The Economical and Environmental way of Transport: Fossil Fuels vs Electric Vehicles

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Abstract. Fossil fuels have been an abundant source of energy and have been economically practical for a long time, but the environmental damage caused by this liquid has already seeped into our lives. Whilst there have been multiple innovations, and breakthroughs in the extraction, refining, and combustion of this liquid, its environmental impact has been reduced drastically, yet it exists. The newest contender in this race towards environmental stability, Electric Vehicles (EVs), which promises the use of clean and low-emission electric sources for transportation. Hence, our goal is to find which type of vehicle is economically and environmentally superior, focusing on the vehicles' extraction, production, and usage phases.

INTRODUCTION

Dependency on transportation via road will only grow over the coming millennia and contributes globally to a major part of energy consumption and greenhouse gas emissions. This shows the rise in demand for gasoline, and diesel, along with the degradation of the global climate and air quality. Hence, among the alternatives, electric vehicles (EVs) have appeared as a strong contender for this race to gain global environmental stability and prevent further damage to the current state of earth. Governments around the globe are suppling funding, plans, and programs for the introduction of electric vehicles and other cleaner alternatives for transport.

The recent upraise in demand for Electric Vehicles, has put a lot of stress on the supply of lithium for making batteries for the same, hence raising its value to tremendous amounts. Due to this, we want to find out which type of vehicle would be the best for the environment and the resource constraints it will impose on future generations. Our project aims at finding which vehicle will cause the least amount of environmental damage while using the least amount of resources. This will allow us to manage the resources efficiently and drastically reduce pollution caused due to automobiles. All the future predictions are accurately calculated by using Machine Learning techniques and algorithms.

The outcome of the project is to create a survey paper that would summarize the environmental impact and the resources used to find the best type of vehicle. The major advantage of this analysis is that all factors from the extraction of the resource to the state of the vehicle 50 years in the future will be considered, and with the help of Artificial Intelligence and Machine learning, while accurately predicting the pollution caused due to physical degradation reducing the efficiency of the engine, thus factoring in the increase in pollution. The minor defect could be the accuracy of the predictions from the Machine Learning algorithms, which could deter the results of the final environmental impact.

LITERATURE SURVEY

At the start of the preliminary study, we first wanted to investigate the lifecycle assessment of the various elements with respect to fossil fuel and electric vehicles. Matsuhashi in the year 2000, has written a research paper titled “Life cycle of CO2- emissions from electric vehicles and gasoline vehicles using a process-relational model” [1], where the author describes the life cycle assessment built on a relational model of processes. They also estimate the vehicles’ life cycle CO2 emissions which includes the manufacturing and use phases. Finally, all the finding that the author has published makes it clear regarding where the resources need to be invested for research and development for gasoline and electric vehicles to help reduce pollution. In 2003, Moghbelli published a paper title “A Comparative Review of Fuel Cell Vehicles (FCVs) and Hybrid Electric Vehicles (HEVs) Part I: Performance and Parameter Characteristics, Emissions, Well-to Wheels Efficiency and Fuel Economy, Alternative Fuels, Hybridization of FCV, and Batteries for Hybrid Vehicles” [5], where the author analyses various fuel cell and hybrid electric vehicles and concludes by stating that hybridization helps lower the costs, while producing the same amount of emissions, and fuel economy of fuel cell vehicles. Baratto in the year 2005, has published a paper titled “Life cycle assessment of fuel cell based APUs” [7]. This study compares the SOFC-based APU's life cycle to that of conventional fossil fuel cells. It has employed various models to calculate emissions at various lifecycle stages.
After understanding regarding various perspectives of lifecycle assessment, we wanted to know how the fuels used for each type of vehicles can affect the environment. Starting with Hawkins, in 2013 the author has published a paper titled “Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles” [10], where they analyze the impact of lithium-ion batteries powered by natural gas and coal, and the conventional vehicles powered by gasoline and diesel, in the various stages in their life cycle. In 2002, Author Wang published a paper titled “Fuel choices for fuel cell vehicles: well-to-wheels energy and emission impacts” [3], where they go on to compare various fuel types and shows how they differ in terms of energy output and emissions. They perform a well to wheel analysis for evaluation of the fuel/vehicular systems. In 2006, Mockus publishes a paper titled “Analysis of exhaust gas composition of internal combustion engines using liquefied petroleum gas” [8]. Here the author examines the manufacturing, combustion, and environmental impacts of vehicular fuels from a chemical perspective. In 2019, Author Huang, published a paper titled “Fuel consumption and emissions performance under real driving: Comparison between hybrid and conventional vehicles” [12], where they compare real world and laboratory parameters for fuel consumption and emissions for hybrid and conventional vehicles.

Now, we wanted to find out the real-life scenarios in which the use of electric vehicles has benefited or detriment the current environmental pollution of that city. In 2021, Milev published a paper titled “The environmental and financial implications of expanding the use of electric cars - A Case study of Scotland” [15], here the author conducts a study in Scotland examining various electric vehicles and effects on environment and its users. Zhang in 2022, has published a paper “Are electric vehicles more sustainable than conventional ones? Influences of the assumptions and modelling approaches in the case of typical cars in China” [19], where the author focuses on comparing the environmental impact of electric vehicles and hybrid electric vehicles with conventional vehicles manufactured and used in China. In 2020, Sharma published a paper titled “Will electric vehicles (EVs) be less polluting than conventional automobiles under Indian city conditions?” [13]. Here they Compare emission of four major pollutants between conventional and electric vehicles operating in an Indian city. In 2021, Digalwar published a paper titled “Evaluation of Factors for Sustainable Manufacturing of Electric Vehicles in India” [14], where they aim to develop and confirm factors affecting the sustainable production of electric vehicles in India. In 2022, Carranza publishes a paper titled “Life cycle assessment and economic analysis of the electric motorcycle in the city of Barcelona and the impact on air pollution” [18], where the author conducts an economic and environmental analysis of electric engine and internal combustion engine motorcycles in a Spanish urban environment. Kucukvar in 2022, published a paper titled “Environmental efficiency of electric vehicles in Europe under various electricity production mix scenarios” [20], where they analyze the footprint efficiency related to the various electricity generation mix in Europe. Another author from Europe name Gustafsson, in 2021, published a paper titled “Well-to-wheel (WTW) climate performance of gas and electric vehicles in Europe “[16], where they Footprint efficiency related to different electricity generation mix in different parts of Europe. In 2021, author Ou published a paper titled “Evaluating long-term emission impacts of large-scale electric vehicle deployment in the US using a human Earth systems model” [], where they evaluate long term emission by introducing substantial number of electric vehicles in the United States of America. Nanaki, in 2013, had published a paper titled “Comparative economic and environmental analysis of conventional, hybrid and electric vehicles – the case study of Greece” [9]. Here the authors analyze environmental impact by considering different carbon emission scenario on different energy mixers. Finally evaluating economic and environmental analysis on the different possibilities. In 2002, Lindly has published a paper titled “Impact of electric vehicles on electric power generation and global environmental change” [2], where the authors provide information on the extent of emission differences that can be expected as sales of electric vehicles increase. This information also acts as a planning tool for finding future generation sites.

Now, we want to look at the various perspective from authors regarding electric vehicles and the future of this industry. In 2004, Chan has published a paper titled “Electric vehicles charge forward” [6], where the author defines many types of electric vehicles and how they differ in terms of battery composition and power consumption depending on resource availability and use are the main points of this article. Carlsson, in the year 2003, has published a paper titled “Costs and Benefits of Electric Vehicles” [4]. Here they clarify how electric vehicles affect the economy. It also proves to them how hybrid electric vehicles perform in terms of noise, fuel efficiency, and particle emission. In the year 2017, Author Palinski had published a paper titled “A Comparison of Electric Vehicles and Conventional Automobiles: Costs and Quality Perspective” [11]. In this paper, the author shows us the characteristics of various systems of both electrical and conventional vehicles from the perspectives of cost and qualitative characteristics.

OVERALL ARCHITECTURE

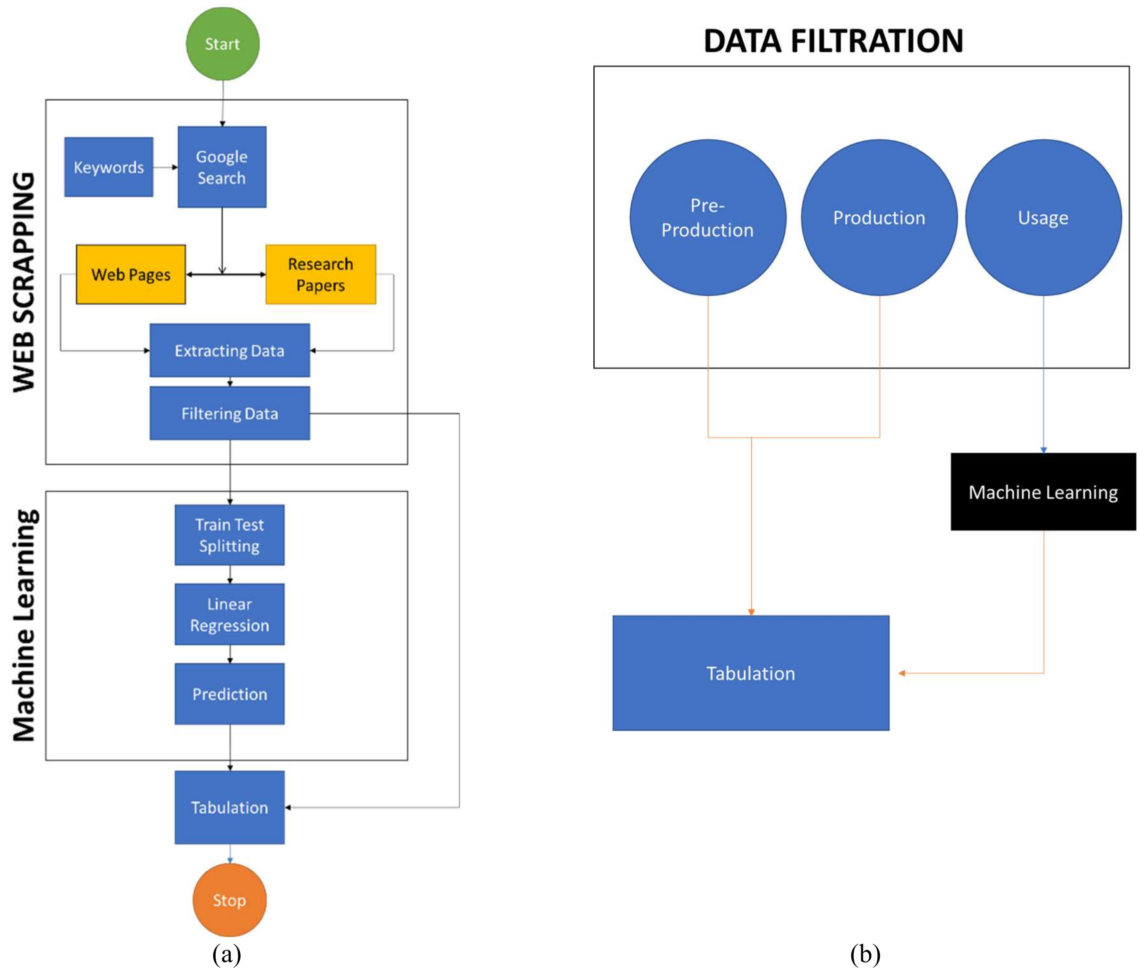


FIGURE 1. a) Workflow diagram of Proposed Methodology.

b) Data Filtration in Proposed Methodology

Overall Architecture Explanation

The workflow of the proposed work will begin with the collection of data. We will be automating this process using web scrapping techniques to collect data on a large scale and filtering it to obtain the required data.

After the collection of required data, we will be obtaining the carbon emissions in the pre-production stage (resource extraction and refining) and production stage (conversion of raw materials into the finished product). We would be tabulating said data and storing it for analysis.

For the final stage of the carbon emission diagram, the usage stage, we will be using machine learning techniques to predict the future carbon emissions for each in the period of 50 years.

Finally, all data will be aggregated and Tabulated, and will be analysed to produce the economically and environmentally viable vehicle.

PROPOSED METHODOLOGY

The data gathering stage is one of the most crucial and important part of the entire project, hence we will be automating this process to obtain reliable and consistent data. First, we manually create a list of keywords whose data is to be collected. Then we create a google search URL, which we will use to obtain the list of various webpages and research papers. We achieve this result by using the python library "bs4", from which we will importing "BeautifulSoup", which will aid us in obtaining the URLs of the webpages and research papers from the search results of the google search.

After obtaining the URL of the webpages and research papers, we proceed to the employ separate methods for each. For the webpages, we will proceed to use the "bs4" python library to obtain any tables in the webpage. For the research paper, we would download and the store the Portable Document Format (PDF) files, after which we will be utilizing the python library "Camelot" to read the PDF files and obtain the tables existing in them.

After getting the tables from both types of sources, we will be filtering out the required data as per the three stages (FIGURE 1.b), Pre-Production, Production and Usage. First, we will be obtaining data for Production of the two types of vehicles. Here we will focus on obtaining materials used and the carbon emissions during production.

Then, we move onto the Pre-Production Stage, where we will be using the data obtained from the Production stage and obtain the carbon emissions of the materials from ore to ingot processes.

Now, we have completed with the static data gather and compilation, now we will move to the dynamic data, where most of the focus of this paper resides upon. The usage stage of the automobile is quite important as it is responsible for the highest production of carbon emissions over time. First, we start of by finding the highest engine efficiency achieved for each of the vehicles. Then we create an engine degradation function for fossil fuel vehicle and Electric vehicle, which will show how the efficiency of the engine degrades over the years (in our case over the span of 50 years).

Now we will be taking the sales data for each of the cars. From the various sources, we have found that the most reliable and consistent data to be between 1999 to 2021 for fossil fuel automobiles, and 2010 to 2021 for Electric Vehicles. Now from the various sources, we will be considering the average of all those data for training reliably.

After obtaining the dataset, we will be using the python library "sklearn" to splitting the data into training and testing datasets using the "train_test_split" method, here we will be varying three key parameters, namely train_size, random_state and shuffle, to find the model with the highest accuracy.

From the same "sklearn" Python library, we can import "LinearRegression", "Lasso", and "Ridge".We will be focusing on Liner Regression, Ridge Regression, and Lasso Regression as sales will increase linearly over time. Random Forest Algorithm could also be utilized here, but due to the data being in time series form. Patterns that correspond with time which shows random increasing or decrease growth, the random forest regression is not capable to predict for any future values outside of the known range. Hence, we will be finding the best regression algorithm for fossil fuel vehicle and electric vehicle sales. The initial step is to create an empty model for each Regression technique and will fit the training data into the same. After which, we will be predicting the accuracy using the testing data. The accuracy of the model is found using r2 analysis, whose functions are available in the "sklearn" Python library.

After getting the accuracy for all the variation as mentioned previously, we will be choosing the one that has the highest accuracy and use that for predicting the future data (For a period of 50 years).

The last step is to the aggregate, tabulate and visualize all the data obtained to show which type of vehicle would be economically and environmentally the best option to choose from.

ANALYSIS AND RESULTS

TABLE 1. First 10 URLs links from Search result web scrapping

Website URL
https://www.iea.org/data-and-statistics/data-p...
https://www.iea.org/reports/global-ev-outlook-...
https://www.bankrate.com/insurance/car/electri...
https://www.virta.global/en/global-electric-ve...
https://explodingtopics.com/blog/ev-stats&sa=U...
https://carsurance.net/insights/electric-cars-...
https://policyadvice.net/insurance/insights/el...
https://www.statista.com/topics/1010/electric-...
https://heycar.co.uk/blog/electric-cars-statis...
https://www.bts.gov/data-spotlight/electric-ve...

TABLE 2. Carbon Emission for production and pre-production stages for Fossil Fuel Vehicles

Material	Average Weight (Kg)	Average Carbon Emission (Kg of CO2 eq.)	Carbon Emission (Kg of CO2 eq.)
Body and Chassis			
Steel	823	1.85	1522.55
Lead Acid Battery			
Lead	11.73	53	621.69
Sulphuric Acid	1.343	0.247	0.335287
Polypropylene	1.037	1.95	2.02215
Fibreglass	0.357	2.1	0.7497

TABLE 3. Carbon Emissions For production and pre-production stages for electric vehicles

Material	Average Weight (Kg)	Average Carbon Emission (Kg of CO2 eq.)	Carbon Emission (Kg of CO2 eq.)
Body and Chassis			
Aluminium	568	14.5	8236
Nickel Metal Hydride Battery			
Silver	0.00046	196	0.09016
Aluminium	0.05819	2.15	0.125109
Calcium	0.15111	0.3	0.045333
Cobalt	1.0143	1.58	1.602594
Copper	0.00299	0.181	0.000541
Iron	3.542	1.9	6.7298
Lanthanum	2.783	0	0
Magnesium	0.00023	6	0.00138
Manganese	0.16698	6	1.00188
Sodium	0.2346	0.425	0.099705
Nickel	4.117	13	53.521
Lead	0.00184	11.73	0.021583
Antimony	0.00023	0	0
Titanium	0.0023	10	0.023
Vanadium	0.00046	17	0.00782
Yttrium	0.00966	197.9	1.911714
Zinc	0.18285	1	0.18285
Plastics	1.0534	3.85	4.05559
Paper	0.5911	0.028	0.016551
Steel	4.761	1.85	8.80785
Lithium Ion Battery			
Lithium	1.4421	15	21.6315

Nickel	9.1839	18	165.3102
Cobalt	1.7457	1.58	2.758206
Aluminium	16.6221	14.5	241.0205
Graphite	12.5235	16.8	210.3948
Copper	10.0947	4.05	40.88354
Steel	0.0759	1.85	0.140415
Plastics	3.1878	1.95	6.21621

TABLE 4. CARBON EMISSION DUE TO FUEL CONSUMPTION

Sources	Carbon Emission (g of CO2 eq, /Km)
Fossil Fuel Vehicles	
Petrol	121.9
Diesel	170.3226
Electric Vehicles	
Natural Gas	20.9494
Coal	138.57
Petroleum	35.76
Nuclear	4
Renewable	50

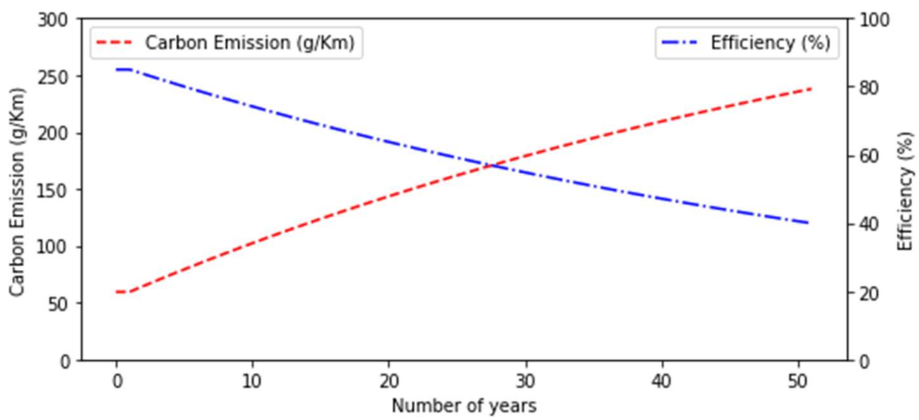


FIGURE 2. Carbon emission vs engine efficiency graph for Electric Vehicles

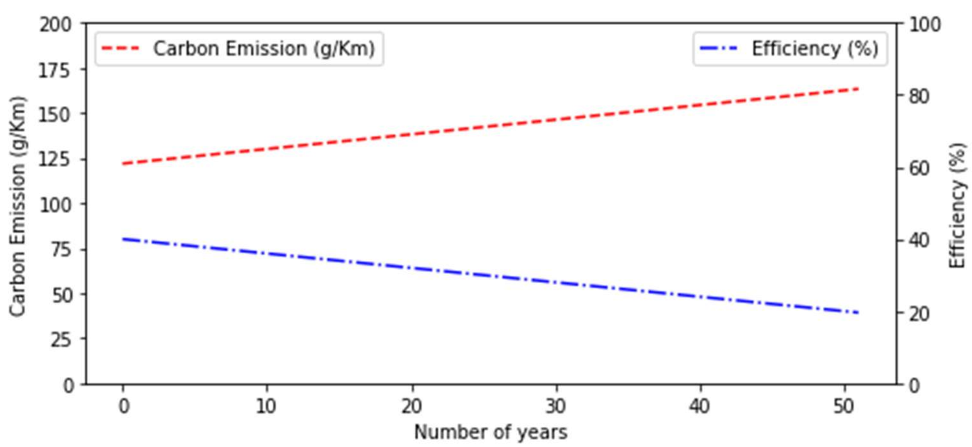
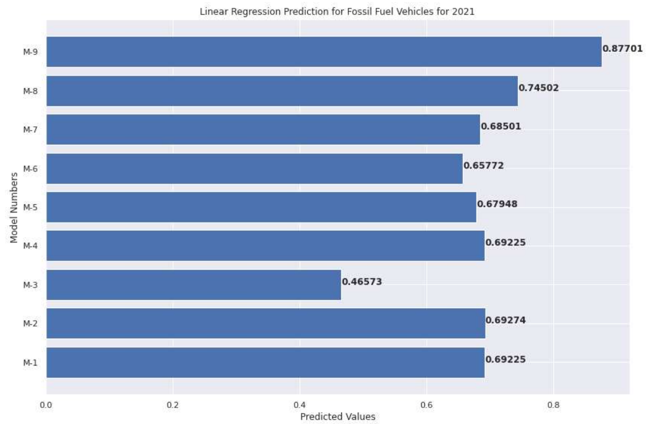


FIGURE 3. Carbon emission vs engine efficiency graph for Fossil Fuel Vehicles



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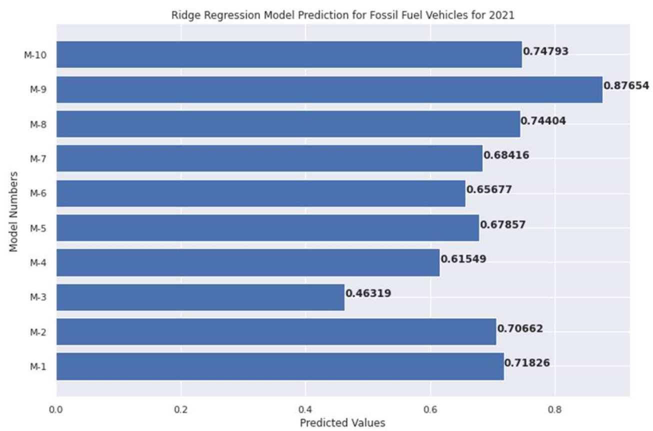

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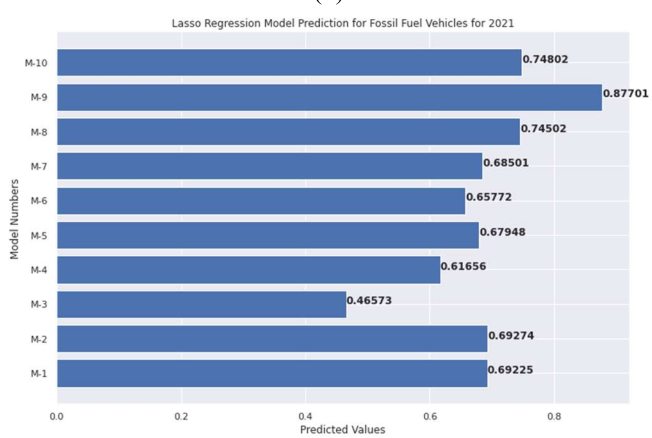
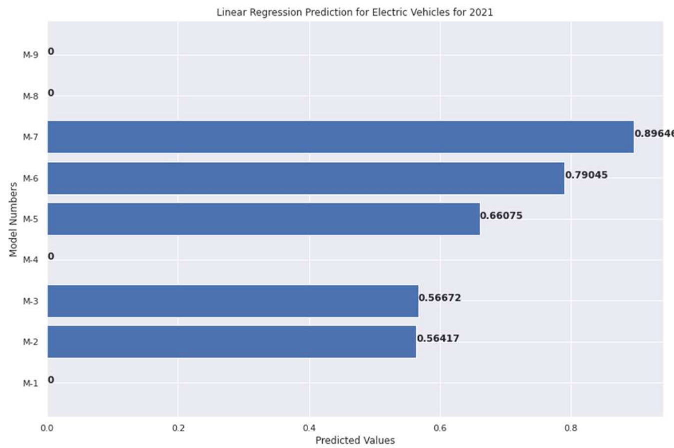


(c)

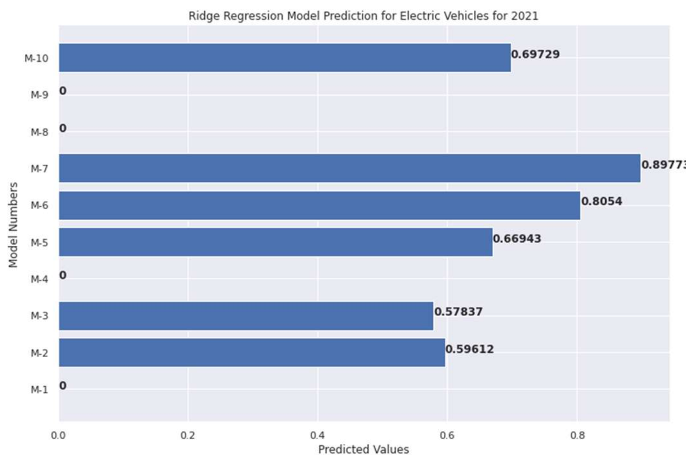
FIGURE 4. Prediction of sales of fossil fuel vehicle for 2021 and its respective model accuracy

(a) Linear Regression Prediction for Fossil Fuel Vehicles for 2021
(b) Ridge Regression Prediction for Fossil Fuel Vehicles for 2021
(c) Lasso Regression Prediction for Fossil Fuel Vehicles for 2021

FIGURE 5. Graph of sales forecast with high accuracy model of fossil fuel vehicle for the study period (50 years)



(a)



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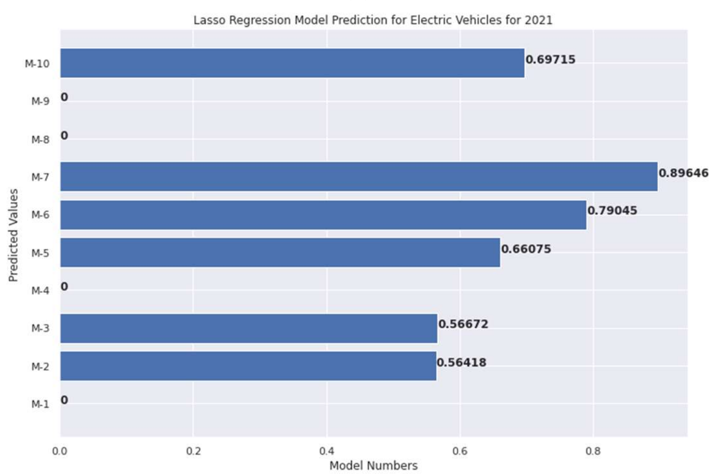

(c)

FIGURE 6. Prediction of sales of electric vehicle for 2021 and its respective model accuracy

(a) Linear Regression Prediction for Electric Vehicles for 2021
(b) Ridge Regression Prediction for Electric Vehicles for 2021
(c) Lasso Regression Prediction for Electric Vehicles for 2021

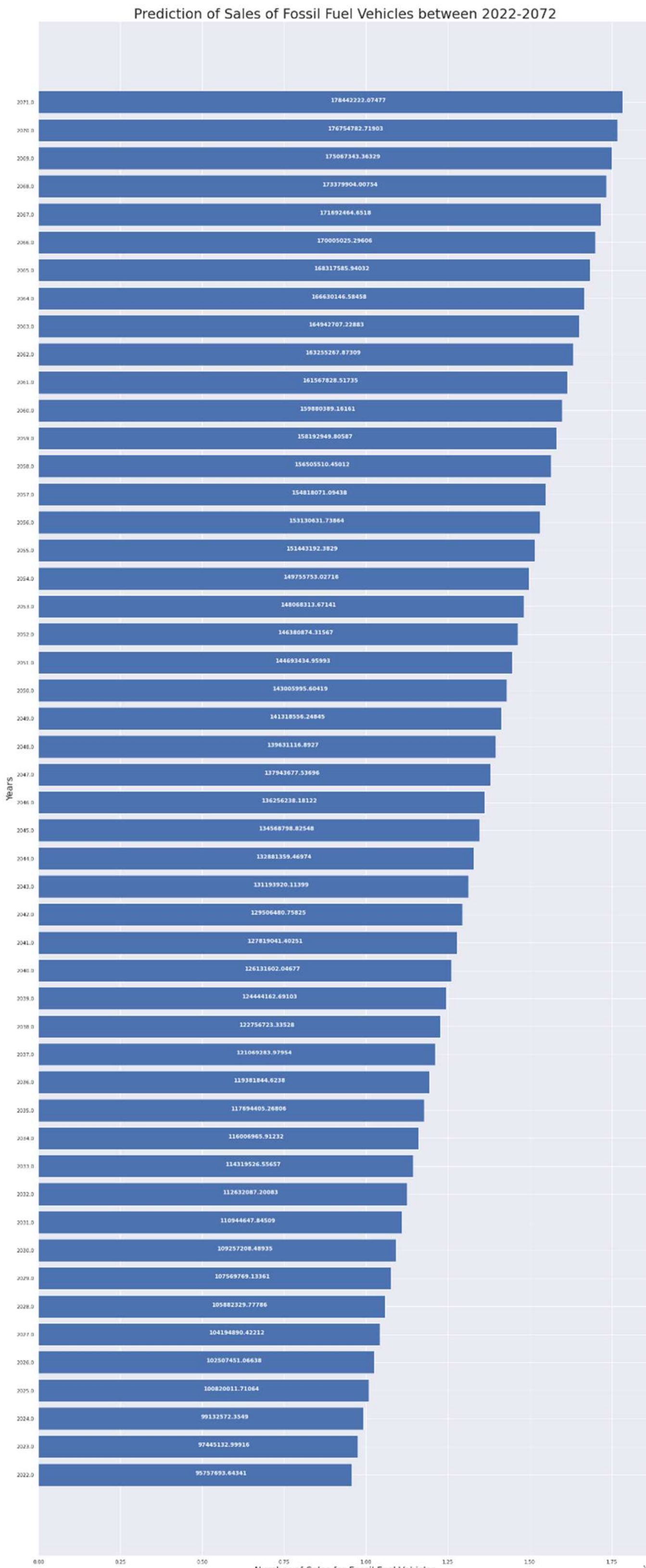

FIGURE 7. Graph of sales forecast with high accuracy model of electric vehicle for the study period (50 years)

TABLE 5. CARBON EMISSION FROM ELECTRICITY GENERATION FOR VARIOUS SCENARIO

Scenario	Carbon Emission (g of CO2 eq, /Km)	Electric Vehicle 1 (0.16 kWh/Km) (g/kWh)	Electric Vehicle 2 (0.181 kWh/Km) (g/kWh)
Realistic	59.42581	61.20744	69.24092
Ideal	4	0.64	0.724
Non-Renewable	65.09313	61.20744	69.24092
Renewable	50	0.64	0.724

TABLE 6. CARBON EMISSIONS FROM FUEL CONSUMPTIONS OF FOSSIL FUEL VEHICLES FOR THE STUDY PERIOD (50 YEARS)

Scenario	Fossil Fuel Vehicle (Kg of CO2 eq)
Petrol	125343636472.67
Diesel	175134159618.38

TABLE 7. CARBON EMISSIONS FROM FUEL CONSUMPTIONS OF ELECTRIC VEHICLES FOR THE STUDY PERIOD (50 YEARS)

Scenario	Electric Vehicle 1 (Kg of CO2 eq.)	Electric Vehicle 2 (Kg of CO2 eq.)
Realistic	7108997021.62	8042052880.71
Ideal	74333415.57	84089676.36
Non-Renewable	11489246766.85	12997210405.00
Renewable	929167694.61	1051120954.53

TABLE 8. TOTAL RESOURCES BY WEIGHT USED IN FOSSIL FUEL VEHICLE FOR THE STUDY PERIOD (50 YEARS)

Material	Total Weight (Kg)
Steel	5641663265901.597
Lead	80409125284.35693
Sulphuric Acid	9206262170.237965
Polypropylene	7108632814.993872
Fibreglass	2447234247.7847753

TABLE 9. TOTAL RESOURCES BY WEIGHT USED IN ELECTRIC VEHICLE FOR THE STUDY PERIOD (50 YEARS)

Material	Total Weight (Kg)
Aluminium	439806042115.24286
Lithium	1116627276.997168
Nickel	7111152658.771441
Cobalt	1351706703.7334146
Aluminium	12870598613.80947
Graphite	9697026352.870144
Copper	7816390938.980182
Steel	58769856.68406151
Plastics	2468333980.730583

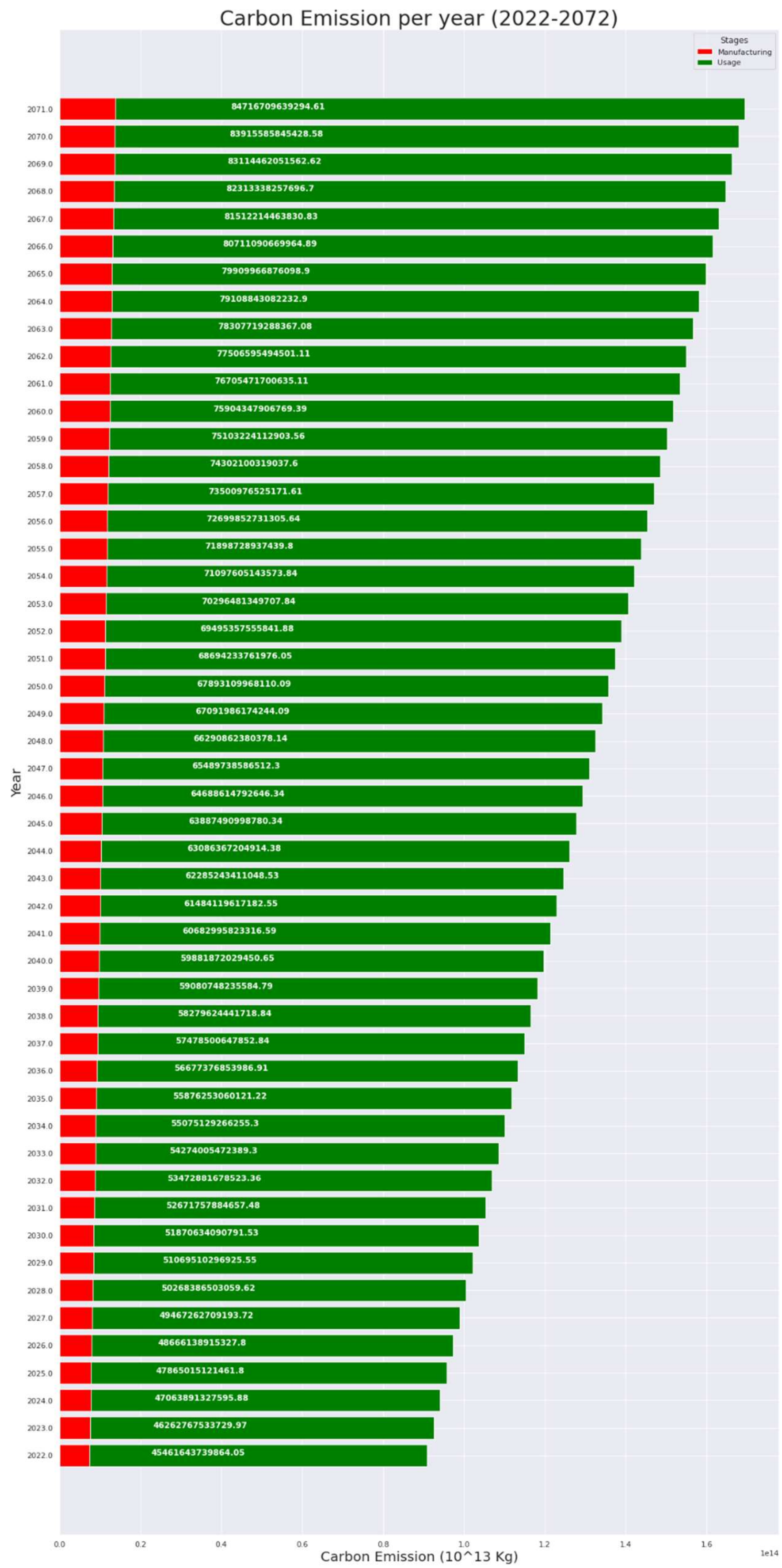

FIGURE 8. Carbon Emissions of fossil fuels for the study period (50 years)

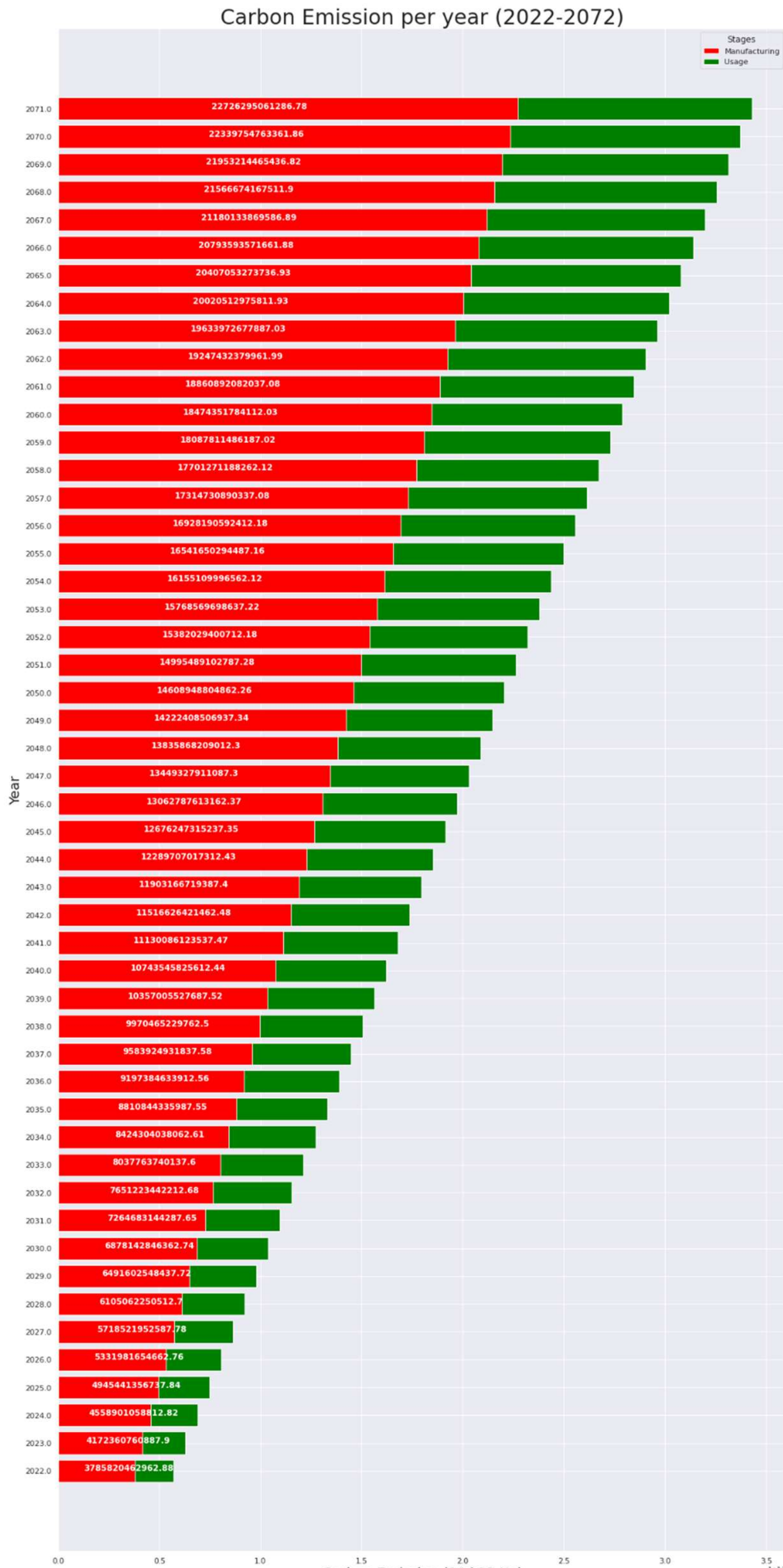

FIGURE 9. Carbon Emissions of electric vehicles for the study period (50 years)

TABLE 10. RESOURCE CONSUMPTION OF RESERVES BY VEHICLES FOR THE PERIOD OF 50 YEARS

Material	Predicted Weight (Million tons)	World Reserve (Million tons)	Percentage Consumption (%)
Fossil Fuel Vehicles			
Lead	5.641	90.4	6.24
Electric Vehicles			
Aluminium	0.46	371	0.123989
Lithium	1.16	22	5.272727
Graphite	9.6	323.8	2.964793
Nickel	7.11	94	7.56383
Cobalt	1.651	7.6	21.72368
Copper	7.81	2800	0.278929

TABLE 11. FINAL CARBON EMISSION OF VEHICLES FOR THE PERIOD OF 50 YEARS

Vehicle Type	Fossil Fuel Vehicle (Kg of CO2 eq)
Fossil Fuel Vehicle	3254458834477729.5
Electric Vehicle	662802888106243.6

DISCUSSION

While following the methodology described in (FIGURE 1.a), we began with a set of keywords, via which we used to obtain the google search results for the same. After which we used web scrapping techniques to obtain the URL of the search results (TABLE 1) and depending on whether the URL leads to a webpage or a research paper, we will employ further web scrapping or table extractor for files respectively to obtain information that is mostly stored in tabular structures.

After obtaining the set of tables, we are employing simple filtering algorithms to navigate through the tables and filter the required information according to (FIGURE 1.b). First, we will look for data regarding the production of the vehicles, i.e., data regarding materials used and the carbon emissions during the manufacturing process. After which we will search for data regarding the production of those materials used in the manufacturing of the car and then we obtain the carbon emissions for all those materials used. (TABLE 2) and (TABLE 3) shows the summary regarding the previously mentioned data for fossil fuel and electric vehicles, respectively. In (TABLE 2), for the fossil fuel vehicles, we are looking at a steel body and chassis with a lead battery acid, as this is the most common combination found in this type of vehicles. In (TABLE 3), we are choosing an aluminium body and chassis with two distinct types of batteries most found in electric vehicles nowadays, namely Nickel Metal Hydride and Lithium Nickel Cobalt Aluminium oxide (Li-NCA) battery. By observing (TABLE 3) more carefully, we can observe that the Nickel Metal Hydride Battery produces significantly less CO2 emissions than the Lithium Nickel Cobalt Aluminium oxide battery. The advantage that the Lithium-ion battery has over the Nickel Metal Hydride, is the smaller and lighter characteristics for similar specifications, which is highly preferred by car manufacturers. For further analysis in this paper, we will be using the Lithium-ion battery as the basis for all the calculations and analysis. Examining (TABLE 2) and (TABLE 3), we can conclude that electric vehicles produce higher amounts of CO2 emissions than fossil fuel vehicles in the pre-production and production phases.

Moving onto the usage stage, we will be calculating the carbon emissions caused by the respective fuels consumed by the engines. For the fossil fuel vehicles, the combustion engine directly converts the fuel into mechanical energy and releases carbon emissions as the by-products. The fuel sources for the fossil fuel vehicle are petrol and diesel. For Electric vehicles, we must identify the various major sources of electricity generation, and find the percentage they contribute to the national electricity grid, we will be analysing various scenarios later in this analysis. All the previously mentioned data are tabulated in (TABLE 4).

Now we will be considering the base efficiency of the engine, and with the degradation of the engine with the passage of time for fossil fuel vehicles and electric vehicles (as shown in FIGURE 2 and FIGURE 3 respectively). If we observe (FIGURE 2), it shows that the efficiency of electric engines decreases at a faster rate than fossil fuel engines. This is due to the battery technology in electric vehicles, as due to frequent charging and discharging cycles will cause for coagulation to occur in the battery, hence blocking or hindering the charging and discharging process, consuming higher amounts of electricity, and thus inducing higher amounts of carbon emission.

Moving onto the prediction of sales for both types of vehicles, first we will construct various training and testing data splits for sales data for each of the vehicles, this will allow for us to obtain the highest accuracy sales model. We will use the training and testing data splits and pass it through Linear Regression, Ridge Regression, and Lasso Regression models and then using r2 analysis, find the accuracy of the model. In (FIGURE 4) and (FIGURE 6) we are predicting the sales of vehicle, fossil fuel and electric respectively, for a year whose data already exists (here, for the year 2021) and then finding which model has the highest accuracy. For fossil fuel vehicle sales, the linear regression has the better accuracy with Model 9 (M-9) with an accuracy of 87.7 Percent, and electric vehicle sales, the ridge regression has the better accuracy with Model 7 (M-7) with an accuracy of 89.77 Percent.

We then use these highly accurate models to predict the future data as per the scope of our study, for 50 years between 2022 till 2072 and has been represented graphically in (FIGURE 5) and (FIGURE 7) for fossil fuel and electric vehicle respectively.

Now after obtaining the sales data for the study period, we can look at different electricity generating scenarios and how it corresponds to utilization in the electric vehicles. In (TABLE 5), we can observe that four scenarios tabulated with two different electric vehicles with different kWh/Km consumption.

The realistic scenario is the current ratio of different electricity generation sources that contributes to the national electricity grid, here the percentage contribution is as follows, 38.3% from natural gas, 21.8% from Coal, 0.5% from Petroleum, 18.5% Nuclear and 20.1% from renewable sources of energy. We will be using this model for further analysis and calculations, to highlight information that can be used for further research and analysis.

The Ideal scenario is where we will be taking the cleanest form of energy production, which is nuclear. Here, we will consider that all the electricity produced is from nuclear power plants. This model is so far the cleanest as it only produces around four grams of CO2 emissions per kWh. This is the future we need to work towards, to make electric vehicles viable and clean.

The Non-Renewable scenario is where we will consider most fossil fuels, as they can be extracted and used at an exceptionally low cost, which returns extreme amounts of electricity.

The Renewable scenario is where we will use various renewable sources of energy generation such as solar, wind, hydro, geothermal and many others. This model is achievable, but the efficiency of these renewable resources is not exceedingly high and hence requires more research and innovation to make them viable.

All the different electricity generation scenarios for two different electric vehicles are tabulated in (TABLE 6). The amount of carbon emissions produced from all these scenarios in descending order is Non-Renewable (65.1 grams of CO2 eq./kWh), Realistic (59.426 grams of CO2 eq./kWh), Renewable (50 grams of CO2 eq./kWh), and Ideal (4 grams of CO2/ kWh). The comparison between the two electric vehicles shows us that the electric vehicle that consumes more kWh, produces more carbon emissions than the other. This shows us that the engine of the electric vehicle also plays a crucial role in carbon emissions, as the efficiency of the engine, converting electrical energy into mechanical energy, can determine whether this mode of transport is viable or would become worse than conventional fossil fuel vehicles.

(TABLE 6) and (TABLE 7) shows us the carbon emissions produced over the study period (50 years) by the fossil fuel and electric vehicles, respectively. In case of the fossil fuel vehicles, we can observe that out of petrol and diesel fuels, petrol produces 28% less CO2 emissions than diesel. In case of electric vehicles, from the various scenarios, the Ideal scenario produces 99.9% less CO2 emissions than petrol and would be the best-case scenario for the future of the earths' health. But to keep up with the realism of this research paper, we will be using the realistic model for further calculations, and analysis.

We shall now proceed to obtain the number of materials used annually and the total amount of materials used after the end of the 50-year period. Total materials used at the end of the study period is shown in (TABLE 8) and (TABLE 9) for fossil fuel vehicles and electric vehicles, respectively. From (TABLE 10) we can observe that by the end of the study period, the resources used in fossil fuel vehicles are still in plenty, but in electric vehicles, Cobalt, Nickel and Lithium will quickly consume those materials within the span of three millenniums. Hence, we should be careful in using the supply and demand chain of such materials, as they can be preserved for future technologies and innovations. Alternatively, batteries of both vehicles can be recycled with up to 90% recovery rate of materials, while only producing less than half of the CO2 emitted during the manufacturing of the same battery. Hence, for better management of these resources, it would be ecologically and economically better to recycle older batteries instead of mining for fresh resources.

In this 50-year study period, 6.85 billion and 774.3 million fossil fuel and electric vehicles respectively will be produced, along with 3.254 trillion tons and 662 billion tons of Carbon emissions by fossil fuel and electric vehicles, respectively. (FIGURE 8) and (FIGURE 9) shows the per year distribution of the carbon emissions. Over the period of 50 years, we can observe that the electric vehicles emit less carbon emissions than fossil fuel vehicles. Also, the Carbon emissions is higher in the manufacturing stage than usage stages. Hence, in the Ideal scenario, where only nuclear energy is used to produce electricity, we can completely reduce the carbon emissions in the usage stage of electric vehicles and only factor in the carbon emissions in the pre-production and production stages.

In conclusion, (TABLE 11) shows us the final carbon emissions for the two types of cars under the study period of 50 years, its shows us that production of electric vehicles would be both economically and environmentally better, as fossil fuels produce 79.63% more emissions than electric vehicles and as electric vehicles consume less amounts of resources by weight, which makes them the much more viable option.

CONCLUSION AND FUTURE WORKS

While an individual electric vehicle produces more carbon emissions than fossil fuels-based vehicles, for the period of 50 years, Electric vehicles emit 81% less CO2 eq. than the conventional fossil fuel cars but may potentially reduce the supply chain of the precious materials like Lithium, Nickel, and Cobalt in this period. Hence, there exists a trade-off between carbon emission and resource use, which should be carefully kept in balance. By using modern recycling methods and techniques, we can recover most if not all the materials which will help reduce the CO2 emissions produced while creating the new product.

With the evolution of battery technology, movement towards efficient renewable energy harvesting solutions, and efficient recycling methodologies with low carbon emissions will allow for Electric vehicles to be the most ideal form of transportation with zero carbon emissions. But until those technologies are achieved, the switch towards electric vehicles should start now to help with the situation of the carbon emissions over a brief period while these said technologies are available in the market.

The current prediction model only takes in a handful of parameters into consideration, so for better and more accurate prediction models, we need to consider multiple factors that will affect the efficiency of the engine, which includes advancement in technologies. This model can be changed to reduce carbon emissions in the production and pre-production stages.

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