Vehicle Health and Environmental Impact Analysis: A Comparative Study of Fossil Fuel and Electric Vehicles

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering with Specialization in Internet of Things

by

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May 2023

DECLARATION

I hereby declare that the thesis entitled "Vehicle Health and Environmental Impact Analysis: A Comparative Study of Fossil Fuel and Electric Vehicles" submitted by me, for the award of the degree of Bachelor of Technology in *Computer Science with Specialization In Internet of Things* to VIT is a record of bonafide work carried out by me under the supervision of Dr.Vishnupriya A.

I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place : Vellore

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Signature of the Candidate

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Internal Examiner **External Examiner**

Head of the Department

Computer Science with Specialization in Internet of Things

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I would like to acknowledge that this project was completed entirely by me and my team, not by someone else.

Date :

Signature

Ramakrishnan J

Student Name

Executive Summary

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 create a cutting-edge web application that provides users with two essential sections. The first section of the application will accurately predict the health of a used vehicle's engine by graphing the degradation of engine efficiency and CO_2 emissions over the years of ownership. This feature helps car owners to keep track of their vehicle's health and take necessary steps to ensure optimal performance. The second section of the application offers users comprehensive information and statistics on fossil fuel and electric vehicles for the next 50 years. This section is an invaluable resource for anyone looking to stay informed on the latest trends and developments in the automotive industry. Users can access data on sales, CO_2 emissions, and materials used for all cars within the 50-year period, allowing them to make informed decisions on their transportation choices. 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 of the future predictions are accurately calculated by using Machine Learning techniques and algorithms.

The outcome of the project is to create a web application to predict the engine health and carbon emissions of used vehicles. This app also would summarize the environmental impact and the resources used. 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.

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List of Abbreviations

EVs	Electric Vehicles
CO_2	Carbon dioxide
GWh	Gigawatt hours
CSV	comma-separated values
EPA	Environmental Protection Agency
kWh	kilowatt hours
MPG	miles per gallon

1. 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 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 supplied 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 create a cutting-edge web application that provides users with two essential sections. The first section of the application will accurately predict the health of a used vehicle's engine by graphing the degradation of engine efficiency and CO2 emissions over the years of ownership. This feature helps car owners to keep track of their vehicle's health and take necessary steps to ensure optimal performance. The second section of the application offers users comprehensive information and statistics on fossil fuel and electric vehicles for the next 50 years. This section is an invaluable resource for anyone looking to stay informed on the latest trends and developments in the automotive industry. Users can access data on sales, CO2 emissions, and materials used for all cars within the 50-year period, allowing them to make informed decisions on their transportation choices. 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 of the future predictions are accurately calculated by using Machine Learning techniques and algorithms.

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2. Literature Survey

A. The environmental and financial implications of expanding the use of electric cars - A Case study of Scotland

This research paper explores the potential implications of the widespread adoption of electric vehicles in Scotland, including their environmental impact and financial feasibility. The study compares the energy requirements and running costs of electric cars versus traditional internal combustion engine vehicles, and estimates that an additional 4 GWh of electricity would be necessary to meet the demand for electric cars. While this would lead to a slight increase in carbon emissions from the electrical grid, it would still result in a significant decrease in overall greenhouse gas emissions compared to the current levels generated by conventional vehicles. Although electric cars have a higher initial cost, their long-term operating costs are projected to be lower. However, certain challenges remain, such as the extended time required for charging and the energy needed for heating in colder weather, which can reduce their range by up to 28%. [1]

B. A Comparison of Electric Vehicles and Conventional Automobiles: Costs and Quality Perspective

This report aims to investigate the current state of the emerging e-mobility market, which is relatively new in the global personal vehicle industry. Specifically, it focuses on analyzing the conditions and challenges faced by buyers in various countries. The study primarily compares the costs of Battery Electric Vehicles (BEVs), hybrids, and conventional vehicles in the spring of 2017. By examining the quality features of each propulsion system, the research delivers an accurate estimate of the actual cost of owning each vehicle type. To test the assumptions made during the research, a questionnaire was conducted to gauge public awareness of electric vehicles. Ultimately, the report seeks to determine whether electric vehicles will become the future of the global car market. [2]

C. Fuel consumption and emissions performance under real driving: Comparison between hybrid and conventional vehicles

Hybrid electric vehicles are commonly believed to be more efficient and less polluting than conventional internal combustion engine vehicles. However, recent evidence suggests that real-driving emissions (RDE) may exceed laboratory approval limits, and the benefits of HEVs over conventional ICE vehicles in real-world driving conditions have not been extensively studied. To address this, this study evaluated the fuel consumption and pollutant emissions of HEVs compared to their conventional ICE counterparts in real-world driving conditions. Two pairs of identical hybrid and conventional gasoline vehicles were evaluated simultaneously using portable emission measurement systems, allowing for a direct comparison of performance while accounting for vehicle configurations, driving behaviour, road conditions, and ambient environment. The results showed that although real-world fuel consumption for both hybrid and conventional vehicles exceeded their laboratory results by 44%–100% and 30%–82%, respectively, HEVs still saved between 23%–49% fuel compared to their conventional ICE counterparts. Additionally, all tested vehicles had pollutant emissions within regulation limits. However, the study found that hybridization did not provide the expected benefits to urban air quality despite achieving the fuel reduction target. [3]

D. *Are electric vehicles more sustainable than conventional ones? Influences of the assumptions and modelling approaches in the case of typical cars in China*

China has taken steps towards transitioning to electric vehicles (EVs) for a more sustainable transport system. However, there is still uncertainty over whether EVs are more environmentally friendly than conventional internal combustion engine vehicles (ICEVs) due to a lack of consistent comparison. This study compares the environmental impact of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) with ICEVs using the BYD Qin Pro series as examples. Environmental profiles of the vehicles throughout their life cycle are analysed, taking into account regional differences, technology improvements, and modelling methods. The study finds that while EVs do have environmental benefits, such as reducing greenhouse gas emissions, there are also significant negative impacts such as mineral resource scarcity and ecological and human toxicity. The results show that these factors can heavily influence the environmental profiles of EVs, and even reverse the environmental priorities of ICEVs, BEVs, and PHEVs. [4]

E. *Evaluation of Factors for Sustainable Manufacturing of Electric Vehicles in India*

The objective of this study is to create and authenticate a list of factors that impact the sustainable manufacturing of electric vehicles in India, which can be utilized by original equipment manufacturers and service providers in the electric vehicle industry. The list is based on a comprehensive review of the literature on electric vehicles, resulting in the identification of seven factors and sixty-seven corresponding variables that affect the sustainable manufacturing of electric vehicles, including technological, social, cultural, economic, political, geographical, and environmental factors. The validated tool of factors influencing the sustainable manufacturing of electric vehicles can be used by manufacturers, service providers, and new market entrants interested in the electric vehicle industry to evaluate potential areas of growth. The insights acquired through this evaluation can also aid electric vehicle engineers in integrating consumer purchasing behaviour into their design. While the validated outcomes of this study are specific to the Indian context, the created tool has the potential to be applied on a global scale. [5]

F. *Environmental efficiency of electric vehicles in Europe under various electricity production mix scenarios*

In order to decarbonize the residential transportation sector, it is crucial to consider the energy mix and the environmental impact of electric vehicles (EVs) over their entire life cycle, including electricity generation. This study aims to analyze the environmental efficiency of battery EVs in different scenarios of electricity mix: average mix, marginal mix (2015-2020), and renewable energy-based mix (2030-2040). Using Eco invent v3.7 life cycle environmental impact data, environmental impacts per kWh electricity generation were estimated for each country, and the well-to-wheel environmental impacts of battery EVs were calculated per km travelled. The study suggests ways to improve the environmental efficiency of battery EVs based on the footprint efficiency results related to different electricity production mix scenarios and future projections.

The results indicate that Finland and the Netherlands are the most environmentally efficient countries for BEVs in all electricity mix scenarios. Furthermore, the study reveals that marginal mixes have higher shares of renewable electricity sources, leading to higher environmental efficiency scores for battery EVs than average mixes. [6]

G. Well-to-wheel (WTW) climate performance of gas and electric vehicles in Europe

This study examines the environmental efficiency of battery electric vehicles under different electricity mix scenarios, including the average, marginal, and renewable energy-based electricity mixes. The analysis considers well-to-wheel environmental impacts per kWh electricity generation and the functional unit per km travelled. Non-restricted and weight-restricted frontier models are used to model environmental efficiency, with Finland and the Netherlands identified as the most efficient countries. The results show that marginal electricity mixes are more environmentally efficient than average mixes due to higher shares of renewable electricity sources. The study offers future projections to improve the environmental efficiency of battery electric vehicles. [7]

H. Comparative economic and environmental analysis of conventional, hybrid and electric vehicles – the case study of Greece

This study considers three electricity production scenarios with varying carbon intensities and evaluates the environmental impacts of electric, hybrid, and conventional vehicles in each scenario. The emissions from material extraction, manufacturing, and decommissioning for renewable energy sources and coal are embedded in the analysis. Normalized economic and environmental indicators are used to compare the vehicles in terms of production stage impacts, fuel utilization stage impacts, and overall impacts. The results show that electric cars emit less than hybrid and conventional cars in all scenarios, but are competitive only when renewable energy sources account for at least 50% of the energy mix. Hybrid cars have significant advantages when fossil fuels are used for more than 50% of the energy mix. The study highlights the importance of electricity production sources for achieving large-scale GHG emission reductions and suggests increasing the range of electric vehicles or producing electricity on-board as a viable solution to improve their environmental performance. [8]

3. Overall Architecture

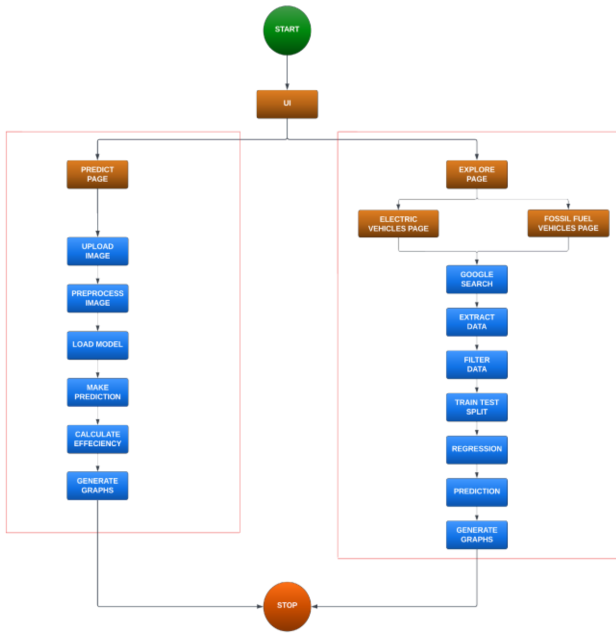


Fig 1. Workflow diagram of Proposed Methodology

The workflow of the proposed work will begin with user navigation to one of two sections; Predict page and Explore page. In the predict page, user is prompted to upload an image of their car. Then our website loads the image classification model and predicts the make and model. Along with that, it also predicts the engine efficiency and carbon emission of the model. Then with the help of the year of purchase, engine efficiency and initial carbon emission, an engine degradation function is created and a graph is drawn for engine efficiency and carbon emission over the years of ownership.

When navigated to the next page, the user has options to view stats for both fossil fuel and electric vehicles. The workflow of this section 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.

4. Proposed Methodology

We developed a web application using Streamlit with two primary sections. The first section predicts the health of a used vehicle's engine and displays a graph of engine efficiency degradation and CO_2 emissions over the years of ownership. The second section provides statistics and information regarding fossil fuel and electric vehicles for the next 50 years. It presents data on sales, CO_2 emissions, and materials used for all cars within the 50-year period.

The engine health page allows users to upload a photo of a car, predicts the car's model using a machine learning model, and then provides the user with data on the car's engine efficiency and carbon emissions. The user is also able to input the year they purchased the car, and the application shows how the car's engine efficiency and carbon emissions have changed over time.

The machine learning model uses a deep learning approach to image classification using the ResNet50V2 architecture pre-trained on the car dataset. The car dataset contains over 180 different car models. The model is implemented using the TensorFlow framework and the Keras API.

The ResNet50V2 model is then constructed by adding a pre-trained ResNet50V2 layer as the base model, followed by a dense layer with ReLU activation and dropout regularisation, and a final dense layer with softmax activation to output the class probabilities. The ResNet50V2 layers are frozen to prevent overfitting and allow the model to leverage the pre-trained weights. The model is compiled with the Adam optimizer and categorical cross-entropy loss, and accuracy is used as the evaluation metric. The model is then trained for 10 epochs using the fit method.

This model is then loaded, and the user is prompted to upload the image of their car. The image is then read, preprocessed, fed into the machine learning model to make a prediction of the car's make and model.

The predicted car's name is then used to filter a CSV file containing data on engine efficiency and carbon emissions for different car models. The data for the predicted car is extracted, and the engine efficiency and carbon emissions are displayed to the user.

To calculate the engine efficiency of a car, we can use the EPA-rated combined fuel economy, which is measured in miles per gallon (MPG). First, we convert MPG to liters per 100 kilometers. Next, assuming the fuel used is gasoline, we convert liters per 100 kilometers to megajoules per kilometer using the energy content of gasoline. Finally, we divide the distance travelled per unit of time by the energy used per unit of time to get the engine efficiency, which is a percentage indicating how much of the fuel's energy is being converted into useful work by the engine.

After asking the user to input the year of purchase for their car, we utilize data on the highest engine efficiency achieved and the starting CO_2 emission for the predicted car model. Using this information, we generate an engine degradation function specific to the user's vehicle, which demonstrates how the engine's efficiency declines over time, leading to an increase in CO_2 emissions throughout the duration of their ownership.

This next part of our website shows some data related to carbon emissions from the production and pre-production stages of both fossil fuel and electric vehicles. It also allows the user to select a regression model (linear, Lasso, or Ridge) to be applied to sales data and visualize the resulting predictions. With our Vehicle Sales Predictor and Carbon Emissions Calculator tool, you can gain insights into the future trends of electric vehicle sales and their impact on the environment.

The data-gathering stage is one of the most crucial and important parts 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 web pages and research papers. We achieve this result by using the python library “bs4”, from which we will import “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 web pages and research papers, we proceed to 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 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 Pre-Production, Production, and Usage. First, we will be obtaining data for the 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. These data will be put up on the website for insight.

Now, we have completed the static data gathering and compilation, now we will move to dynamic data. 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 off by finding the highest engine efficiency achieved for each of the vehicles. Then we create an engine degradation function for fossil fuel vehicles and Electric vehicles.

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 Linear 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 show random increasing or decreasing growth, the random forest regression is not capable to predict any future values outside of the known range. Hence, we will be finding the best regression algorithm for fossil fuel vehicles 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 variations as mentioned previously, we will be choosing the one that has the highest accuracy and uses that for predicting future data (For a period of 50 years). Then it predicts the sales of vehicles and generates a bar chart to visualize the sales trend. The model takes into account the number of years as an input and predicts the sales for each year, from 2022 to the end year specified by the user.

Then finally, carbon emissions produced by cars are calculated based on the number of cars sold and the yearly carbon emission rate. It then generates a bar chart that shows the carbon emissions for each year between 2022 and the end year specified in the input. In addition, it also estimates the weights of materials that would be needed to produce the number of cars sold for a range of years. This information can help you understand the impact of the sales trend on the environment and the resources used in the production of cars.

5. Analysis and Results

TABLE 5. 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 5. 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 5. 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 5. 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

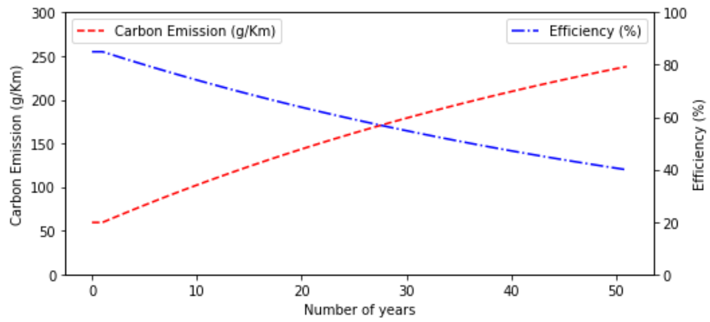


Fig 2. Carbon emission vs engine efficiency graph for Electric Vehicles

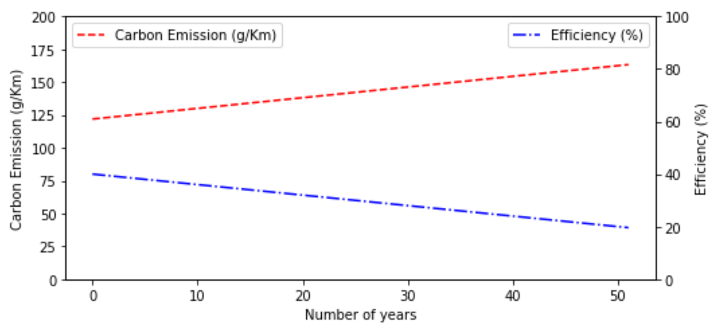
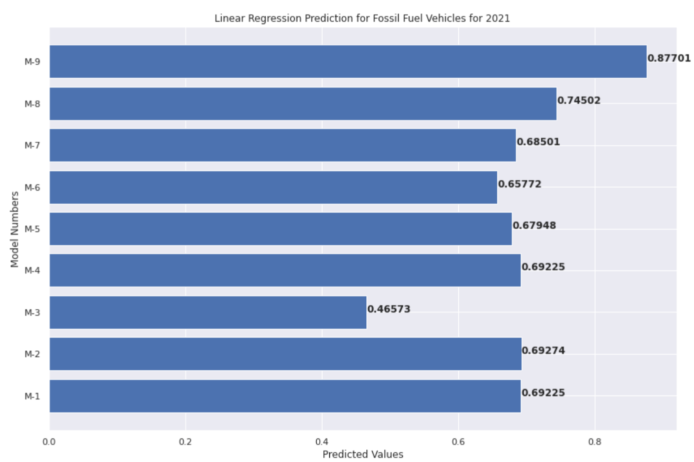
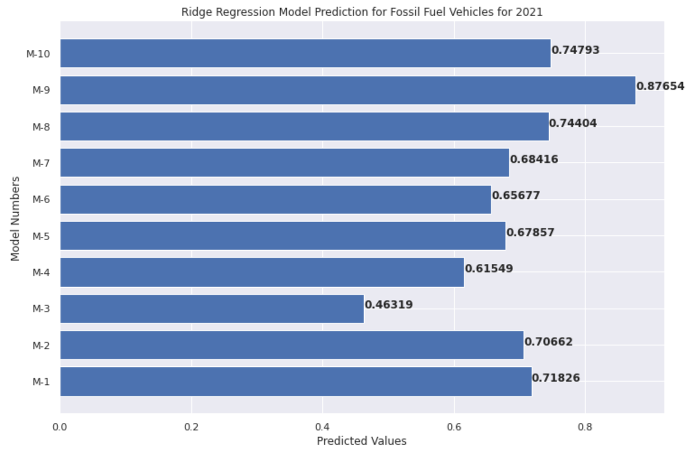


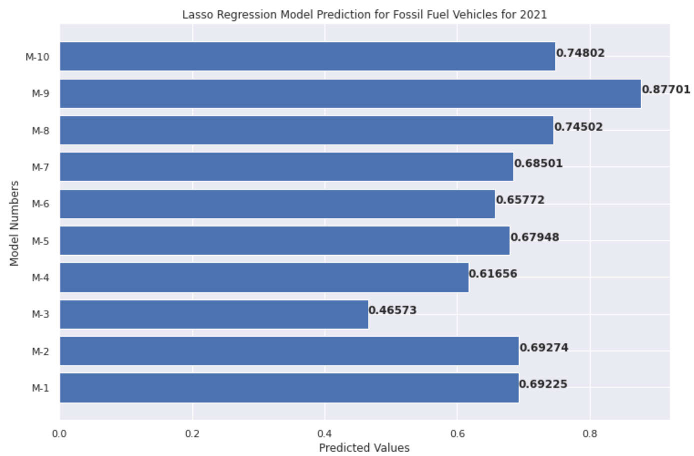
Fig 3. Carbon emission vs engine efficiency graph for Fossil Fuel Vehicles



(a)



(b)



(c)

Fig 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

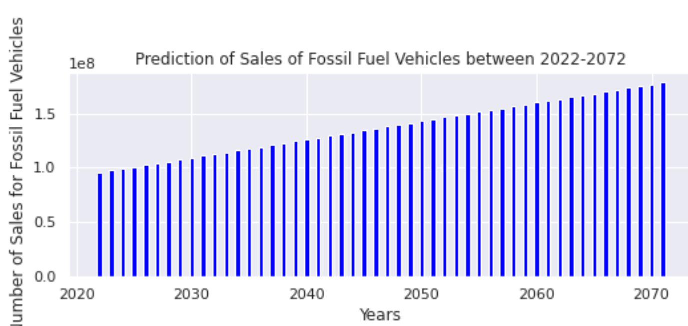
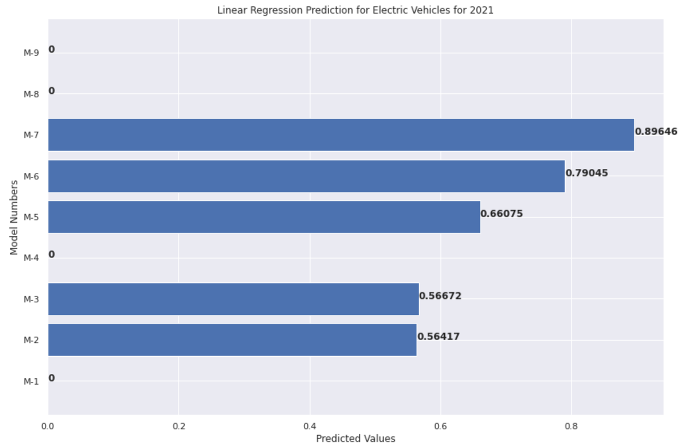
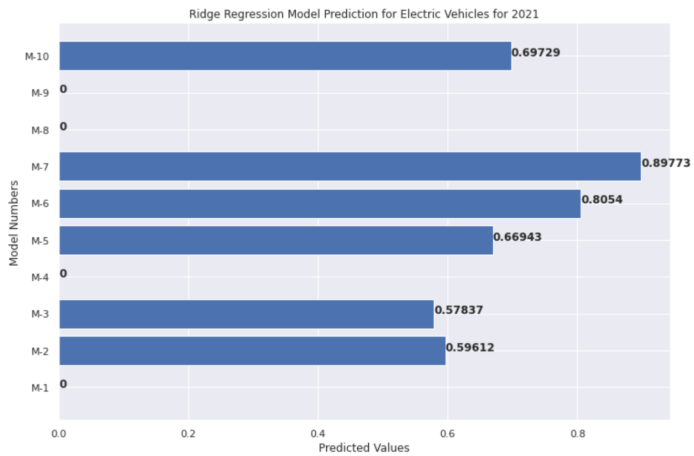


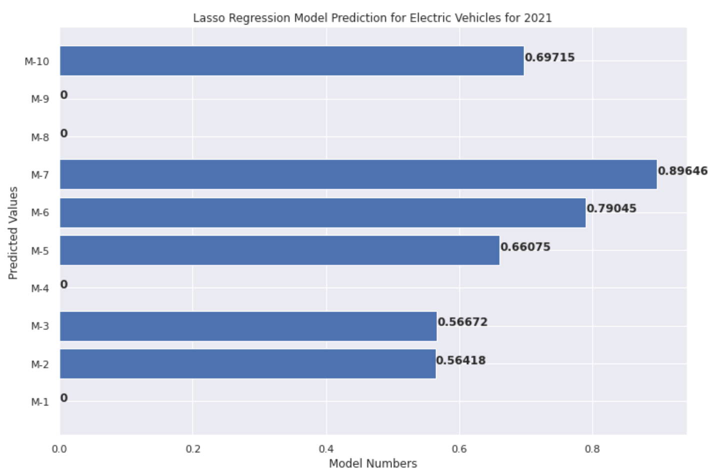
Fig 5. Graph of sales forecast with high accuracy model of fossil fuel vehicle for the study period (50 years)



(a)



(b)



(c)

Fig 6. Prediction of sales of electric vehicle for 2021 and its respective model accuracy
(d) Linear Regression Prediction for Electric Vehicles for 2021
(e) Ridge Regression Prediction for Electric Vehicles for 2021
(f) Lasso Regression Prediction for Electric Vehicles for 2021

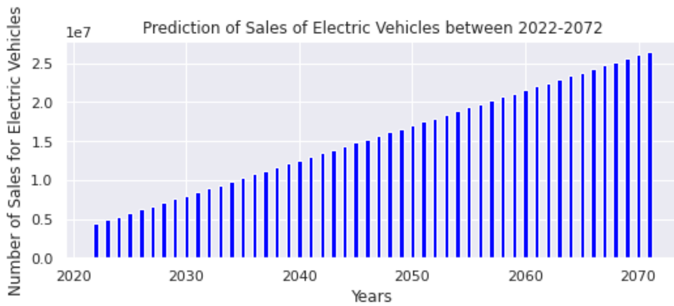


Fig 7. Graph of sales forecast with high accuracy model of electric vehicle for the study period (50 years)

TABLE 5. 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 5. 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 5. 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 5. 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 5. 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

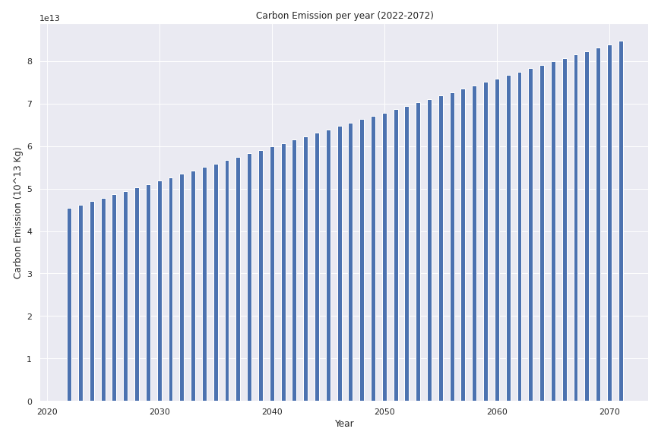


Fig 8. Carbon Emissions of fossil fuels for the study period (50 years)

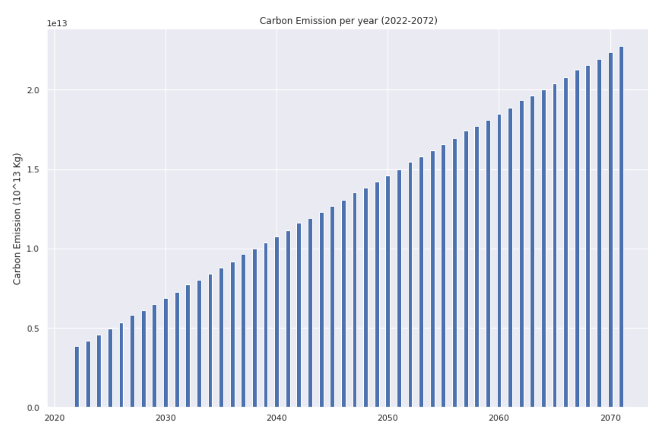


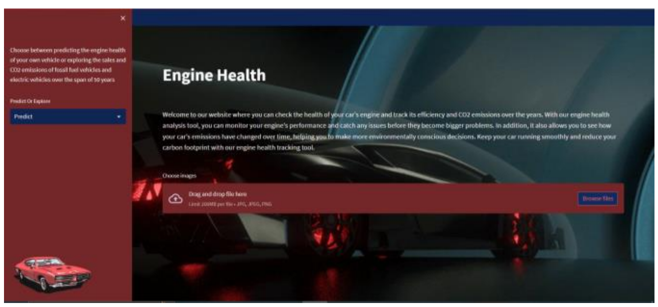
Fig 9. Carbon Emissions of electric vehicles for the study period (50 years

TABLE 5. 10 RESOURCE CONSUMPTION OF RESERVES BY VEHICLES FOR THE PERIOD OF 50 YEARS

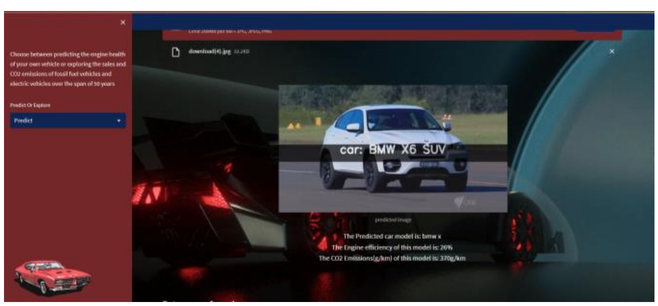
Material	Predicted Weight (Million tons)	World Reserve (Million tons)	Percentage Consumption (%)
Fossil Fuel Vehicles			
Lead	5.641	90.4	6.24
Electric Vehicles			
Aluminium	0.46	371	0.123989
Lithium	1.16	22	5.272727
Graphite	9.6	323.8	2.964793
Nickel	7.11	94	7.56383
Cobalt	1.651	7.6	21.72368
Copper	7.81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

TABLE 5. 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



(a)



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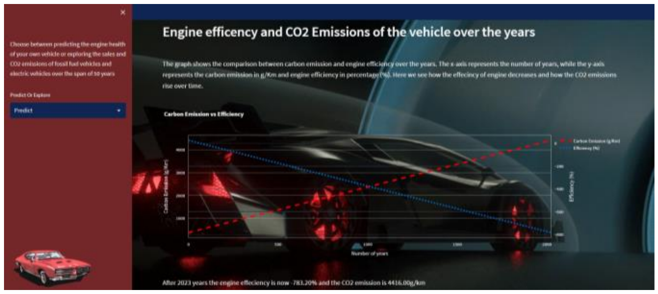
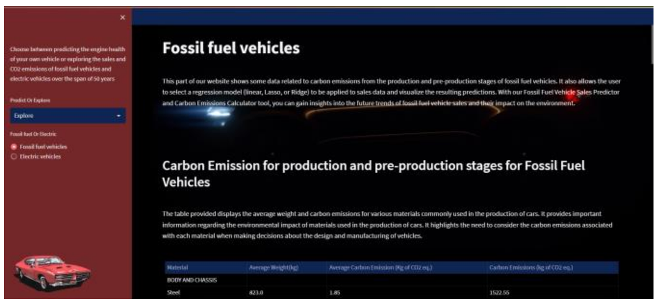


(c)

Fig 10. Predict part
(a) Predict page
(b) Prediction of car make, model
(c) Efficiency vs co2 emission graph



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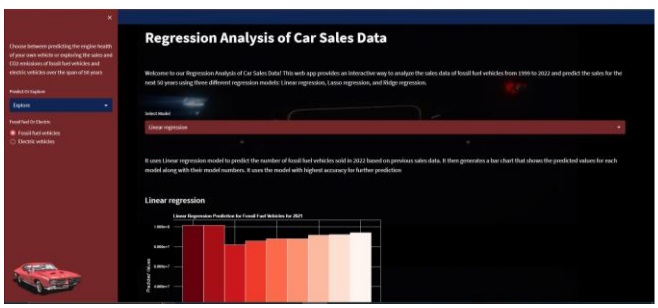

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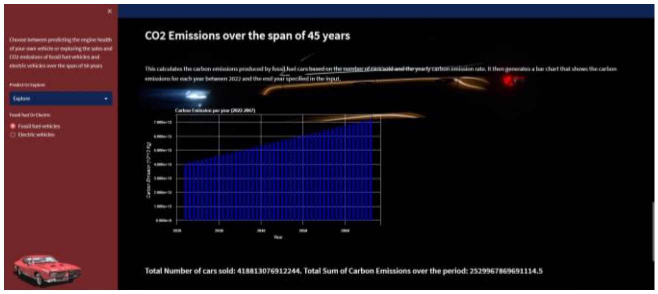
(c)



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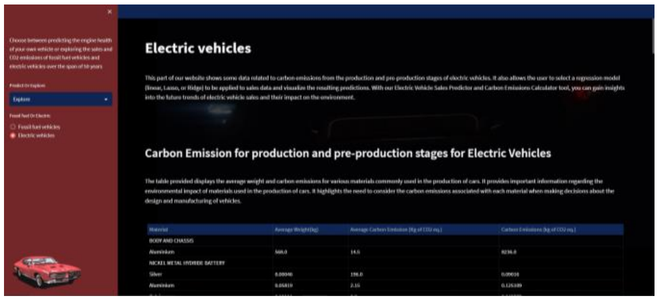

(e)

Fig 11. Explore part

(a) Explore page for fossil fuel vehicles
(b) Regression models
(c) Sales graph
(d) Carbon emission graph
(e) Explore page for electric vehicles

5. Discussion

While following the methodology described in (Fig 1.) for the exploration part, 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. 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 searching for data regarding 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 4) 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 Fig 2 and Fig 3 respectively). If we observe (FIg 3), 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 (Fig 4) and (Fig 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 (Fig 5) and (Fig 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 5). 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. (Fig 8) and (Fig 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. 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.

Now these data are used in our website to educate our users on the current trends. (Fig. 10 (a)) is the predict page that predicts the car model, its engine health and carbon emission over the years of ownership. The user uploads an image, and in (Fig. 10 (b)), we can see the predictions made for the car image uploaded. With the help of the cars purchase year, highest engine efficiency and initial co2 emission, an engine degradation function and the graph for engine efficiency vs emission is plotted out in (Fig. 10 (c)).

Next, in the explore section, we have 2 pages for fossil fuel and electric vehicles. (Fig. 11 (a)) shows the data about materials used in the production and pre-production of vehicles and their carbon emission. Then sales of these vehicles are predicted into the future (Fig. 11 (c)) through various regression that we can choose from (Fig. 11 (b)). Again using that regression model with the highest accuracy, carbon emissions for all vehicles up to 50 years are calculated and graphed (Fig. 11 (d)). All of these are calculated and analyzed for electric vehicles too (Fig. 11 (e)).

Overall, this web application provides valuable insights into the future trends of electric vehicle sales and their impact on the environment, allowing users to make informed decisions about their vehicle ownership and its impact on the environment.

6. CONCLUSION

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 of 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 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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