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Predicting the effect on Energy Sector and Greenhouse Gas (GHG) Emissions due to the electrification of the Indian Automobile Sector

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***Abstract*— Global Warming continues to be the most critical man-made issue in the modern world. Global Warming causes a rise in temperature which could lead to melting glaciers, which would cause severe floods, droughts, and other extreme weather conditions. To tackle this looming threat over the whole world, most of the countries are reducing their carbon emissions across various sectors by using various innovative ways. In 2015, India signed a landmark Paris climate agreement with more than 170 countries, marking an important step that unites developing and developed countries in the fight against global warming by reducing GHG emissions. In India, the transport sector is the largest user of oil, which has resulted in it becoming the second-largest source of CO_2 emissions worldwide [1]. India hopes to reduce its GHG emissions by introducing electric vehicles across several segments in the Indian Automobile Sector. In this paper, we analyze and predict the effect on GHG emissions, while factoring in the growth of electric vehicles in India. India has also set a national goal of achieving 30% electric vehicle penetration across multiple segments by 2030 and introduced the NMTMBS to improve local EV production.**

Keywords*— *Greenhouse Gasses (GHG), National Mission on Transformative Mobility and Battery Storage (NMTMBS)

I. INTRODUCTION

Over the years, the exploitation of natural resources has caused pollution and serious damage to the atmosphere. Such exploitation of natural resources has resulted in Global Warming, which has become one of the most critical man-made issues in the modern world. This has created an immediate need for environment-friendly solutions to our already existing services and products which contribute towards polluting the environment. In India, the transport sector is the largest user of oil, which has resulted in it becoming the second-largest source of CO_2 emissions worldwide [1]. India hopes to reduce its GHG emissions by introducing electric vehicles across multiple segments in the Indian Automobile Sector. There are a lot of advantages of using electric vehicles over petroleum-based vehicles. These electric vehicles are environmentally friendly and do not release GHG that are harmful to human beings as well as the environment. Even though the motorization rate in India is among the lowest in the world with 22 cars per 1000 people. The automobile industry in the transport sector is growing at a rapid pace, with the domestic vehicle sales of 2-wheelers, 3-wheelers, passenger vehicles, and commercial vehicles at ~4% CAGR. This is happening due to the increase in income of the people and rapid urban growth in the mobility market.But will the rapid expansion of electric vehicles in the Indian automobile industry result in the drastic reduction of greenhouse gas emissions (GHG) in India?

The Government of India (GOI), which signed the Paris Agreement in 2015, aims to reduce carbon emissions in its gross domestic product (GDP) by 33-35% compared to 2005 levels by 2030. In India, more than 300 million vehicles travel across the country, adding roughly 30 million vehicles every year [2]. This confirms that the transport sector is the third-largest emitter of greenhouse gasses (GHG) and the majority comes from road transport [3].

To understand whether electric vehicles are the future or not?. And whether electrification of the Indian automobile sector will result in a reduction of greenhouse gas emissions? We are doing a study on the growth of electric vehicles in India and their effect on greenhouse gas emissions (GHG).

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II. LITERATURE SURVEY

This section briefly covers the work done by various researchers regarding the effect on the Energy Sector and Greenhouse Gas (GHG) Emissions due to the electrification of the Indian Automobile Sector.

In Ref. [4], authors Marc Barbar, Dharik Mallapragada, Meia Alsup, and Robert Stoner have predicted various future possible scenarios of Indian electricity demand using a custom regression model.According to this paper, two major factors for the increase in electricity demand are air conditioning and electric vehicles.An hourly temporal resolution at a customizable level of spatial aggregation is used to make projections. The study is useful in future studies for infrastructure planning of charging stations.The paper projects electricity consumption data sets spanning up to the year 2050 in five-year increments which is useful in further studies of the impact of vehicle electrification on electricity demand.

In Ref. [5], Carbon Footprint Reduction with the Adoption of the Electricity-Powered Vehicles; the paper was published under the authorship of Olumide A. Towoju. The paper suggests that adopting the electric vehicle does not necessarily result in a reduction of CO_2 emission. CO_2 emission due to electricity generation required for electric vehicles needs to be reduced to make them more environmentally friendly. According to the paper, the adoption of electric vehicles along with renewable energy for electricity generation is necessary to reduce CO_2 emissions.

In Ref. [6], Addressing the challenges to electric vehicle adoption via sharing economy: an Indian perspective; is a study done for investigating the challenges before India for electric vehicle adoption by 2030. The study takes into consideration measures taken by the Government of India to promote electric vehicles and hurdles such as the high cost of electric vehicles and purchasing power of Indian consumers.

III. PROPOSED SYSTEM

To Predict the effect on Energy Sector and Greenhouse Gas (GHG) Emissions due to the electrification of the Indian Automobile Sector we compared direct CO_2 emissions from ICE vehicles and the indirect emissions caused by electric vehicles. Next, for calculating the direct CO_2 Emission due to ICE vehicles, we gathered data of total vehicle registration in India and extrapolated it till 2030 using the ARIMA model. After that, for estimating the indirect CO_2 emission due to electric vehicles we predicted the total CO_2 emission from power plants required for powering electric vehicles in 2030.
For doing this, we gathered total energy generated from various sources in India and expected energy generated according to the IEA report and NDC compliant in 2030. In our study we have calculated the total CO_2 emission due to electric vehicles for 30% EV penetration and 100% EV penetration scenarios.

1. ARIMA Model:

ARIMA Stands for the Autoregressive Integrated Moving Average model, it's a univariate model consisting of three parameters : p determines the number of autoregressive terms, q determines the number of errors terms, d determines the number of differences needed to create a stationary time series. The ARIMA model is great for modeling non-seasonal time series whose exogenous factors effects can be observed by looking at the time series itself.

To use the ARIMA model we need the time series to be stationary thus the first step of forecasting is to differentiate the series from its own lagged values to create the stationary series. The number of differencing required is the value of d.AR is a forecasting model where the next value of the time series is the weighted sum/linear combination of the previous values of the time series and MA is a forecasting model where the next value of the time series is the weighted sum of the previous errors from the previous forecasting models. Our ARIMA model's equation is:
Predicted Yt = Constant + Linear combination Lags of Y (up to p lags) + Linear Combination of Lagged forecast errors (up to q lags)Where the order of p decides the number of lagged terms and the order of q decides the number of error terms.Finding the correct parameters to forecast our time series was done using the auto_arima function in the pmdarima. Arima module where d was found by Kwiatkowski–Phillips–Schmidt–Shin test and p and q values were found by fitting them to our registered vehicles data in the 2,2 and 5,5 state space. We use this model to predict the growth of ICE vehicles and Electric Vehicles.

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IV. METHODOLOGY

A. Estimating CO_2 Emission Due To Electricity Generation:

India stands third in the world for the production of electricity. In India, electricity is generated from thermal sources which include fossil fuels like natural gas, coal, oil, etc, nuclear sources, hydropower, and other renewable sources. Major production of Electricity in 2020 is achieved through thermal power plants which are around 62% of the total power generation. Followed by Renewable sources and Hydropower plants which generate about 23.5% and 12% of India's total power generation. Nuclear power plants generate less than 2% of total power generation.

The following table shows energy generated from various power plants in India taken from CEA(Central Electricity Authority) Report 2019-2020[7].

TABLE I
Energy generated from various power plants in India

Year	Thermal	Nuclear	Hydro	RES	Total
2003	76762	2720	26767	1628	107877
2008	91907	4120	35909	11125	143061
2013	151531	4780	39491	27542	223344
2018	222907	6780	45293	69022	344002
2020	230600	6780	45699	87028	370106

*Renewable Energy Sources (RES) includes Small Hydro Project (≤ 25 MW), Biomass Power, Urban and Industrial Waste Power and Solar Power.

Nationally Determined Contribution (NDC), is an organization that makes climate action plans to cut emissions and adapt to climate impacts. According to a report published by NDC, 3443 TWh of electricity is expected to be generated from 839 GW capacity power plants by India in the year 2030.

IEA(International Energy Agency) which provides analysis, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy, published a report predicting the total electricity production in 2030.According to which India is expected to have 985GW installed capacity generating 3631 TWh of electricity.

The table below shows installed capacity and electricity production for the year 2021 taken from the CEA report[8]. It also consists of predicted installed capacity and electricity production for the year 2030 based on the IEA report and NDC compliance.

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Table II

Predicted installed capacity and electricity production for the year 2030

Type Of Res.	2021* (Recent Year)		2030 (IEA)		2030 (NDC)	
	IC (GW)	EP (TWh)	IC (GW)	EP (TWh)	IC (GW)	EP (TWh)
Coal	203	981.2	223	2032	361	2156
Gas	24.9	51.02	85	145	24	41
Diesel	0.5	2.04	0	0	1	0
Lignite	6.6	29	9	13.5	4	6
Hydro	51.3	150.3	89	263.8	83	246
Wind	40	60.15	170	423.5	110	274
Solar	49.3	60.4	333	555.6	178	297
Nuclear	10.17	42.9	17	110.9	61	398
Other RES	10	26.65	59	86.76	17	25
Total	**395.7**	**1403.6**	**985**	**3631**	**839**	**3443**

Note: IC = Installed Capacity,
EP = Electricity Production

Based on CEA CO_2 Baseline Database for the Indian Power Sector user guide[9], weighted average specific emission for fossil fuel-fired stations in FY 2019-2020 in t CO_2 /MWh is given below.

TABLE III

Weighted average specific emission for fossil fuel-fired stations in FY 2019-2020 in t CO_2 /MWh

Coal	Diesel	Gas*	Lignite	Oil
0.98	0.58	0.43	1.36	-

*Only gas-fired stations that do not use any other fuel. Stations that use naphtha , diesel, oil as a second fuel are excluded from the weighted average.

According to the above table, the highest CO_2 /MWh factor is 1.36 CO_2 /MWh of Lignite followed by Coal and Diesel emitting 0.98 and 0.58 CO_2 /Mwh. Gas-fired stations emit 0.43 CO_2 /Mwh.

Based on table I and table II total CO_2 emissions from electric

power plants in a Million tons of CO_2 are given below.

TABLE IV
CO_2 emission from electric power plants
(In a Million tons of CO_2)

All resources	2021 (In Millions Tons Kg of CO_2)	2030 IEA Report (In Millions Tons Kg of CO_2)	2030 NDC Compliant (In Millions Tons Kg of CO_2)
Emission from all the resources	1024.13	2072.07	2138.67

Above table shows that 2072.07 Million Tons Kg of CO_2 is expected to be emitted from all resources in the year 2030 according to the IEA report whereas 2138.67 Million Tons Kg of CO_2 in 2030 based on NDC Compliant.

B. Estimating Total Vehicles Registration in 2030

We have used the ARIMA model to project total vehicle registration data till 2030. Registered Vehicle Data was taken from the MORTH 2021 report and consisted of registrations till 2019[10].

ICE emissions depend on the amount of fuel consumption and an increase in Total Vehicles Registration indicate an increase in total vehicles on road for that year .CO_2 emissions are best estimated from total fuel consumption however models that rel y on fuel consumption data could not be used as fuel consumption data on a national level is unavailable for India.

We have categorized the vehicles into following categories.

TABLE V
Total Vehicle Registration from 2000 to 2019 in India
(In millions)

Vehicles	2000	2005	2010	2015	2019
Two-Wheelers and Three-Wheelers	34.2	58.8	91.6	154.3	221.6
Cars, Jeeps, Taxi	6.2	10.3	17.1	28.6	38.4
Buses	0.5	0.9	1.53	1.97	2.1
Goods Vehicles	2.7	4.03	6.4	9.4	14.8

Other Vehicles	5.4	7.5	11.1	15.8	20.3
Total	49	81.5	127.7	210	297.2

In Table VI we have projected the total vehicle registration in 2030 based on data given in table V using the ARIMA model.

TABLE VI
Projected Vehicle Registration in 2030 India
(In millions)

Vehicle Type	2019	2030
Two-Wheelers and Three-Wheelers	221.6	467
Cars, Jeeps and Taxis	38.4	74.8
Buses and Goods Vehicles	15.8	26.68
Other Vehicles	20.3	30.9

C. Total Electric Vehicles Registration in 2030

As you can see in figure 2.1, The total registered electric vehicle taken from Vahan Dashboard accessed on 5th March 2022 in India is 10,27,207 [11]. Out of which, maximum vehicle stock comes from the 2 and 3 wheelers segment. The 3 wheelers and 2 wheelers segment contributes about 65.3% and 31.5% respectively.

TABLE VII
Total Electric Vehicle Registration till 2022 India

Vehicle Type	Total EV's till 2022
Two-Wheelers	3,23,018
Three-Wheelers	6,70,247
Cars	28,402
Buses and Goods Vehicles	5,540
Total	10,27,207

D. Charging demand of electric vehicles

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According to a Brookings Institution India report, Total electricity demand for EVs may vary between 37 and 97 TWh under 33 percent and 100 percent penetration of EVs by 2030. Analyzing the charging time of these vehicles during the day, it can be seen that the total peak BEV charging load is a little over 30 GW, which is about 6% of the total peak load by 2030 (480 GW). In the peak time (between 10 am - 6 pm) the demand can reach up to 48GW (10% of total peak load, normally it is 6% of total peak 30GW).

TABLE VIII
Daily Charging Demand For Electric Vehicles Demand

Vehicles Segment	Daily kms driven	Battery capacity in kWh	Driving range in km/ full charge	Daily charging demand in kWh
E-2W	40	2.5	80	1.25
E-3W (passenger / cargo)	120	7	100	8.4
E-car (personal)	40	30.2	312	4
E-car (commercial)	100	21.2	181	12

For the 2-wheelers, 3 wheelers, cars and buses, and goods vehicles daily charging demand is 1.25 kWh, 8.4 kWh, 10kWh, and 153kWh respectively. Analyzing this data, we estimate that the yearly charging demand for all these vehicles will be around 2.616TWh.

E. CO_2 emission from Electric vehicles

To calculate CO_2 emission from electric vehicles, firstly we identified how many electric vehicles are currently present in India (Table VII). After that, by using the daily charging demand (Table VIII) of EVs we calculated the total electricity required to power all the EVs. The total electricity demand is around 2.616TWh in one year. CO_2 emitted from the power plants to generate this much amount of electricity will contribute towards the indirect emission from all EVs. As we know that the GHG emission from renewable power plants is negligible so we have only considered GHG emission from non-renewable power plants.

Yearly Charging demand of EVs = Vehicles daily charging demand * 365 * Vehicle Stock.

Using this method we calculated the total CO_2 emission from all the EVs in India till 2022, which came to around 1.906 Mt CO_2 . In FY 2030 total charging demand of EVs according to our predictions will be around 33TWh considering 30% EV penetration and 97TWh considering 100% EV penetration. By our estimations, the indirect CO_2 emission for the 30% EVs penetration scenario will be around 21.113 MtCO_2 and for the 100% scenario will be 55.352 MtCO_2 .

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TABLE IX
CO_2 emission from EV's in different scenarios

All resources	2022	2030	
		30% penetration EV's	100% penetration EV's
All Vehicles (2W, 3W, buses,cars)	1.906	21.113	55.352

F. CO_2 emission from ICE vehicles

To calculate CO_2 emission from ICE vehicles, the first approach that we used is based on VKT (vehicle kilometers traveled) data. We obtained the value of all registered vehicles that are currently in running state, then we used the efficiency and VKT data of these vehicles to calculate the total CO_2 emission from ICE vehicles but the VKT data is somewhat unclear in India. For example, the data for average distance traveled by different categories of vehicles in India is inconsistent and different across multiple studies which were conducted. So we used an alternate approach to calculate total CO_2 emission from ICE vehicles. In this approach, we first obtained the categorical CO_2 emission data from all types of vehicles in a one-year period. According to the IEA Report 2019, the total CO_2 emission from 2 & 3 Wheelers is 57MtCO_2 , for cars is 58MtCO_2 , for Trucks is 131 MtCO_2 and others contribute about 91MtCO_2 .

Based on the IEA report[] and Table V we have calculated the Co2 emission rate of vehicles.

TABLE X
CO_2 emission rate

Vehicle Category	2019
Two-Wheelers and Three-Wheelers	0.2572
Cars, Jeeps and Taxis	0.5104
Buses and Goods vehicles	8.2912
Others	4.4828

Above table shows that the emission rate of 2 & 3 wheelers, cars, jeeps and Taxis, Buese and Goods Vehicles and others are 0.2572, 0.5104, 8.2912 and 4.4828 respectively. This emission rate will not significantly change in the next few years because efficiency will increase and due to this reason the emission rate will decrease.Based on Table VI and Table X we have calculated

category wise Co2 emission by vehicles in 2303 by multiplying the Co2 emission rate and vehicles registered . So the maximum emission of CO_2 in the year 2030 by ICE vehicles is 592.81 $MtCO_2$

TABLE XI
CO_2 Emission

Vehicle Category	2030 (In $MtCO_2$)
Two wheelers	120.1
Cars, jeeps and taxis	112.98
Buses and goods vehicles	221.21
Others	138.52
Total	592.81

V. CONCLUSION

As humanity continues to thrive on planet earth while using its natural resources, we as human beings should limit the harm caused to the environment by various man-made sources. The threat of Global Warming is getting more severe day by day. 19 out of 20 warmest years until now have occurred in the 21st century. As a result countries across the globe have started adopting alternative sources, across various sectors to cut down on their GHG emissions. In India, the transport sector is the largest user of oil, which has resulted in it becoming the second-largest source of CO_2 emissions worldwide. Electric vehicles are considered to be the most effective solution to this problem.

Our study has shown that by the year 2030 if India is able to achieve its goal of 30% EV penetration across multiple transport sectors, then India would reduce its annual carbon emission by more than 150 million tonnes of CO_2 , which would be nearly 26% of the total carbon emission. This proves that electric vehicles are the way towards a sustainable future.

VI. FUTURE WORK

Our study is based on the goal set by the Indian Govt. which is, 30% Electric Vehicle penetration across multiple automobile segments by the year 2030. In the future, as the Electric Vehicle sales data for a longer period of time becomes available, a prediction model with high accuracy could give a better understanding of the goal set by the Indian Govt. As the fuel prices in India are skyrocketing, and the Indian Govt. introducing various schemes and subsidies for purchasing electric vehicles, these factors might further boost the sales of electric vehicles in India. Thus the goal of achieving 30% electric vehicle penetration by 2030 might be reached quite sooner.

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