A study on the sustainability of Electric Vehicles.

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ABSTRACT: The centuries-old automobile industry is gearing up with the new transformation, electric vehicles. And electric vehicles are capturing the automobile industry with the tag of "0 emissions". Are electric vehicles green just because they use Electricity rather than Fuel? With this paper, we want to discuss whether EVs are sustainable. This paper presents an in-depth study that indicates why our society and consumers are welcoming EVs in a brief time, increasing the demand for more electricity production. This paper also discusses people's perspectives on electronic vehicles and their sustainability. This study aims to analyze the EVs and conventional vehicles' CO2 emissions at the different levels of reading, manufacturing, and on-road emissions. With this study, we want to understand electronic vehicles and their sustainability in depth.

Keywords: Electric vehicle (EV), Internal Combustion Vehicle (ICV), CO_2 emission, Pollution, Environment

INTRODUCTION

Global warming is the first world problem, and one of the main reasons for the rise in the earth's temperature is the burning of fossil fuels. On the other hand, daily the number of vehicles is increasing on the road, so how do we tackle the pollution problem? This question comes with two solutions, one is to reduce the usage of the vehicles, and the other is to find an alternative for fossil fuel vehicles. Reducing the use of vehicles is more of a utopian idea because the usage of vehicles is increasing rapidly but never decreasing. So, the other alternative that can be considered is to replace the conventional vehicle.

The world is witnessing a new facet in the automobile industry, which is the boom of EVs, and the world is welcoming that change as a ray of hope to make our world a better place to live in by reducing CO_2 emissions. Now, this gets us to a question, is EV a new concept, or does it hold any history?

Talking about electric vehicles, they aren't any new concept. The invention of electric vehicles dates back to the 19th century, but they did not gain recognition because of high maintenance, short range, low speed, infrastructural issues, and many more. So, the demand for electronic vehicles declined worldwide. As environmental concerns increased in the 21st century, EVs gained much attention; people started showing interest in EVs. Before, electric cars were popular among those who preferred short distances because of the lack of infrastructure and low battery capacity. But there were so many reforms done in the EVs too. Now, even people prefer EVs for long distances because of their excellent battery size and many more things.

So many governments are promoting EVs by giving incentives and tax benefits. The Indian government recently announced that FAME, or Faster Adoption and Manufacturing of (Hybrid and) Electric vehicles, is India's flagship scheme for promoting electric mobility. Currently, in its 2nd phase of implementation, FAME-II is being implemented for three years, eff. 1st April 2019 with a budget allocation of 10,000 Cr.

With all these things, EVs are attracting many people's interest. A report from RSBA stated that India's electric vehicle market is expected to grow at a very high rate that is expected to grow at a compounded annual growth rate (CAGR) of 90 percent in this decade to touch $150 billion by 2030.

EV sales are boosting. Will EVs take over the future of the automobile industry? Will EVs play a significant role in making our planet green? Are EVs sustainable?

HYPOTHESIS

Given that, India is witnessing a boom in electric vehicles. People are fascinated by the fact that electric vehicles are CO2 emission-free. We are seeing the era of climate change, global warming, rising temperatures, depletion of the ozone layer, and uncertain weather conditions. EVs hit the world like a ray of hope with the tag of "0 emissions". Governments worldwide are encouraging EVs by providing subsidies and tax reductions. So, with this in our hypothesis, we consider that EVs are sustainable and a ray of hope for a green future.

RESEARCH OBJECTIVE

- To understand the consumer's perspective on electric vehicles through primary research.
- To compare the CO2 emissions caused by the manufacturing of EVs and conventional vehicles.
- To compare the on-road emissions of EVs and conventional vehicles in India.

METHODOLOGY

The present study is based on both primary and secondary research. Qualitative and quantitative methodologies have been adopted for the study.

Primary research: I have conducted a research survey with some set of questions on consumer perspectives about EVs.

Secondary research: I have used secondary sources available in study materials, such as books, journals, research papers, websites, and many more.

I want to capture an in-depth understanding of the phenomenon of EVs and their sustainability.

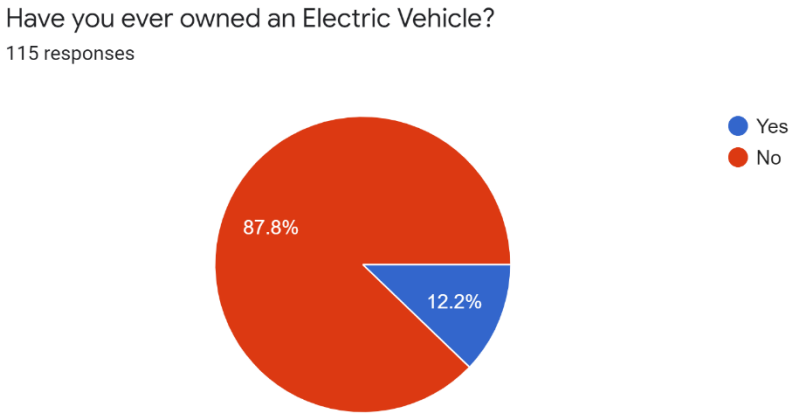
RESEARCH ANALYSIS

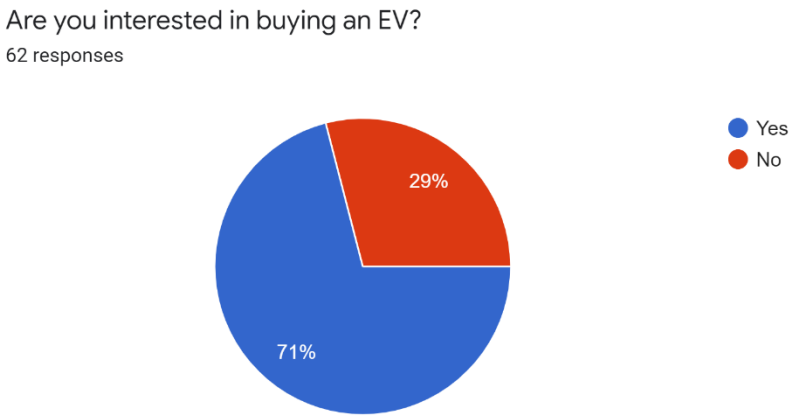
CONSUMER PERSPECTIVE ON ELECTRIC VEHICLES

India is witnessing rapid growth in the sales of EVs as consumers are switching from gasoline-powered vehicles due to varied reasons. EV sales tripled in India in 2021 to 14,800, showcasing a promising future.

We surveyed 115 people with the help of a questionnaire to understand their perspective on EVs.

From the survey we have conducted, it can be derived that, out of 115 people, only 12.2 % of the people own EVs. We know this number is pretty low when compared to conventional vehicles. Still, another question analyses the interest of people in buying EVs. Out of 115 responses, 71% of the people are interested in purchasing an EV. This shows us the people's interest in EVs and how EVs were successful in gaining public trust and confidence.

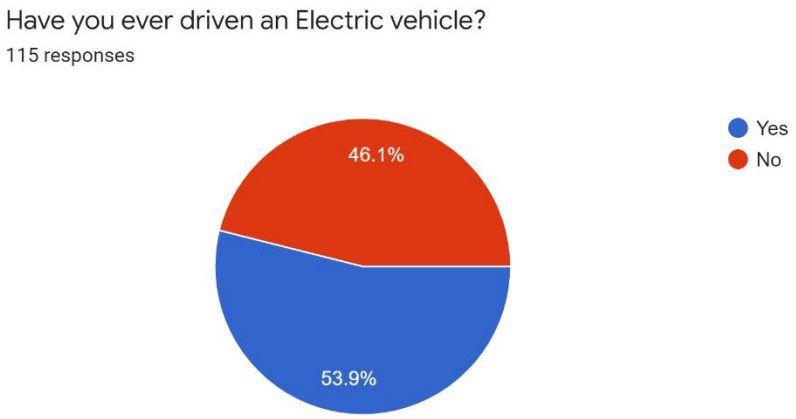


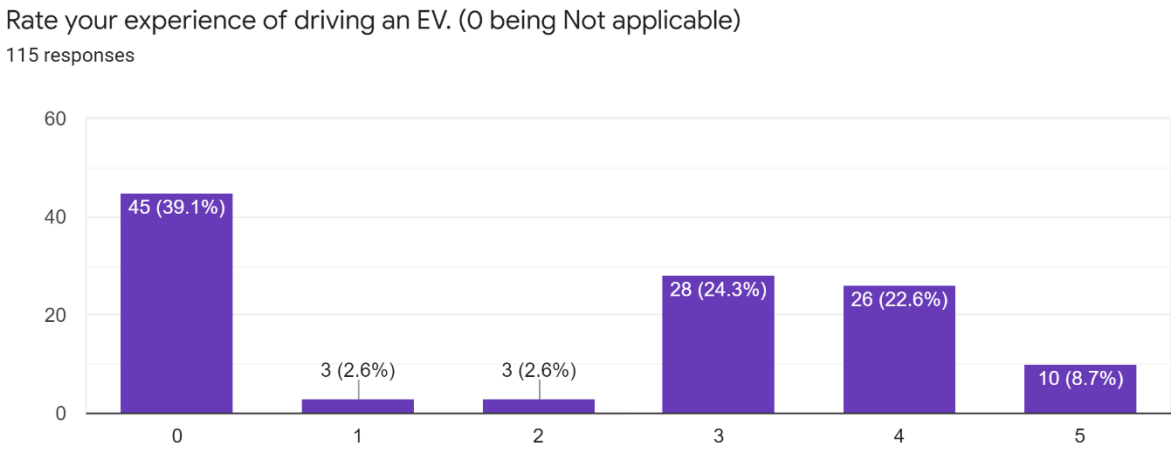


EV sales are increasing daily, so as the demand for EVs, let us try to understand the factors impacting EV sales.

DRIVING EXPERIENCE

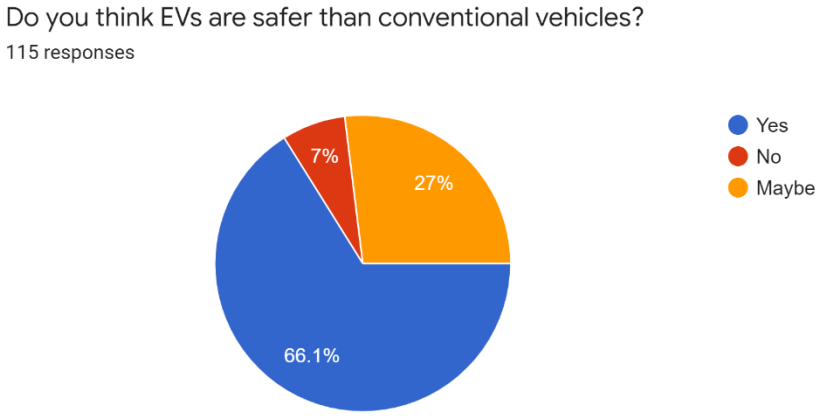
Out of 115 people surveyed, only 53% of the people have driving experience with EVs. Out of the people who have driven the EV, 2.8 of the people rated as 1, 2.8% of the people rated as 2, 24% the people, rated as 3, 22% of the people rated as 4, and 8% of the people as 5. We can say that most people have good experience driving an EV.





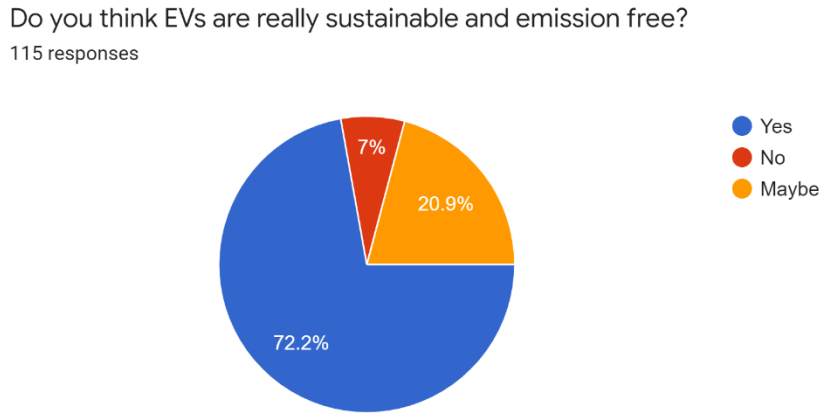
SAFETY

From our survey, out of 115 people, 66% of the people think that EVs are safer than the conventional vehicle, whereas 27% think that they are unsafe, and 7& are not sure about the safety of EVs.



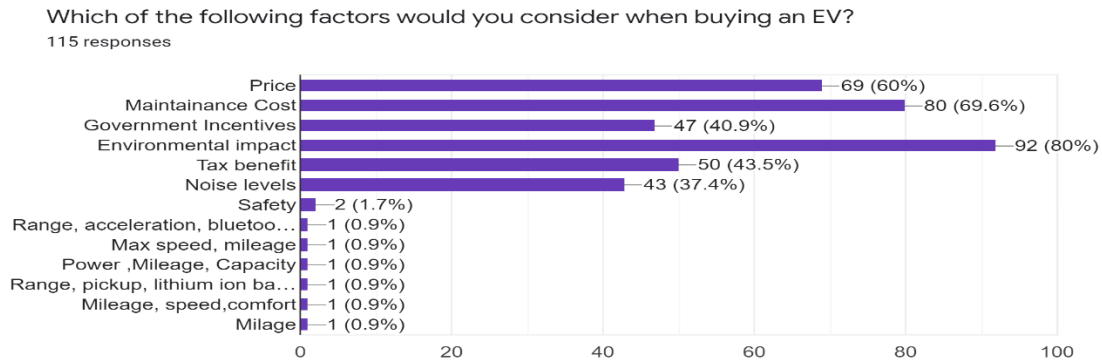
ENVIRONMENTAL IMPACT

From our survey, out of 115 people, 72% think EVs are CO2 emission-free,7% believe that they are not emission-free, and 20%



are unsure.

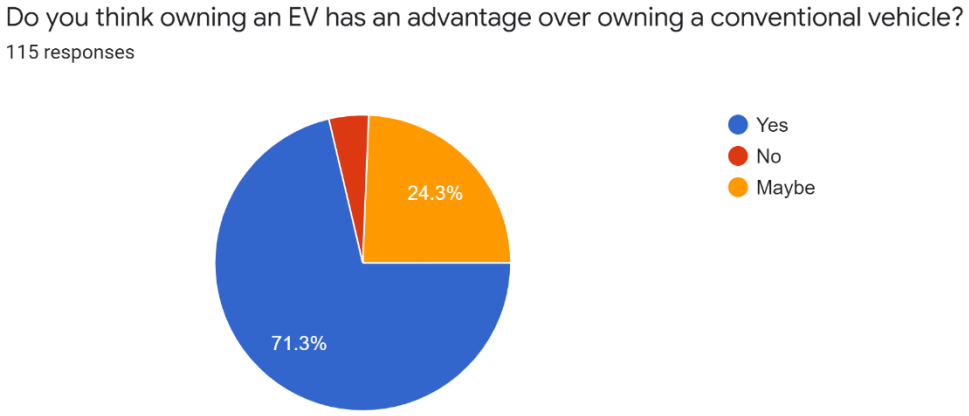
From our research survey, the below graph shows us the factors that people consider while buying an EV



From the above graph, we can analyze that 69% of the people consider price, 80% of the people consider maintenance cost, 47% of the people consider government benefits, 92% of the people believe the environmental impact, 50% of the people consider tax benefits, 43% of the people consider noise levels.

With this, we can see that most people consider maintenance cost and environmental impact as their primary factors while buying an EV.

Here, we can say that because of all the reasons and factors stated above, out of 115 people, 71% of the people think that EVs have an advantage over conventional vehicles.



Let us broaden our lens and understand this thought process to understand.

PERCEPTION OF CO2 EMISSIONS

Ev's are the future of personal transportation. They do a fantastic job at removing pollution from the populated cities, they are fun to drive, and you can get free parking sometimes. There will be a place for Ev's in the future but not today.

Climate change is a global problem caused majorly by increasing co2 concentration in the atmosphere. So, to understand this, let's put a box around the earth, and we would indeed find co2 around the planet. One of the main reasons is believed to be the emissions from the tailpipe of the vehicles. Let us also draw a box around the vehicle, so we would again find co2 in the box. Society's solution to the problem is the box around an EV. Now try to measure the co2 levels in the box. You won't find any. Based on this way of measuring co2, we have called it zero emission. Now let us consider a box around a horse; it breathes in the air and exhales co2 so that we can find the co2 emissions in this box. Surprisingly, the horse emits as much co2 as a corvette, so based on this way of measuring co2, our only possible conclusion is that if we convert all cars into horses, we will be emitting as much co2 as a corvette. The Ev's are green than horses.

Is it good for the environment if we replace all the vehicles with horses? Yes, it is, because even though the horse exhales co2 into the atmosphere, it will convert into oxygen inhaled by the horse again. Here we can see that co2 is in a cycle; because of this cycle, pollution doesn't increase, but in contrast with the car, we dig oil out of the ground, burn it, and produce co2 in the process of searching and burning. With this analysis process, you may be skeptical about the thought process. Now let us go back and reconsider the box around the EV if we broaden our perspective and redraw the box. We consider so many other things such as the manufacturing process, production of Electricity, and many more before we conclude Ev's are co2 emission-free.

COMPARATIVE ANALYSIS OF INTERNAL COMBUSTION VEHICLES AND ELECTRIC VEHICLES

From the above chapter, it was clear that EVs have emissions, and so do Internal Combustion vehicles (ICV). There was an uncompromising belief in the consumers that Evs are emission-free and better than ICVs in emission, but that's something questionable. So, considering all the emissions of an EV and ICV from its birth to the end of life, we can conclude whether Evs are emission-free and Weather they are better than ICVs when the emission parameter was considered.

Using the data from all the references, we can compare Evs and ICVs, taking the parameter of co2 emission, which is the primary concern of the whole world at present. There are three main phases in the life of a vehicle where a certain amount of co2 is emitted into the atmosphere. So, in a Life cycle analysis of an EV and ICVs, we are considering different phases of vehicles.

MANUFACTURING PHASE

In this phase, we consider all the indirect emissions in manufacturing a vehicle. A vehicle obviously cannot be manufactured in the air without any emission; when manufacturing a vehicle (Mainly we are considering passenger cars), It has to go through a lot of assembling processes, and all the components have to be manufactured with the raw materials which release some amount of co2 in their mining processes, and also many other components discharge co2 into the atmosphere in the process of their production. For both ICVs and Ev's, some components would be similar, like tires, lead acid batteries, and chassis. But ICVs have an engine and gear transmission mechanism that Ev's do not, and Ev's have an LI-ion battery that ICVs do not. For an ICV, the major contributor to the emission in its manufacturing phase is the manufacturing of the engine and transmission, whereas, for an Ev, the significant emission in its manufacturing phase is from the production of LI-ion battery which has three main components: the cell, pack, and battery management system, the group was made of aluminum to make it lightweight, and it constitutes for 17% of the total carbon footprint from the production of battery and the cells contribute a significant amount of carbon footprint because of lithium mining.

LITHIUM MINING

Lithium mining was not new to the world. It is used in the batteries of laptops and cell phones, and it was used in the glass and ceramic industries as well. So, until the era of EVs began, Lithium was mined but in less quantity. When EV was introduced to the world, Lithium mining increased along with the demand for an EV, it rose from 25,400 tons in 2008 to around 100,000 tonnes now, and it is expected to reach 183.4-kilo tones by 2025. [1,2]. Lithium, unlike other materials, was not so abundant; it is only available in some parts of the world like Chile, Australia, Argentine, China, and some other countries in Europe, of which Australia was the major player in lithium mining.

Lithium was being mined in different ways. In Australia, Lithium is produced by ore mining, whereas in China and Argentina, it is made from salt deserts, also called salars. From salars for the Lithium to be extracted, it needs to go through several processes. The first step was to evaporate it in large basins, which release a lot of emissions. The remaining saline solution is gone through several methods to obtain Lithium that can be used for a battery of an EV.[1] In both processes of receiving Lithium, a large amount of co2 is emitted into the atmosphere, and even locals around Lithium mining locations complain about a decrease in groundwater level and an increase in draughts. Still, it was not yet considered a cause of lithium mining.

Calculating all the emissions from the production of all three components of a battery, the total carbon footprint for producing a lithium-ion battery was 73kg co2 equivalent/kwh. [3] So, in creating a 40kwh battery, 2920kg of co2 is made. The carbon footprint from battery production is directly proportional to the storm's size. The average battery size of an EV in India is 40kwh [4]; hence the total co2 emission from the battery produced of an EV for an Indian vehicle is 2920kg. The other components also have a carbon footprint in their production process. The emissions from all the ingredients are as listed below.

Components	***Co2 emissions per vehicle (kg)***	
	ICV	***EV***
Body: Including interior, exterior, and glass	2767.9	4393.5
Chasis (without battery)	1684.7	2665.5
Powertrain system	2092.5	145.6
Transmission system	617.4	455.2
Traction motor	NA	1179.1
Electronic controller	NA	1010.2
Lead acid batteries	24.5	15.1
Li-ion batteries	NA	2920
Fluids	230.2	98.3
Tires	677.1	677.1
Assembly		
Lead-acid battery assembly	14.1	8.7
Li-ion battery assembly	NA	141.5
Vehicle assembly	1064.1	1064.1
Total	**9172.5**	**14773.9**

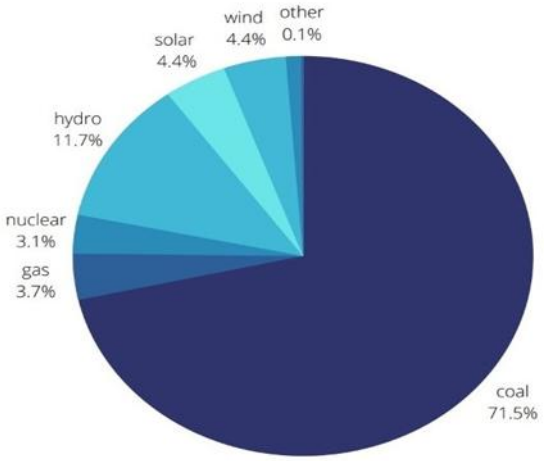
It is clear that EVs have a significant carbon footprint than ICV in the manufacturing phase. Producing an EV emits about 1.6times that an ICV emits in its production process.

On road

In the on-road phase, we consider the emissions from the combustion and production of Fuel and Electricity. EV needs to be charged, and an ICV needs to be supplied with Fuel that emits co2 when undergoing combustion. So, when an ICV runs on the road, it is responsible for fuel combustion and production emissions. At the same time, EV uses Electricity from power stations, which may be produced either by burning fossil fuels with a considerable carbon footprint or from a renewable resource. Hence EV is responsible for emission from electricity production that it uses while running on the road.

Emissions from electricity production

In India, a substantial amount of Electricity was generated by burning coal and other fossil fuels and only a tiny amount from renewable resources like solar and wind. Currently, 71.5% of Electricity is produced from coal which is responsible for a massive amount of co2 emission into the atmosphere.



In generating Electricity from fossil fuels, they are burnt in the presence of air which releases greenhouse gases into the atmosphere. The amount of co2 generated in the process is different for individual fossil fuels, and even renewable resources have a carbon footprint in the production of Electricity. Though no natural co2 is emitted while producing Electricity via renewable resources, a certain amount of co2 is released during the setup and manufacturing of components like solar panels and the blades of a windmill. The amount of co2 emitted per kWh of Electricity generated from each source is as follows [7]

Source	***Co2 emitted (kg/kwh)***
Coal	1.001
Natural gas	0.469
Nuclear energy	0.016
Hydro	0.024
Solar	0.046
Wind	0.012
Biomass	0.230
Other	0

Emissions from an EV during its functioning:

To calculate the emissions from an EV while it is running on the road, we calculate the amount of Electricity it consumes, and the emissions from the electricity production are considered as production from an EV. On average, a passenger car in India travels 12000km in a year. [8] So, as an EV in India has an average of 246km [9], it needs to be charged for 48times.

The average distance covered by a vehicle in a typical year = is 12000km Average range for an EV in India = is 246km

Number of times that an EV needs to be charged in a year = 12000/246 = 48 times

Each full charge of the battery consumes electricity equivalent to the size of the battery. So as an EV generally is being charged 48 times, it consumes electricity corresponding to 48 times the battery size, and an average battery size of an Indian EV is 40kwh [9].

Hence, electricity consumed by an EV in a normal year = 48* average battery size = 48*40 =1920kwh

Thus, an EV consumes an amount of 1920kwh per year while running on the road in a typical year. The EV gets this from a Power station which gets Electricity produced from various sources in the electricity grid. In the general case, an EV uses Electricity generated from multiple sources, according to the above pie chart. And the distributions are as follows.

Source	***Percentage of Electricity generated by the source***	***The amount that an EV uses from the source (1920kwh * percentage)***

Coal	71.5	1372.8
Natural gas	3.7	71.04
Nuclear energy	3.1	59.52
Hydro	11.7	224.64
Solar	4.4	84.48
Wind	4.4	84.48
Biomass	1.08	20.736
Other	0.12	2.304
Total		**1920kwh**

The distribution of Electricity was clear from the above. As each source contributes a different amount and has its respective carbon footprint, as shown in table 2, emission from each source adds up to the total emission from an EV in a general year.

Source	**Co2 emitted in the production of Electricity from source (kg/kwh)**	**Amount from the source for an EVin a year (kwh)**	**Emission from each source in supplying an Ev with Electricity (kg/year)**
Coal	1.001	1372.8	1374.17
Nuclear	0.469	71.04	33.31
Hydro	0.016	59.52	0.95
Natural gas	0.024	224.64	5.39
Solar	0.046	84.48	3.88
Wind	0.012	84.48	1.01
Biomass	0.230	20.736	4.76
Other	0	2.35	0
Total emission			**1,423.47 kg**

Therefore, the total emission from EV during its functioning in a general year is 1423.47kg of co2.

Emissions from an ICV during its functioning:

An ICV, while running on the road, releases co2 from its tailpipe, which is a by-product of the fuel combustion that takes place in the cylinder of an engine, and the carbon footprint of the fuel production is considered an indirect emission from an ICV. The Fuel burnt inside the cylinder under high pressure releases a massive variety of exhaust gases that are being ejected into the atmosphere from the tailpipe through the catalyst, which converts the toxic gases in the emission into less harmful ones using a catalyst. Companies generally update this catalyst according to the regulations; for example, in India, we have BSVI, according to which manufacturing companies update their catalyst.

In calculating the emissions from an ICV while it's running on the road, emissions from Fuel combustion and Fuel production need to be calculated, which are as follows.

- Fuel Combustion and Production

In India, a passenger car covers an average distance of 12000km in a general year. India's average fuel economy of gasoline and diesel cars is 17kmpl and 18kmpl [10], respectively. So the average amount of Fuel consumed by a gasoline and diesel car in a year is as follows

the amount of Fuel consumed by a gasoline car = 12000/17 = 705.88 liters

amount of Fuel consumed by a diesel car = 12000/18 = 666.67 liters

the carbon footprint of fuel combustion is calculated as the amount of co2 released when a liter of Fuel is burnt, and in the case of fuel production, there are a lot of processes for the Fuel to be produced and to drive it to the filling station. So, emissions from crude oil mining, refining, and transportation through ships and vehicles to the filling stations are considered, and emission from the production of Fuel is calculated.

Type of Fuel	***Emissions from fuel combustion (kg/litre)***	***Emissions from fuel production (kg/litre)***

Gasoline	2.420	0.720
Diesel	2.670	0.640

Hence, in a year, the total emissions while an ICV is running is calculated as the total emissions from fuel combustion and production for 705.88 liters and 666.67 liters for gasoline and diesel, respectively.

- Gasoline

co2 emissions from production = 0.720*705.88 = 508.23kg of co2 co2 emission from combustion = 2.42*705.88 = 1708.22 kg of co2 total emission from gasoline vehicle in a year = 2216.45 kg of co2

- Diesel

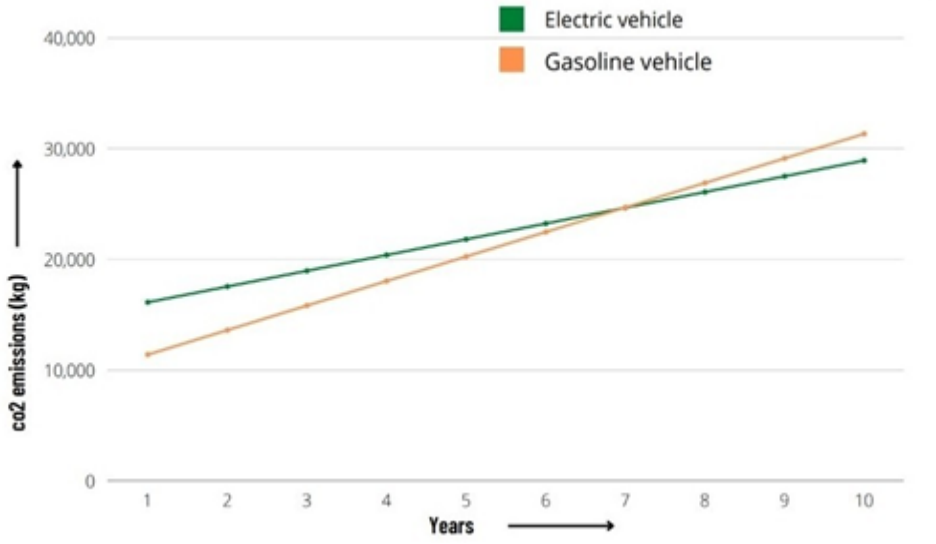
co2 emission from production = 0.640*666.67 = 426.66kg of co2
co2 emission from combustion = 0.2.67*666.67 = 1780kg of co2
total emission from diesel vehicles in a year = 2206.66 kg of co2

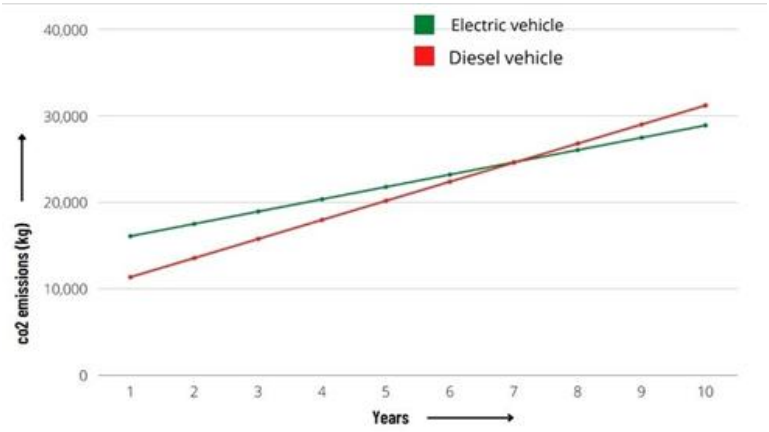
Therefore, we calculated total emissions from an ICV in a general year as 2216.45kg of co2 and 2206.66 kg of co2 for Gasoline and Diesel, respectively.

Comparison between EV and ICV based on emissions from manufacturing and functioning phase for tenten years.

The carbon footprint of EV and ICV emissions from both vehicles are calculated for each consecutive year for ten years. Each year, the amount of co2 emitted during the vehicle's functioning is added, and emissions from the manufacturing phase are added in the first year.

Year	**Emissions (kg of co2)**		
	EV	**ICV**	
		Gasoline	***Diesel***
1	16,117.47	11,388.95	11,379.16
2	17,540.94	13,605.40	13,585.82
3	18,964.41	15,821.85	15,792.48
4	20,387.88	18,038.30	17,999.14
5	21,811.35	20,254.75	20,205.80
6	23,234.82	22,471.20	22,412.46
7	24,658.29	24,687.65	24,619.12
8	26,081.76	26,904.10	26,825.79
9	27,505.23	29,120.55	29,032.44
10	28,928.70	31,337.00	31,239.09





CONCLUSION

In this study, our hypothesis was proved wrong that EVs are sustainable. A ray of hope for a green future. from our comparative study between EVs and conventional vehicles, it is evident that for the first seven years, the emissions from EVs are more than that of ICVs. The average life of an Indian passenger car is ten years. EV has the edge over ICV only for the last three years of its life. Now when we go back to our question, are EVs sustainable? Then the answer is no because EVs are not emission-free. They just have a thin edge compared to conventional vehicles and may not be utterly sustainable today. Still, they can improve with some advancements in Lithium mining, battery recycling, and adopting renewable energy sources. When we talk about sustainability, even conventional vehicles can become sustainable by adopting some alternatives for Fuel like hydrogen fuel, synthetic Fuel, and CNG. EVs and conventional cars are on the same platform when it comes to sustainability, but we can

WAY FORWARD

This study can have a further review and research on the following issues.

When we go back to the history of the automobile industry, once upon a time if witnessed the era of electric vehicles, but conventional vehicles captured the automobile industry by clearing the shortcomings of electronic cars. Now are again seeing the age of electronic vehicles by talking about the problem of co2 emissions.is there any chance that conventional vehicles can again capture the automobile industry with improvised techniques?

The government plans to replace30% of vehicles with electric vehicles by 2030; from our study, we found that conventional and EV have a fragile line of difference when it comes to sustainability, so is it a viable option to build infrastructure and all for the EV?

Even in the case of vehicles, fuels can be replaced by synthetic and hydrogen fuels. So, can we expect an era of alternative fuel options?

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