicle manufacturers to emerge. I am excited to see where the future takes us and I hope to soon be sitting in the front seat of my very own electric vehicle.

About the Author

Wilson Skinner is a sophomore from San Rafael, California. He is on track to complete a combined major of Human Factors Engineering & Environmental Studies. Wilson serves as a research group member in the Technical Analysis sector of the Tufts Investment Club and has a passion for environmentally significant investment opportunities. In his free time, Wilson enjoys hiking, environmental service work, and skiing.

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