Group 5: Study the Impact of EVs on Indian Economy

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1 Introduction

At COP21, India had pledged to reduce its carbon footprint by 33-35% by 2030 below 2005 levels. It has also pledged to increase the share of non-fossil fuels-based electricity to 40 per cent by 2030. Considering the same, it is high time to switch to alternative fuel options to minimize air pollution and rising crude oil import bill of the country so that we can meet our commitments at the global level.

The transport sector in India is the largest user of oil and second largest source of CO2 emissions worldwide. India has seen a rapid increase in adoption of automobiles since the last ten years. Currently, Indian transportation sector accounts for one-third of the total crude oil consumed in the country, where 80% is being consumed by road transportation alone. It also accounts for around 11% of total CO2 emissions from fuel combustion.

With one of the lowest motorization rates in the world (22 cars per 1,000 people), India is among the fastest growing countries in transportation sector. From 2011 to 2020, India's domestic vehicle sale has grown at 4% CAGR. With rising income and rapid urbanization, the Indian mobility market is expected to expand rapidly. Transportation, however, has contributed significantly in India's overall GHG emission. During year 2016, transport sector contributed to 270.6 MT CO2e of GHG emission, third highest, only after power industry and industrial combustion. Within transportation, road transport has been the highest contributor to the GHG emission. With the rising transport industry, India is also facing intense emission challenges.

Government of India had notified the National Electric Mobility Mission Plan 2020 which seeks to enhance national energy security, mitigate adverse environmental impacts from road transport vehicles and boost domestic manufacturing capabilities for Electric Vehicles. In addition to this, the Government has notified Phase-II of Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme to stimulate the market of EVs in the country, de-licensed the charging infrastructure business and specified guidelines standards for charging infrastructure for electric vehicle thereby opening up the market of public charging infrastructure ensuring a roadmap for development of charging infrastructure, and introduced various financial incentives to reduce upfront cost of EVs and charging infrastructure.

While, Government of India has taken crucial steps towards faster adoption of EVs, there are several challenges and gaps existing in the EV ecosystem that must be addressed. In this context, our report on "Study the Impact of EVs on Indian Economy" will analyze different aspects of EVs and how it is going to impact our economy by 2030. This analysis will help us to understand the existing gaps in current landscape of EV industry India and the key action items required for enabling accelerated adoption of EVs to support India's vision of transitioning to sustainable and green mobility.

2 Problem Statement

Our country India invests its large amount of capital into import of crude oil and natural gas (petroleum products) and this is around 32% of total import done by India. Since that amount is paid in form of dollars, it causes the devaluation of Indian Rupees in international market. This gives rise to inflation and due to this Indian economy suffers a lot.
In order to relax the economic dependence on petroleum products, the Government has taken initiative to promote the electric vehicles. This is directly related to common men's life and has ability to bring out a revolution in transport sector of India and boost up the economy.
So we would like to analyse the following aspects:

1. Analysis of EV Sales by 2030

As we have previous data of number of EV yearwise from year 2016 to 2021, based on that data we will predict EV sales in future from 2022 to 2030. We will also analyse EV sales data monthwise as well as yearwise.

2. Study the Impact of EVs on Oil prices and Oil imports

As we know that our country is the 3rd largest importer of Oil and petroleum products ($4,057,000$ bbl per day).A large chunk of this imported material is being consumed into transport sector so here we are going to do analyse how oil imports and oil prices are affected due to introduction of Electric Vehicles.

3. Predict EVs future market share and study its impact on Indian power sector

As the sales of EV is increasing with time, we are going to predict EVs market share yearwise from 2022 to 2030. We will also calculate the electricity required by EVs in upcoming years to show its impact on Indian power consumption.

4. Study the impact of EVs on future petrol prices

An increase in fuel prices has affected not only those who have their own vehicle but also those who don't own one. Rising fuel prices impact citizens' lives because steep fuel prices lead to higher inflation. It affects prices of other essential goods. The value of essential commodities like food , medicines etc. have been adversely affected by a rise in fuel prices. So we are going to analyse the impact on fuel prices because of EVs.

5. Study the monetary impact of EVs on Indian Economy

As we know EVs are going to replace Oil-fuel based vehicles in the future, we will find out amount of money saved from oil and we will also calculate the extra electricity cost required by EV yearwise from 2022 to 2030. So finally we will calculate the expected effective money saved because of EV introduction.

6. Study the impact of EVs on reduction in CO_2 emission

As the oil-fuel based vehicle emits large amount of CO_2 which has adverse affect on environment. But EV runs on rechargeable battery that doesn't emit any harmful gases. So we will find out reduction in CO_2 emission because of introduction of EVs.

3 Salient features of Dataset used

Data Set 1: No. of registered vehicles in India

Vehicle dataset[1] contains 70 excel datafiles monthwise from JAN 2016 to OCT 2021. Each datafile contains following:

- Rows in each datafile contains different vehicle class data.
- Columns in each row contains different fuel type(petrol, diesel, electric etc) vehicles registered in India in that month.

Data Set 2: Electricity consumed by Evs

EV_Electricity_consumption.xlsx datafile[2] contains following:

- Rows contain 14 different types of EV in India.
- Columns in each row contain Daily km driven, Battery capacity in kWh, Driving range in km/full charge and Daily charging demand in kWh by the EV.

Data Set 3: Electricity prices in India

$electricity - price - in - india.xlsx$ datafile[3] contains following:

- There are 11 rows in datafile from year 2009 to 2019.
- Each row contains yearwise electricity price (Rs/kWh) in India.

Data Set 4: Oil data

Oil import year(2011-12 to 2020-21).csv[4]

- This data set contains the oil import data (in '000 Metric Tonnes) month-wise in respective years.

Oil_price_modified.csv[5]

- This data set contains the oil import price (Rs./bbl) starting from April-2011 to November-2021.

4 Methodology

4.1 Analysis of EV Sales by 2030:

4.1.1 Data Pre-processing :

We have 70 Excel datafiles monthwise from JAN 2016 to OCT 2021 in vehicle dataset which contain number of vehicles registered in that month. We collected yearwise and monthwise data in a dataframe in following steps:

1. we extracted all fuel type vehicle sales from 70 Excel datafiles monthwise and kept it in vehicle_dataset dataframe.

2. From vehicle_dataset dataframe we extracted diesel, petrol and electric vehicle sales data yearwise from 2016 to 2021 and kept it in DPEV_year_dataset.

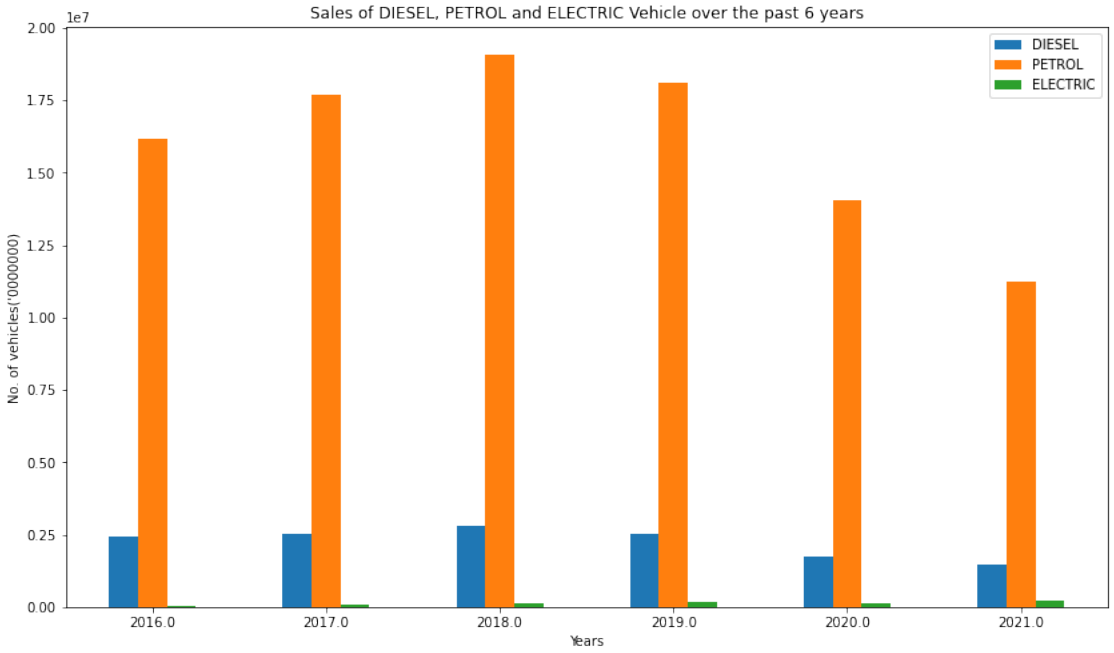

Figure 1: Comparision graph of Sales of DIESEL, PETROL and ELECTRIC Vehicle over the past 6 years

3. From vehicle_dataset dataframe we extracted diesel, petrol, electric and total vehicle sales data monthwise from JAN 2016 to OCT 2021 and kept it in DPEV_month_dataset dataframe. We added 'timeinterval' column which contains entries from 1 to 70 where each entry represents month from JAN 2016 to OCT 2021, 'Log ELECTRIC' column which contains *log* of column 'ELECTRIC' and 'Log TOTAL' column which contains *log* of column 'TOTAL' in DPEV_month_dataset dataframe.

4.1.2 ML Algorithms used :

In our model we have used Linear Regression as an ML algorithm. Linear regression performs the task to predict EV sales from year 2022 to 2030.

4.1.3 Implementation :

We have implemented this task in following steps:

- firstly we have taken the dataframe DPEV_month_dataset and removed the last one year data because it was affected due to covid-19 as it was anomalous in analysis.
- we have taken "time interval" feature as x variable and "Log ELECTRIC" feature as y variable and trained our model against these data points.
- RMSE value of our model is estimated 0.1981335 and R2 score is estimated 0.8967913.
- Here the plot of No. of EV's(In log) against month is drawn below as generated by our model.

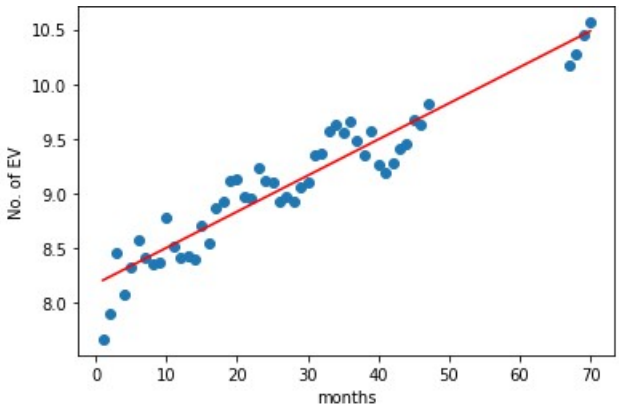

Figure 2: Model estimation of no. of EV's

- In next step we shall estimate that by the these many EV's will be in the market, what impact will this create on consumption of oil.So we have taken the data of total number of diesel and petrol vehicles in india in past years and how much petrol and diesel is consumed yearwise.
- After getting these many data we have calculated on an average vehicle(diesel or petrol)consumption of oil, We have find out that a diesel vehicle consumes 226.025 barrels and petrol vehicle consumes consumes 10.86 barrels in an year.
- Now we shall calculate what amount of oil consumption will be reduced in future because of increasing no. of ev's as predicted earlier by our model. After operating on collected and estimated data so far we find out this result.

	Year	No of EV	Reduced DP (in Mb)
0	2022	571780	21.787260
1	2023	849822	32.381843
2	2024	1263069	48.128299
3	2025	1877267	71.531851
4	2026	2790134	106.315947
5	2027	4146904	158.014653
6	2028	6163436	234.853109
7	2029	9160556	349.056125
8	2030	13615099	518.793127

Figure 3: no. of EV's vs reduced oil consumption till 2030

4.1.4 Result and its analysis:

Using the above prediction model we have predicted the No. of EV's for future years. Roughly we shall have around 4 crore EV's by the year 2030 as predicted by our model.

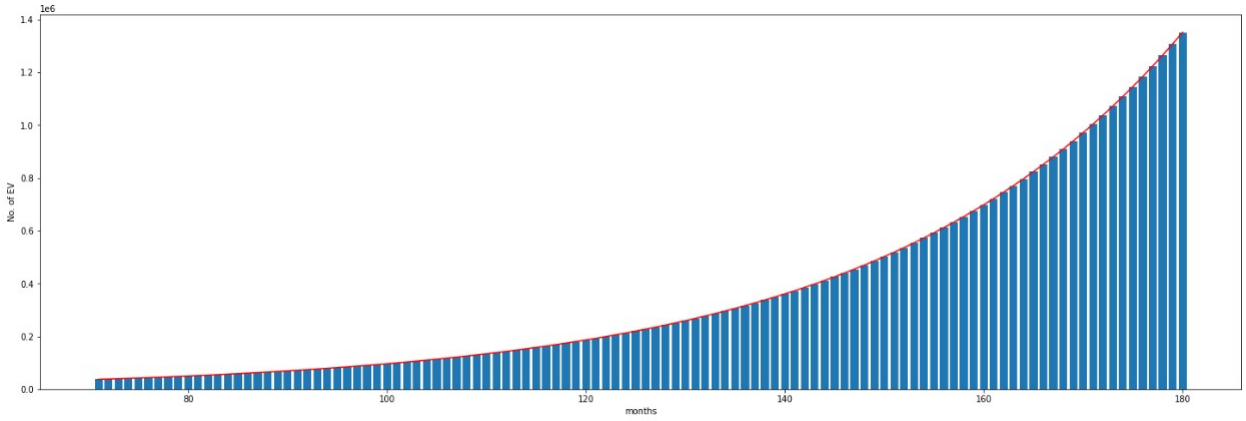

Figure 4: Model prediction of no. of EV's in future

4.2 Study the Impact of EVs on Oil import prices and Oil imports:

4.2.1 Data Pre-processing :

We read the csv file to get the relevant details using pandas. From the Oil import year(2011-2021).csv files we have extracted the Oil import data(in bbl) month-wise starting from year 2011 to 2021 in dataframe df_oil_import. The target feature oil import quantity type is being changed from series format to numeric format(float). Oil import data was given in ('000)metric tonnes format so it has converted into barrels by multiplying with 7330 (1 metric tonne = 7.33 Barrels)

We have used matplotlib.pyplot to visualize the distribution of features in the dataset. We have oil import features in the df_oil_import dataset which is drawn against the months starting from April 2011 to March 2021.

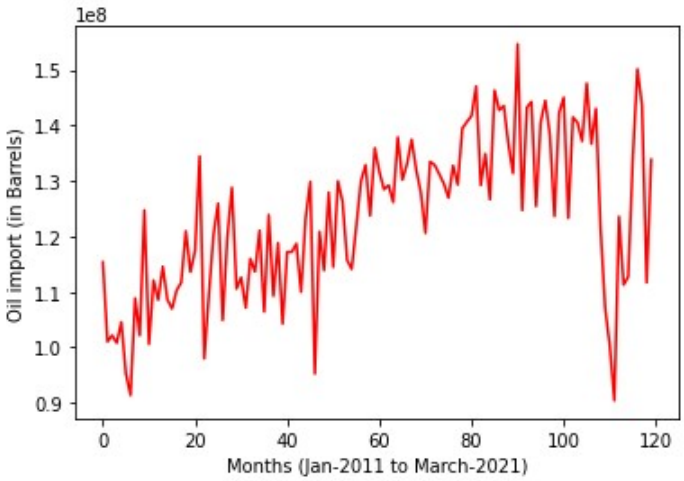

Figure 5: Oil import in past years

Similarly now we read the csv file oil_price_modified.csv. We have extracted oil import price(in Rs./bbl) month-wise starting from year 2011 to 2021 in data-frame 'Oil_price_df'. We have mapped the data month-wise and taken the features month and year along with price(Rs./bbl) in the data-frame. we have also changed the price category into numeric data type.

We have used matplotlib.pyplot to visualize the distribution of features in the dataset. We have price(Rs./bbl) feature in the Oil_price_df dataset which is drawn against the months starting from April 2011 to March 2021

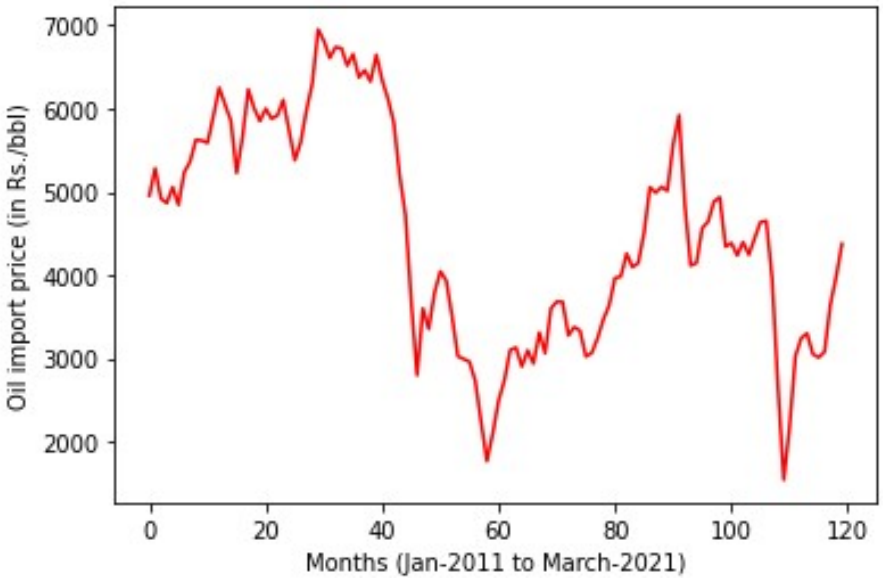

Figure 6: Oil import price in past years

4.2.2 ML Algorithms used :

In our model we have used Linear Regression as an ML algorithm. Linear regression performs the task to predict a dependent variable(target) based on the given independent variable(s). Here dependent variable is oil import price and independent variable is oil import.

4.2.3 Implementation :

- We have taken input variable from dataframe df_oil_import as 'oil quantity(in barrels)' and output variable from oil_price_df as 'price(Rs./bbl)'.
- We have done split our data into train and test data set category. Then a linear regression model is trained against provided data set and learned two parameters named as "y_intercept" and "coe". For our model we get Root Mean Square Error = 1271.6963.
- Plotting a graph Oil price Vs Oil Import using our regression model looks like as given below.

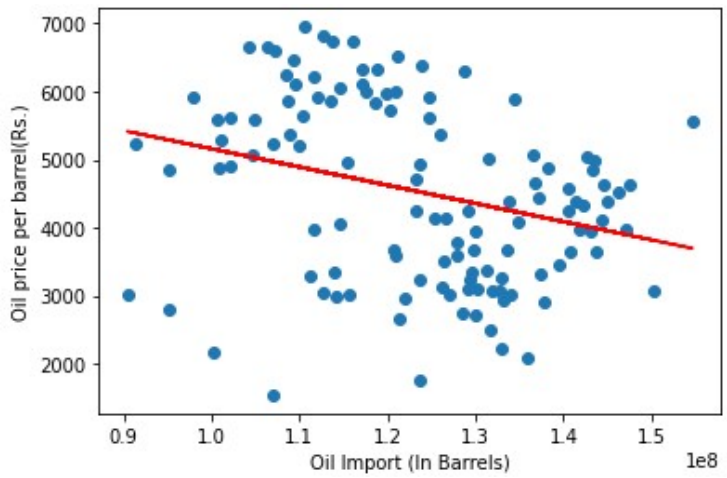

Figure 7: Oil import price vs oil import

4.2.4 Result and its analysis:

	Year	import oil(Mbbl)	import price(Rs./bbl)
0	2022	965.202450	4712.930708
1	2023	1001.942949	4585.287689
2	2024	1035.801711	4467.656332
3	2025	1064.382416	4368.361884
4	2026	1084.075662	4299.944048
5	2027	1089.466993	4281.213609
6	2028	1072.456554	4340.310895
7	2029	1020.950843	4519.250885
8	2030	916.918067	4880.679233

Figure 8: Oil import price vs oil import in future years

From Electric Vehicle analysis we come to know that how much oil(in Mbbl) shall we need in coming years(2022-2030). With using this model we have predicted the oil import price(Rs./bbl)in coming years till 2030. Hence analysis is done for oil import price(Rs./bbl) against oil import(in bbl).

4.3 Predict EVs future market share and study its impact on Indian power sector.

4.3.1 Implementation :

Step-wise implementation procedure is as follows:

1. We fetched total vehicle sales column from Vehicle dataset monthwise from 2016 to 2021 and took log of the column. We removed the data from 2020 to 2021 as vehicle sales were affected by Covid'19 pandemic, this was done in order to remove outliers from out datafile as it may impact the future prediction.

2. To predict sales of total vehicle we used linear regression and trained it on our dataset. Now using this trained model we predicted sales of total vehicle from 2022 to 2030.

3. To calculate EVs market share in future we used number of EV (already calculated above) and total vehicle sales from 2022 to 2030.

$$EV\ market\ share\ =\ \left(\frac{Number\ of\ EV}{Number\ of\ total\ vehicle}\right)\ \times\ 100$$

   From the above formula we found out EV market share from 2022 to 2030 yearwise.

4. We fetched daily charging demand by EV column from "Electricity consumed by EVs" datafile. Then computed its mean and multiplied it with 365 to find out average electricity required to charge an EV yearly.

5. To find electricity required by total EVs from 2022 to 2030, we multiplied number of EV (already calculated in objective-1) to average electricity required to charge one EV yearly.

   $Electricity\ required\ =\ Number\ of\ EV\ *\ Average\ electricity\ required\ to\ charge\ one\ EV\ yearly$

4.3.2 Result and its analysis:

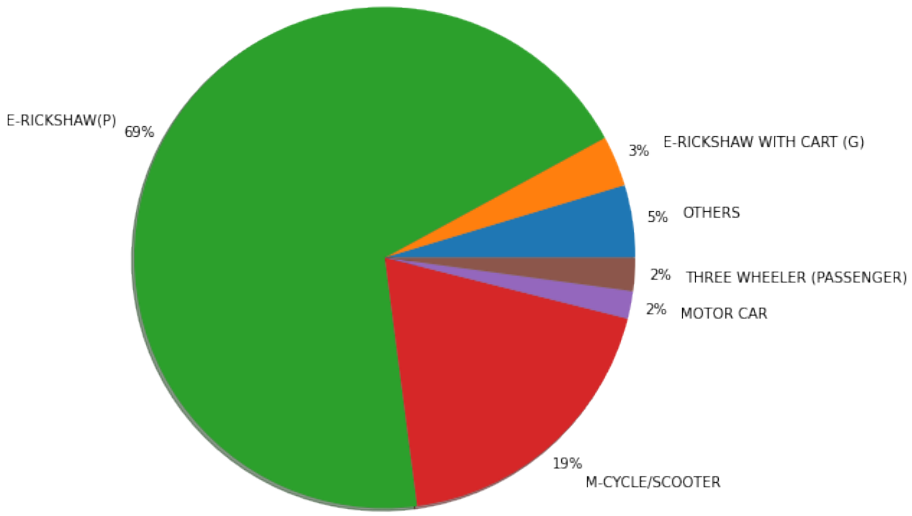

Figure 9: Current market shares of differnt type of EVs

As per govt. sources EV sales will be around 30 to 35% in India[6]. Also from the result in below figure, we can observe there is large number of EV sales in upcoming year and by 2030 EV market share is expected to reach around 36% of Auto mobile sector.

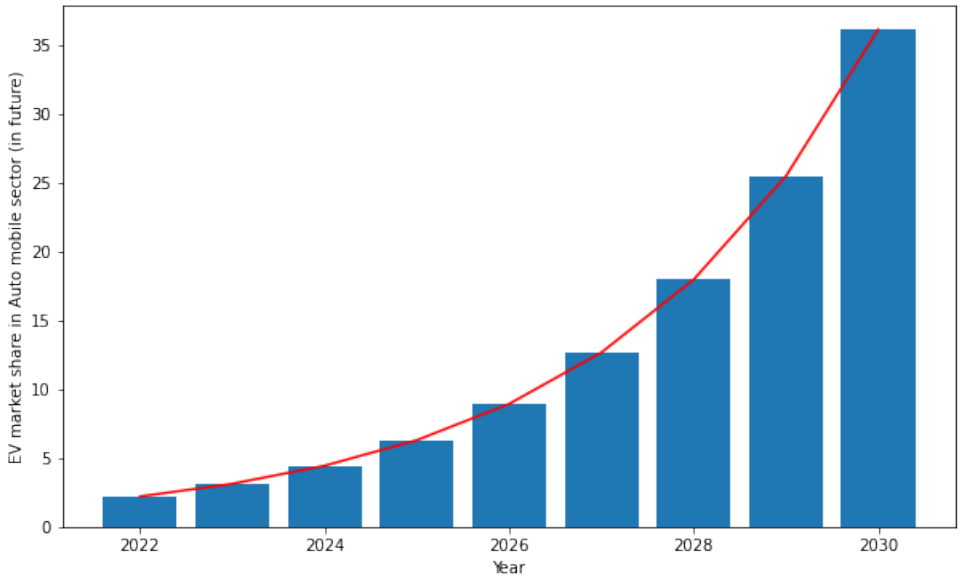

Figure 10: Expected EV market share in percentage in Auto mobile sector from 2022 to 2030

From the result in below figure, we can observe there is huge demand of electricity as the number of EV sales increases in upcoming year. According to our analysis in the year 2030 India will require 9.8×10^{10} kWh of electricity to charge.

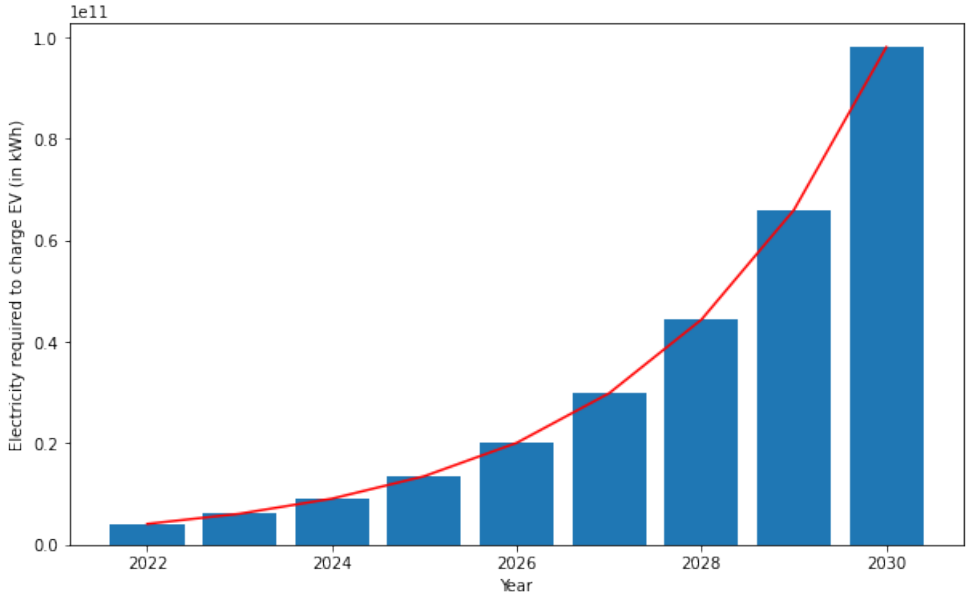

Figure 11: Expected Electricity required to charge EV from 2022 to 2030

4.4 Study the impact of EVs on future petrol prices

4.4.1 Data Pre-processing :

In preprocessing we have converted the monthwise oil import price data from oil_price_df dataframe in annual form (1 annual = April-March) and selling price of petrol in indian market is extracted manually from a internet source[7].

4.4.2 ML Algorithms used :

After pre-processing the data, we have obtained the Oil selling price data(Rs.) and Oil import price(Rs./bbl) data over the years. We have used a Linear Regression model to train Oil selling price data given the Oil import price data. The trained model has a MSE(Mean Squared Error) of 11.22.

4.4.3 Implementation :

We will use the Linear Regression model which was trained in the above step. Now we need to predict the future Oil prices based on the Oil imports by india over the upcoming years. This can be done in the following steps:

1. We can predict the Oil import price for the upcoming years using the model Oil import vs Oil import price.
2. Now we have used the Oil selling price vs Oil import prices model to predict the Oil selling prices for the upcoming years.

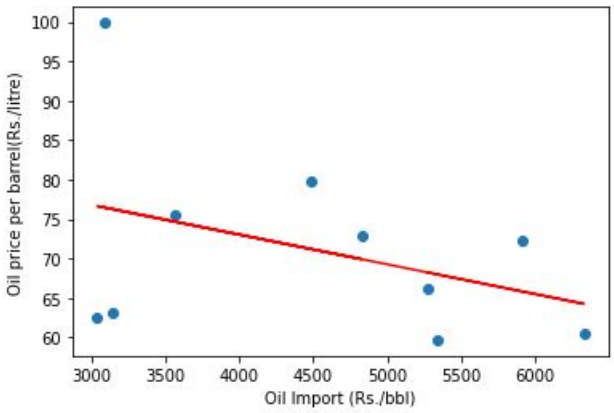

Figure 12: Linear model showing correlation between Oil import price(Rs./bbl) vs Oil Price per Litre(Rs./Litre)

4.4.4 Result and its analysis:

There is no co-relation b/w oil import price and oil selling price in India, number of factors responsible for influencing petroleum prices other than cost of crude oil like- demand and supply imbalances, taxes and duties on petroleum products and market conditions, production and consumption of petroleum products, petroleum reserves, imports of petroleum products, international prices of petroleum products, subsidy on petroleum products, and locational effects, etc.

	Year	Oil price(Rs./Litre)
0	2022	70.255270
1	2023	70.699157
2	2024	71.108228
3	2025	71.453530
4	2026	71.691458
5	2027	71.756594
6	2028	71.551080
7	2029	70.928804
8	2030	69.671914

Figure 13: Predicted petrol prices for the upcoming years

4.5 Study the monetary impact of EVs on Indian Economy

4.5.1 Implementation :

Step-wise implementation procedure is as follows:

1. We fetched electricity price(Rs/kWh) column from Electricity price in India dataset from 2009 to 2019.

2. To predict future electricity price(Rs/kWh) in India we used linear regression and trained it on our dataset. Now using this trained model we predicted electricity price(Rs/kWh) from year 2022 to 2030.

3. To calculate total electricity cost to charge EVs in a year we multiplied total electricity required in kWh (already calculated in objective-2) with predicted electricity price(Rs/kWh) from 2022 to 2030.

   $$Electricity\ cost\ of\ EV(Cr) = (Electricity\ required((kWh)) \times Electricity\ price(Rs/kWh)) \times 10000000$$

   From the above formula we got electricity cost of EVs from 2022 to 2030 yearwise.

4. We used 'oil consump reduced bcoz of EV (in Mb)' column (already calculated above) and we also used predicted oil import price in Rs/barrel (already calculated above) from year 2022 to 2030. We multiplied both of them yearwise to get money saved from oil import because of EV.

   $$Money\ saved\ from\ oil\ import(Cr) = \frac{Reduced\ oil\ consumption(Mb) \times Predicted\ oil\ import\ price(Rs/barrel)}{10}$$

5. Then finally we calculated total money saved because of EV introduction by subtracting electricity cost of EVs from money saved from oil import yearwise.

   $$Total\ effective\ money\ saved(Cr) = Money\ saved\ from\ oil\ import(Cr) - Electricity\ cost\ of\ EVs(Cr)$$

4.5.2 Result and its analysis:

As electric vehicles sale is going increase in future, the demand for oil consumption will automatically reduce. Which in turn will reduce the total oil import of India but the demand for electricity will increase as we have more electric vehicle to charge which will impact the total electricity cost. Still we can save significant amount of money as shown in the figure below from 2022 to 2030.

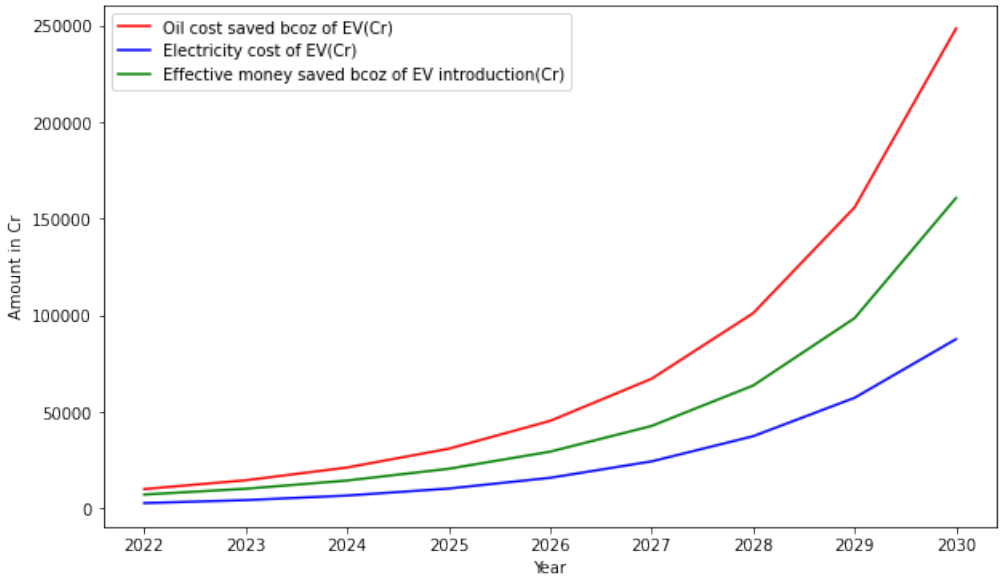

Figure 14: Expected effective money saved because of EV introduction from 2022 to 2030

4.6 Study the impact of EVs on reduction in CO_2 emmision

4.6.1 Implementation :

Step-wise implementation procedure is as follows:

1. To calculate reduction in CO_2 emission because of EVs in future we used number of EV (already calculated in objective-1) from 2022 to 2030.

2. From the government sources we found out that a typical oil-fuel based vehicle emits about 4.6 metric tons of CO_2 per year[8]. So to calculate reduction in CO_2 emission yearwise we multiplied total number of EV with 4.6 metric tons of CO_2 emission.

$$Reduction\ in\ CO_2\ emission(Metric\ ton)\ =\ Number\ of\ EV\ \times\ 4.6$$

4.6.2 Result and its analysis:

As electric vehicles market share is going increase, oil-fuel based vehicles market share will reduce in future, resulting in reduction of CO_2 emission in environment. As per our analysis we found out that total expected reduction of CO_2 emission in 2030 will be around $1.8\ \times\ 10^8$ metric tons. Below figure shows expected reduction in CO_2 emission because of EV introduction from 2022 to 2030.

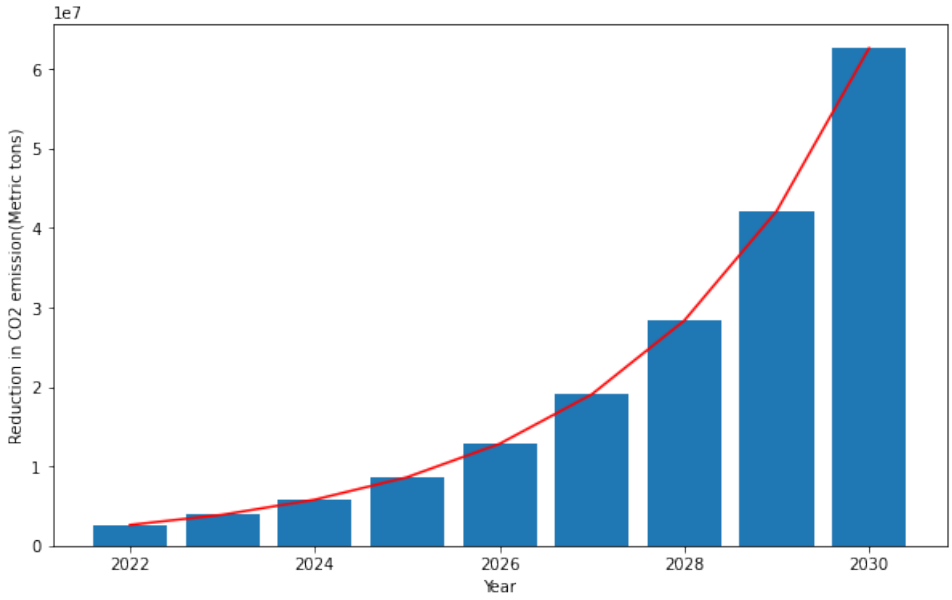

Figure 15: Expected reduction in CO_2 emission because of EV introduction from 2022 to 2030

5 Disadvantages of EV

As we saw above EVs have lot of advantages on our economy and environment but there are few concerns that needs to be taken care. These problems must be addressed and solved as soon as possible.

EV batteries manufacturing requires Lithium as a raw material which causes serious impact on environment. Lithium is used as cathode in lithium ion batteries. The most used technique of lithium sourcing is far from being eco-friendly. According to some sources, between 2008 and 2018, annual production of lithium rose from 25,000 to 85,000 tons. More than half of this lithium comes from the so called lithium triangle that lies under Argentina, Bolivia and Chile. To extract it, miners drill hole in the ground and pump out mineral rich brine to the surface. This brine is left out in open for several months to evaporate. A huge area of land is required for this purpose which could otherwise have been used for wildlife.

These process uses a lot of water(nearly 2 million litres) for each ton of lithium production. Lithium containing saltwater from underground lakes is brought to the surface and evaporates in large basins. This impacts the surrounding ecosystem as well as local farmers.

A common thread among successful areas of lithium extraction is that they are located in hot, dry, mountainous regions. Over time, the minerals lithium, sulfate, potassium, and boron that majorly comprise mountain ranges sink into the salt flats below the surface where lithium is derived. As well as being in a lithium dense area, it is efficiently produced if located in a region that has low precipitation and frequent sun so that the water can be evaporated in the least amount of time possible. Not only that, these large evaporation pools are not properly sealed. This sometimes leads to the discharge of toxic substances into the surrounding water supply. This happened in Tibet once, the accidental release of substances like hydrochloric acid killed large amounts of aquatic animals such as fish.

EV batteries also contain other components, apart from lithium, such as cobalt and nickel which also have potential harmful impact on environment. Moreover, the way that batteries are disposed at the end of their life also potentially damages the environment, if not properly handled. The best way is to recycle

them. Apart from this, the major portion of electricity required to run EVs is generated by non-clean sources(burning coal). This can lead to secondary environmental impacts like acid rain and respiratory problems in humans and animals.

On an average, the battery life of Electric vehicles as offered by tesla is 300,000 to 500,000 miles before it needs complete replacement[9]. Depending upon the distance covered by an average electric vehicle, the lifetime of battery in years is nearly 10 to 20 years. I will take the average battery life as (10+20)/2=15 years. So, after 15 years the battery will need to be replaced.

Amount of lithium used in the battery of one electric vehicle: A typical EV battery cell has perhaps a couple of grams of lithium in it. That's about one-half teaspoon of sugar. A typical EV can have about 5,000 battery cells. Building from there, a single EV has roughly 10 kilograms—or 22 pounds—of lithium in it[10].

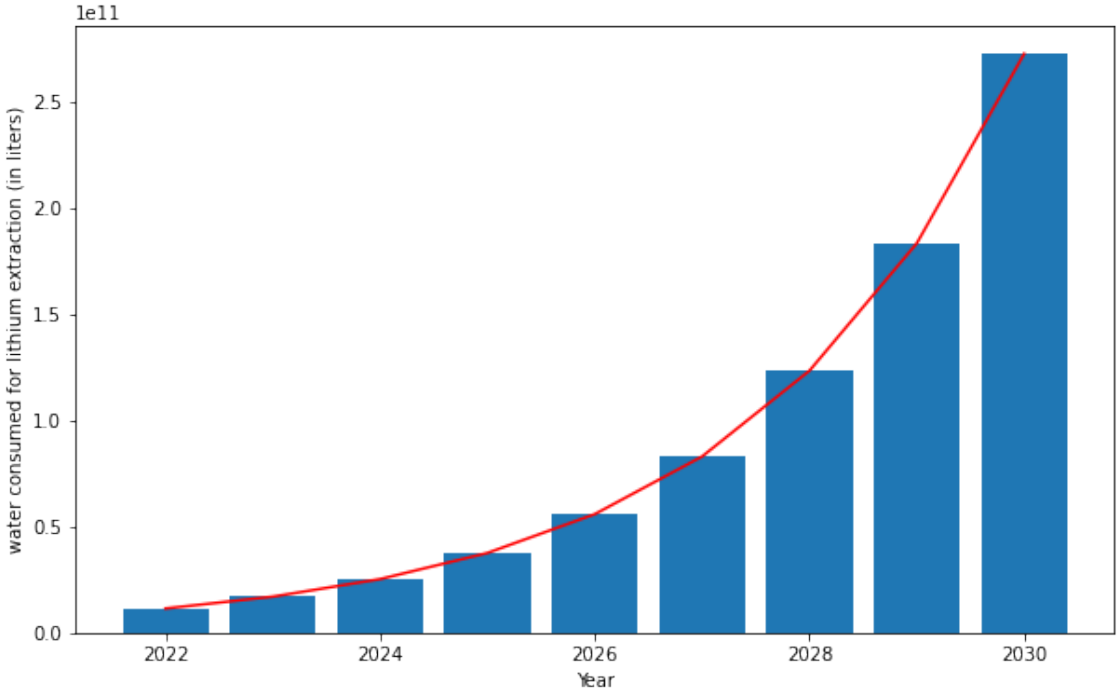

Figure 16: Predicted water consumption for lithium extraction from 2022 to 2030

6 Future Work

We have analyzed Impact of EVs on Indian economy but still there are many aspects left to analyzed and see how its going to change India's EV market. Here we have listed few of the aspects we would like too analyze in future.

Availability of adequate charging infrastructure is a key to faster adoption of electric vehicle. To accelerate the adoption of electric vehicles in India, the Ministry of Power has taken various measure. There was lot of apprehension about licence requirement for setting-up of charging station. EV charging industry considered the same as a major roadblock in development of charging infrastructure. So we can study the current no. of charging stations in India and predict its future requirements to cope up with EV demand.

Air quality changes due to the transportation and power sector scenarios. So we can analyse the impact of EV on modest changes in air quality index and related premature deaths in the country compared to the large total air pollution health burden in India.

The central government itself has backtracked on the 100% e-vehicles by 2030 target. They realised that you can't have electric charging infrastructure in place by 2030 to achieve that target. So since our current study of EVs was till 2030, but we expand it to 2050 to understand EVs demand in India for next 30 years from now and if India could achieve 100% EVs by 2050.

While many around the world have already made the shift to environment-friendly vehicles, Indians are just starting to appreciate the potential and usefulness of electric cars. In 2019-20, electric vehicle sales were up by 20%. So we can compare different Indian electric vehicles manufacturers on different aspects and report our result.

7 Conclusion

In this project, we have estimated the number of EVs for future years. As per our analysis there will be around 4 crore EV's by 2030. That will be 36% of automobile market share by 2030. The increasing sales of EV will save worth INR 4.5 lakh crore by 2030.

This affects the oil imported by India from international market. We have estimated that we shall reduce the oil import around 4000Mb by 2030. It will create impact on oil import price. But there is no co-relation b/w oil import price and oil selling price in India, number of factors responsible for influencing petroleum prices other than cost of crude oil like- demand and supply imbalances, taxes and duties on petroleum products and market conditions, production and consumption of petroleum products, petroleum reserves, imports of petroleum products, international prices of petroleum products,subsidy on petroleum products, and locational effects, etc.

As the EVs sale is growing year by year there will be huge demand of electricity in upcoming year. According to our analysis in the year 2030 India will require 9.8×10^{10} kWh of electricity to charge EVs. So in order to fullfil this demand of electricity India needs to upgrade its power infrastructure rapidly. Since a large amount of electricity is produced using non-clean energy sources(like coal), we need to shift to cleaner sources of energy to produce electricity.

Because of EV sales in upcoming years, it will lead to a significant amount of reduction in oil consumption and CO_2 emission in transport sector in future. We have found out that India will be reducing 1.8×10^8 metric tons of CO_2 emission by 2030.

This will help India fulfil its global commitments to lower carbon emissions and increase use of cleaner sources of energy and transportation as required by the Nationally Determined Contributions (NDCs) under the United Nations Framework Convention on Climate Change (UNFCCC).

EVs are lot more environment friendly than fuel based vehicles but this doesn't mean EVs are completely clean. The lithium used in the battery of EVs consumes huge amount of water for its extraction. A large amount of land is also kept reserved for this purpose for several months. We need to adapt to cleaner way of extracting lithium.

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