How do Electric Vehicle owners feel about their Electric Vehicle's carbon footprint and are the Electric Vehicles actually green in Georgia?

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Introduction

Electric vehicles are the future. Whether or not one believes this is subjective to their vehicular preferences. However, it is a common misconception that electric cars are a new concept. Electric vehicles (EVs) have been around for over 100 years, dating back to the late 19th century. The first commercially viable electric vehicle in the United States was developed around 1890; this 6-passenger vehicle could travel at a top speed of 14 miles per hour (mph) (Matulka, 2014). The electrified wagon sparked many automakers' interests and grew popular very quickly; by 1900, 1/3 of nearly all vehicles in the US were electric (Matulka, 2014). However, Electric Vehicles, although a lot older than internal combustion engine cars (gas cars) are less popular.

As seen, EVs are relatively old, however, people do not know much about them, as everyone tends to think of them as a relatively new technology. The early designs of EVs worked by using a battery source connected to a motor, which connected to the mechanical transmission (Ehsani et al, 2019). While these EVs worked, they were not efficient for long distances as they had to be near power stations and the storage battery was heavy, which caused problems with reliability and manufacturing. (Gold, 2020). This resulted in the increase of gas-powered cars, even though EVs were preferred by many because of their quiet and smooth performance. Many did not mind the small range as people only traveled small distances throughout their day. This was not the only reason that electric cars did not sell. Oliver P. Fritchle was an electrical engineer and chemist who set out to build his own electric car. Fritchle's Victoria model claimed to have a range of 100 miles on a single charge. In order to prove this Fritchle conducted a publicity stunt in 1908 in which he drove from Nebraska to New York city. He successfully completed this 1,800 mile trip in 20 days, taking breaks and charging the car at night (Barber, 2017). For comparison, today the average Tesla can travel an average of 300 miles in one charge.

Over 100 years earlier an electric car with 1/3 the range of a car today was beat by the gas car. This was all due to the high price of the car.

A gas car might have cost $650 while an EV cost $2000 (Barber, 2017). Even though costs for EVs are still higher than internal combustion engine vehicles, (ICEV) recently they have been picking up speed once again. It has been noticed that "the market is mainly driven by factors related to increase in global fuel prices. Rising concerns towards achieving environmental sustainability and pollution free eco drive" (Global Electric Car (EV) Market to Witness a CAGR Growth of 19% | Market Is Projected to Worth of $354.80 Billion by 2028 | Key Players Change the View of the Global Face of Industry | Vantage Market Research, 2022). The rise in gas prices and increased awareness of global climate change has inspired a greater number of vehicle owners to consider the purchase of EVs.

Gap in Research

Pre-existing research outlines that EVs are generally better for the environment because they have no tailpipe emissions. It also outlines the different reasons for purchase, and details more about plug-in hybrid EVs (PHEVs) but the gap that this research is looking to fulfill is that how much better are battery powered EVs (BEVs) than ICEV (gas cars) and do the owners of the EVs also believe that they are better. This research will help new EV owners and existing EV owners to understand the impact of their vehicle on the environment. As well as see the differences between gas cars and EVs. The research is focused in the State of Georgia because this was convenient for the researcher as well as it fit the gap because a similar study has not been conducted in Georgia. The researcher will also look at the EV owners' reason for purchase to open room for future research as well as allow the researcher to truly understand what EV owners in Georgia believe about their vehicle. The guiding question for this research will be:

How do Electric Vehicle owners feel about their Electric Vehicle's carbon footprint and are the Electric Vehicles actually green in Georgia?

Literature Review

Climate change has been a serious problem for many years and many Nations have risen to fight climate change together, but it was not until the end of the 20th century before scientists realized the effects of climate change and the early 21st Century before people saw the effects. Scientists and companies all over the world have started investing in research to find causes of increased CO2 pollution. As it turns out, vehicles have been a major source of pollution and the leading cause of climate change. In the United States, fuel consumption accounts for nearly 28% of all greenhouse gasses (Miotti et al., 2016). To solve this problem many nations have turned to the use of electric vehicles in place of standard internal combustion engine vehicles (ICEV). Electric vehicles are said to reduce pollution and help the climate, but according to the United States Governmental protection agency, "…Generating the electricity used to charge EVs, however, may create carbon pollution" (Electric Vehicle Myths, 2021).

EVs are considered to be "green" vehicles because they do not produce any emissions through their tailpipe (a tailpipe is the rear part of a vehicle through which gas vehicles release exhaust (CO2)) when being used. Moreover, the positives of an EVs outweigh the negatives in comparison to a gas car. For example, EVs are much quieter and provide smoother operation (Ehsani et al., 2019). EVs also conserve more energy than the average gas car by using a feature Called regenerative braking, based on Newton's first law of motion, which allows the energy from braking to be incorporated back into the battery and charge it, creating a more efficient EV. (Ehsani et al., 2019).

There are many innovative technologies being implemented and researched to make vehicles more eco-friendly. This has led to many countries trying to promote the use of EVs. In the 2011 State of the Union address, the President at the time of the United States, Barack Obama, set a goal of putting 1 million EVs into use before 2015 (Wu & Zhang, 2017). Many governments have started supporting the use of EVs and promoting citizens to buy them since. Which has led to an increase in the purchase of EVs in the past years and will most likely continue selling as a green vehicle. The move towards smart cities will require EVs to assist with the connection of cars to the city (Tabuchi & Plumer, 2021). This will only lead to a bigger market for EVs. This makes it vital to fully understand the impact of EVs and how they affect the environment.

Most EVs produce more emissions in production than the average ICEV. This is mainly due to CO2 released when manufacturing the battery. The manufacturing of the lithium-ion battery creates a lot of pollution which leads to increased emissions for the EV (Gonçalves, 2018). Even after the manufacturing process EVs have emissions because of the electricity for the car which can come from fossil fuel plants such as those in the Midwest parts of the United States. While the car itself has zero emission the car indirectly is still causing pollution in a distant plant (Goncalves, 2018). The use of fossil fuels to generate electricity causes an increase in the emissions and leads to the EV not being a "green vehicle" (Tabuchi & Plumer, 2021). Depending on the location an EV can cause more or less pollution.

There are 2 types of EVs: battery EVs (BEVs) and Plug-in Hybrid EVs (PHEVs). BEVs run entirely off of electricity while PHEVs can run off of gas and electricity (Explaining Electric & Plug-in Hybrid Electric Vehicles, 2015). Previous studies have researched the impact of PHEVs but not BEVs. A study was conducted in California in which the researchers looked to better understand PHEV owners (Heffner et al., 2007). There has been research done to see if

electric vehicles are green and their effect on the environment. There has been separate research done to understand what different people think of electric vehicles, not the EV owner's opinion on the car but rather people's opinion on the overall EV and the EV owner themselves (Bennett & Vijaygopal, 2018). There has been research done on if EVs are green, for example many researchers have done emission tests, battery tests, and other such tests to determine the carbon emissions released by an EV, but no one has researched what the consumers/owners of the EVs think about the EV and how much pollution is caused by electricity generating plants.

Methodology

This study explores what electric vehicle owners think about their car's emissions and what the actual emission is. This study will be analyzing the people who think their electric vehicle is environmentally friendly – which will be established by comparing the emissions created by the electricity plant to charge that vehicle and the emission of a normal internal combustion engine vehicle (ICEV). This is important because there has been a rise in the purchase of electric vehicles and the promotion of EVs by the government, so it is important to understand the opinions of the EV owners and the facts regarding EVs.

I will be using a statistical analysis for this study. Statistical analysis is used to interpret data to discover patterns or trends (Statistical Analysis: What It Is and Why It Matters, n.d.). This approach allows me to compare the different types of data (qualitative and quantitative) with each other. For this method the researcher will be using 2 forms of data collection. First is the online survey that will be conducted, the second is the data the researcher will collect about an electric vehicle's emission. The survey will allow the researcher to gather electric vehicle owner's experience about their electric vehicle. This will let the researcher understand the perspective of the electric vehicle owners. The information the researcher will collect will allow

the researcher to compare the emission of each electric vehicle to see if the vehicle can be considered green. An important perspective that comes up is when looking at EVs should they be graded to be 100% green or just greener than ICEVs? For the purpose of this research it was decided that if they are considered to be greener than ICEV then it will be more applicable because most things today are not fully green. Since the data the researcher gathering mixed data a statistical analysis will allow the researcher to draw conclusion from the research. In the statistical analysis the researcher will be able to analyze the number of people that think their electric vehicle is green to actual number of electric vehicles that are green. For this process the researcher will be using a Chi Square test for independence. A Chi Square test for independence is one in which you can use qualitative and quantitative data to check for the match of 2 variables (JMP, 2022). For the purpose of this research the 2 variables will be if the users of the electric vehicle think they are green and if the car is actually green.

Subjects

The subjects for this study are those people who own a battery powered electric vehicle. These people were chosen for this specific study because as the electric vehicle owner they would know the reason for purchasing the electric vehicle, they would be the group of people who would be able to know the most about what they think. Since they are the consumer, the researcher would get the most accurate data. In order to find the subjects the researcher plans leave a note on electric vehicles that he finds, asking if they would like to participate in the study. They will have a QR code to the consent form and survey. Similarly the researcher will place posters and notes at local grocery stores where there are electric vehicle charging stations requesting them to participate in the survey. These are ideal places to reach out to EV owners because these places are always full, and many different people pass through them each day.

Procedures

The procedure that the researcher ended up using was as follows. The researcher first created a poster (appendix D) to send in social media groups that could have EV owners. Then the author put these posters at grocery stores and charging stations so that many different EV owners would be able to see these posters. They posters had a QR code that led to the survey (appendix B). The survey first asked the subject to read the consent form (appendix A) and only move forward if they consent to participate in the research. The consent also let the subject know that they may opt out at any stage and may choose not to answer any portion of the survey. The consent form informed the subject that their name and their personal information will not be released. After the subject is identified and has filled out the consent form and survey, the researcher will be able to access the data and clean the data (linked to a google sheets). A survey was chosen because it will allow for maximum accessibility to people in different locations. It is convenient for both the subject and the researcher. It allows for easy data access, cleaning, and analysis. The data will also be protected since it is on the researcher's password protected computer and then on his google account protected by 2 factor authorization. The survey process will be secure and simple.

Limitations

Since this study requires the researcher to analyze a lot of the results there could be possible bias. In order to eliminate bias in the study the researcher will try to keep the sample size big so that there is a variety of data and opinions. The limitation that the researcher faces with that is finding people who own electric vehicles. Since as of 2023 there were estimated only 3 million electric vehicles in the United States, the researcher presumes that it will be difficult to find a large sample of electric vehicles (Kilgore, 2022). To solve this issue, the researcher will

also be putting up the information about the study in local grocery stores, parking lots, and sending it out on media as much as possible. The use of this will allow the researcher to reach out to as many electric vehicles owners as possible and gather as much data as possible.

Findings

After reaching out to the EV owners the researcher gathered 18 survey responses in total. Five of which were determined to be invalid for the research. They were invalid because question eight: "How much do you spend on electricity monthly for this car? (estimate)" was answered with an invalid response or the car entered was not a battery powered EV, but rather a hybrid EV. The 13 responses that were determined to be valid were used to analyze the data. The 13 respondents were each assigned an ID value 1-13 corresponding with their response, i.e., respondent 1 is ID1 (see table 4). All of the 13 respondents answered yes to question nine: "Do you think electrical cars are better for the environment than standard gas-powered cars (explain)"? ID7 responded by explaining how the electricity produced in Georgia is 60% fossil fuels whiles gasoline cars use 100% percent fossil fuels. ID2 stated that we are moving in the right direction, but we need to find a greener battery option. ID11 responded with a similar response talking about the mineral mining required for batteries followed by ID13 who stated that lithium-ion batteries are bad for the environment but overall are better for the environment because they don't use fossil fuels (see table 4). In total all the respondents believed that EVs are better for the environment than standard gas-powered cars, with some raising concerns for the battery's environmental impact. For question seven: "What made you buy the electric car over a standard gas-powered car (explain)"? (see table 1). For this question, the researcher categorized the answers into 3 themes: environment, cost, and technology. Eight respondents answered that they bought it because they considered the vehicle to be environmentally friendly. Seven

respondents answered that they bought it because of the rising cost of gas and cheap cost of electricity. Four respondents stated that they bought it because of technological advancements. ID11 stated that they bought the car because of "ease of home charging and environment". In the survey question eight asked the respondents, "How much do you spend on electricity monthly for this car?(estimate)"? The range for this question went from 15-65 dollars (see table 2). ID 5 in the survey did respond with 120 which after further clarification with them was the cost for 2 their cars, they said one car would be 60 dollars. ID 2 said "50-80" so the researcher took the average value of the 2 ranges and used 65 dollars for charging (see table 4). In Georgia the average price for charging your EV is 0.12 dollars per kilowatt-hour (kWh) ("Charging – Drive Electric Georgia"). For each price the researcher found the number of kilowatt-hours. Then used that to calculate the average kWhs for all the data gathered. The researcher also found the amount of CO2 (in kilograms) released per kilowatt-hour of electricity generated in Georgia. About 0.036 kg of CO2 is release per kilowatt-hour of electricity in Georgia. The researcher was then able to multiply the average kilowatt-hours by the amount of CO2 per kilowatt-hour and get the average amount of CO2 release caused by an EV in a month in Georgia (see table 3).

Analysis

The analysis was made up of both the qualitative data and the quantitative data. The subjects were asked three questions to which their responses will be analyzed. Question nine: "Do you think electrical cars are better for the environment than standard gas-powered cars (explain)?", question eight: "How much do you spend on electricity monthly for this car?(estimate)", and question seven: "What made you buy the electric car over a standard gas-powered car (explain)?". The responses from the three questions were primarily used to explain the reason behind buying the EV. As explained in the findings section and seen in table 3 the

researcher used the answer to question 8 to determine how many kilowatt-hours each car uses in a month and that to calculate the amount of CO2 released in kilograms per month of EV use. The analysis was to be conducted using a Chi Square test for independence. A Chi Square test for independence allows to compare and draw conclusions about a certain population based on a sample (Turney). To first conduct this test a two-way table has to be made. The row of the table contains the conclusion drawn from question eight. The column contains the answer to question nine. Once this table was made it was found that there was not enough data to conduct a Chi Square Test. In order to create table 6 from question eight the researcher first found the amount of CO2 released in kilograms per month of EV use and then found the approximate amount of pollution released by a gas-powered car in a month. The typical gas-powered passenger vehicle releases 4.6 metric tons of C02 per year, which is about 4600 kgs (about 10141.25 lbs) of C02. For each month about 383.33 kgs of C02 are released. From the data collected it was found that the highest amount of CO2 produced by a single EV in a month was 19.5 kgs of CO2 (table 5). This is significantly less than the CO2 emissions of gasoline cars. Using a two-way table, I was able to display the data that I found (table 6). In the table below we can see that the number of EV owners that thought that EVs were green vs the number of EVs that were actually green were the same. All 13 respondents thought that EVs are green and all 13 EVs were green. As seen in table 1 8/13 survey respondents bought the EV because of the positive impact of EVs on the environment.

Conclusion

This study addresses many gaps from previous research. The first gap that was addressed in this research was the opinion of the EV owners. In many pre-existing research papers why the EV owners are buying the EV and what the EV owners think of EVs is not included. Without

properly understanding the reason EVs are being purchased the EVs owners' opinions about the EV cannot be correctly understood. In former studies the opinion of others on EVs owners has been analyzed. This information was also not specific to Georgia, but rather more towards the western coast. The second gap that was filled was that the amount of pollution caused by EVs is severely overlooked. Since EVs do not cause pollution directly through their tailpipe, many say that they are zero emissions, but the emissions caused by indirect forms such as electricity power plants needs to be considered. This gap was the initial gap identified and served as the basis for this research.

Implications

The main implications or advantages of this research is that in the future potential EV owner, business, and politicians will be able to better understand the use of EVs and how they perform in Georgia. The results will help Georgia better understand their electricity power plant generation impact on other sectors and how to better move towards clean energy. As ID 2 stated in their survey response to question nine, "Yes. We are in the right direction to greener technology and EV is a great start. There are areas we need to improve on such as finding a greener battery, but we will with time". Many respondents believe that we are moving towards a greener era, but the batteries still hold a major issue. ID 11 and ID 13 also agreed. This study will allow future research to be done in other states to determine which states need to improve their electricity generation plans and move towards more clean energy. The other implication is that it will allow companies to better market EVs in a form that will allow customers to want to purchase the EV.

Limitations

With the research there were some limitations. While the researcher tried to keep the research as unbiased as possible and include as many responses as possible there may be a chance for bias because of the limitations. The first limitation was that the sample size was a bit small compared to the population size. The total number of responses collected was 18 and the total number of responses determined to be valid was 13. The small sample size was due to time and resource limitations. As stated in the methods section, the researcher went to many different locations to get people who own EVs to fill out the survey, but still a total of 13 responses were collected. The second limitation was also due to the time constraints, some of the respondents were people that the researcher knew. This may have caused some bias, but in order to reduce and avoid as much bias as possible the researcher asked the respondents to try and be unbiased and asked questions that would not generate bias. In order to reduce this bias he also tried to randomize the selection of the people that were asked to fill out the survey.

Areas for Future Studies

The study still has spots for improvement as well as opening the floor for new studies. Similar studies can be conducted in different states, countries, and regions to determine the impact of EVs and the opinion of the EV owners. This study can be conducted again in Georgia as well, removing some limitations by including a bigger sample size as well trying to randomize the respondents to eliminate bias and get a better understanding of the region's impact. The study also allows future researchers to look into the impact of marketing on the opinion of EV owners and how that affects the way they think about their EV. In this research the respondents were asked what was their reason for EV purchase. By understanding this and the different marketing strategies used, in the future marketing for businesses can be made more effective.

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Appendices

Appendix A: *Consent Form*

The opinion and facts of Electric Vehicles Owner on Electric vehicles being green

Investigator Name: _____

Email Contact Information: _____

You are being asked to participate in a research study. The purpose of this study is to analysis the opinion of Electric Vehicle owner on Electric vehicles being green compared to facts. We would like your input concerning the use of your Electric Vehicle. The data from this research will be used in an academic paper and presentation and oral defense for the College Board AP Capstone Program.

Participation in this study will require approximately 10 minutes of time. The collection of surveys will take place from location of your choice(virtual).

There are no foreseeable risks associated with this study and the investigator does not perceive more than minimal risk from your involvement in the study. Your decision to participate in this study will have no bearing on your current employment or academic status. Your participation in this study is voluntary; you may choose not to participate and may withdraw at any time without consequence.

If you are minor, parental consent is required and should have been obtained prior to you being provided with this link.

No identifying information will be placed on the survey instrument; therefore, all responses provided are completely confidential. All unidentifiable survey results will be saved on a password-protected computer and ------- Schools password-protected OneDrive. Data from the information given will be used for quantitative and qualitative research purposes. Survey results may be shared during presentations and publications. Individual responses are confidential and will be presented using representative statistical measures or generalizations of responses.

Participation or Withdrawal

Your decision to participate or decline participation in this study is voluntary. You may decline to answer any question and you have the right to withdraw from

participation at any time. Withdrawal will not affect your relationship with _____ in any way. You may stop the survey early by X-ing out at any time.

Contacts

If you have any questions about this research project, or if you would like to receive a copy of the final results of this study, please contact *Researcher name* via email: *researcher email* and *research teacher* via email: *teacher email*. *School name* IRB reviewed study # 22-017 Reid and approved it on 01/26/23.

Thank you in advance for your time and participation!

Please do not forward this link to others.

Please print a copy of this document for your records.

Appendix B: *Survey Questions*

1. Are you older than 18?
*
Yes
No

2. Do you agree to participate in this survey?

*
Yes, start the survey
No, Stop the survey

3. Do you own an Electric Car?
*
Yes
No
4. What brand is your car?
*
Short answer text
5. what is the model of the car?
*
Long answer text

6. Is this car what you use for standard transportation?
*
Yes
No
Sometimes
Other:___
7. What made you buy the electric car over a standard gas powered car (explain)?
*
Long answer text
8. How much do you spend on electricity monthly for this car?(estimate)
*
Long answer text
9. Do you think electrical cars are better for the environment than standard gas powered cars (explain)?
*
Long answer text

Appendix C: *Data tables*

Table 1.

Frequency of Themes in Question Seven	
	What made you buy the electric car over a standard gas powered car (explain)?
Environment	8
Cost	7
Tech	4

Table 2.

Price for charging an EV per month($)	
Mean	46.15

Median	50
Low	15
High	65
Range	50

Table 3.

Total emissions					
price of electricity per kWh	price for car(dollars)	kWh(per car)	average kWh for all cars	emissions in KG per kWh	total emissions caused for one month(kg)
0.12	20	166.6666667	346.1538462	0.036	12.46153846
0.12	65	541.6666667			
0.12	20	166.6666667			
0.12	60	500			
0.12	60	500			
0.12	60	500			
0.12	50	416.6666667			
0.12	30	250			
0.12	50	416.6666667			
0.12	15	125			

0.12	30	250			
0.12	30	250			
0.12	50	416.6666667			

Table 4.

Survey Responses						
	What brand is your car?	what is the model of the car?	Is this car what you use for standard transportation?	What made you buy the electric car over a standard gas-powered car (explain)?	How much do you spend on electricity monthly for this car?(estimate)	Do you think electrical cars are better for the environment than standard gas powered cars (explain)?
ID1	Tesla	Model Y	Yes	Environmental	$20	Of course, yes. To Stop polluting nature
ID2	Tesla	Model 3	Yes	Driving a significantly less harmful vehicle for the environment, price in the long run in cheaper, and the car's autopilot and	$50-$80	Yes. We are in the right direction to greener technology and EV is a great start. There are areas we need to improve on such as finding a greener battery but we will with time.

				innovation is like none other.		
ID3	Tesla	Y	Yes	Environmental impact, high tech	$20	Yes for each car. Overall - not sure
ID4	Tesla	Model Y	Yes	Security Features, Auto Pilot, overall cost	$60 on charging	Yes. No pollution
ID5	Tesla	Model 3	Yes	Cost efficiency	120	Yes. Less carbon emissions
ID6	Tesla	Model 3	Yes	Green transportation	$60	Yes, reduced emissions vs gas powered cars.
ID7	Tesla	3	Yes	Environment	$50	Yes, for certain. 40% of the power produced in GA is from non fossil fuel sources while gasoline is 100% fossil fuel. Hopefully we'll install solar in the near future and we'll be 100% clean power.
ID8	Tesla	Model Y	Yes	Raising gas price	$30	Yes
ID9	Tesla	Model Y	Yes	Environment friendly	50$	Less pollution
ID10	Tesla	Model X	Yes	I liked the idea of never paying for gas	$15	Yes. Electric cars do not require oil, gas, or any of the typical

				and oil (especially living in California during the time).		chemicals needed to maintain a standard vehicle. There are no exhaust pipes needed, thus leading to less air pollution.
ID11	Tesla	Model y	Yes	Ease of home charging and environment	30	In general yes with respect to emissions. Need to understand impact of mining the minerals for batteries.
ID12	Chevrolet	Bolt	Yes	Avoid pollution and save on gas	30	Yes
ID13	Tesla	Model 3	Yes	Saving money on gas	$50	Yes, but not the car battery. The batteries are actually shown to be environmentally destructive. Overall, reducing fossil fuel emissions is a net positive of driving an EV.

Table 5.

Total emissions

price of electricity per kWh	price for car(dollars)	kWh(per car)	emissions in KG per kWh	total emissions caused for one month(kg)
0.12	20	166.6666667	0.036	6
0.12	65	541.6666667	0.036	19.5
0.12	20	166.6666667	0.036	6
0.12	60	500	0.036	18
0.12	60	500	0.036	18
0.12	60	500	0.036	18
0.12	50	416.6666667	0.036	15
0.12	30	250	0.036	9
0.12	50	416.6666667	0.036	15
0.12	15	125	0.036	4.5
0.12	30	250	0.036	9
0.12	30	250	0.036	9
0.12	50	416.6666667	0.036	15

Table 6.

Observed	yes	no
yes	13	0
no	0	0

Appendix D: *Poster*