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How Clean is the Green? Electric Vehicles the Way Forward

Ananya Chowdhery, Samarthya Bindlish

[1]*Student Grade 12, Sat Paul Mittal School, Ludhiana, Punjab, India*
[2]*Student Grade 10, Vivek High School, Chandigarh, India*

Abstract - *Humanity has come a long way, particularly where development is concerned. Unfortunately, we have paid a heavy price for it too. Man has encroached upon nature, and now is reeling under the after-effects of the same. With the effects of pollution and subsequently climate change felt acutely by one and all, the entire world is in a race to discover quick fixes for it. In this attempt, electric vehicles are being hailed as the magical formula that will deliver us from the evils of environmental pollution. It has the 'clean' label attached to it. But are they as 'clean' as is being claimed? This question is especially of vital importance when it comes to a country like India. India has seen a meteoric rise in the last few decades. It's on the fast-track road to development but at the heavy price of forsaking the environment. The necessity to change the development track to take environmental sustainability into account is of utmost importance. So, the question that arises is, are EVs really right for India? Do we really have the infrastructure in place to claim EVs to be the elixir vitae delivering us from the evils of environmental pollution? Will it really be the panacea we are hoping it to be, or are we running after a mirage?*

Key Words: **Electric vehicle, India, Carbon footprint, Electricity, Fossil fuel, Environment, Lithium**

1. INTRODUCTION

History has taught us that economic development and environmental degradation go hand in hand. We have always impinged upon nature and the environment for industrialization and urbanization. We might have progressed over the suffering of nature, but now this trade-off is threatening our own survival. Humans have realised that they cannot lord and master over nature. There is a dire need for development to work along with environmental preservation. Now we need safe progress-progress where we are progressing whilst keeping our environment safe.

In the race for finding safer, cleaner solutions, hunting for solutions for vehicular pollution is among the forerunners. The transport industry alone is responsible for 25% of all emissions that are emitted into the atmosphere, with road transport accounting for 75% of those emissions. The advent of electric vehicles is slowly but surely revolutionising the transport sector. It is being hailed as the Di catholicon that will deliver us from the evils of the automobile industry. It has the 'clean' label attached to it. But ever since they have been rolled on the roads, the 'clean' label is under constant scrutiny. Are they as 'clean' as they claim? Are they really the solution to the environmental pollution we have desperately sought?

India is on the fast-track road to development. But we are paying a heavy price for it by sacrificing the quality of the environment around us. The smog conditions of North India and the fact that quite a few Indian cities feature in the world's most polluted cities is proof enough. Just as across the world people of India are looking forward to electric vehicles on roads believing them to ease the pressure on the environment. The projected rate of growth just for India alone is supposed to be 35% until 2026. As the entire automobile industry is facing a radical shift, with an obvious inclination towards cleaner and greener vehicles, electric vehicles are becoming the norm. But the million-dollar question of how green these vehicles are remains unanswered. It is especially of vital importance when it comes to a country like India. Will it really be the panacea we are hoping it to be, or are we running after a mirage?

2. ADVANTAGES OF ELECTRIC VEHICLES

There are several features of electric vehicles that are beneficial to the environment. As per data collected by various research organisations, electric vehicles help in improving air quality as they release a very small amount of greenhouse gases and air pollutants as compared to conventional cars. Their carbon dioxide emissions while driving is almost nil as they do not have any tailpipe emissions. 1.5 million grams of CO_2 on an estimate is saved by an electric car. Electric vehicles are much quieter than regular cars thereby reducing noise pollution considerably. In fact, it is said that with electric vehicles streets are cleaner and quieter, thereby making the cities more peaceful for all and especially the pedestrians and cyclists.

The running costs of electric vehicles are pocket friendly too. To cover the same distance as compared to conventional cars, the cost of charging an electric car is 40% less than the cost of refueling. With the advent of charging stations at all destinations,

charging has become straightforward and effortless. Be it malls, fuel stations, metro stations, workplaces, etc. electric vehicle owners don't have to spend extra time to charge their vehicles. One can even charge their car while they shop or have their lunch.

Due to all these aspects, electric vehicles are being promoted as the most viable mode of transport which offers unprecedented benefits and enjoyment to the owners and businesses. However, this industry is still in its nascent stage and does leave one wondering. Are these vehicles really as green as they are being advertised? Are we just shown one side of the coin? Or do behind-the-scenes tell a different story?

Any car during its life cycle- namely manufacturing, usage, and recycling discharges greenhouse gases. To find out the damaging impact of both regular cars and electric vehicles, all three stages need to be considered.

3. THE MANUFACTURING PHASE

In the production stage, to determine carbon emissions, all processes must be studied. Mining of ores, refining of materials, manufacturing various components, and finally assembly, i.e., how are various elements procured and transformed.

On average manufacture of a diesel/petrol car emits approximately 10 tonnes of CO_2 per car as compared to approximately 15 tonnes for an electric car, out of which approximately 3.2 tonnes of carbon emissions result from the manufacturing of battery only. Lead-acid batteries used in regular cars are quite economical to produce, making them an affordable source of energy. However, using these batteries can produce a much higher carbon footprint. But in electric vehicles, the manufacturing stage alone contributes to more than a third of total emissions discharged during the lifetime of an electric car.

One of the major reasons for the higher rate of emissions is the production of lithium batteries, which is a vital part of an electric vehicle. The raw material for the batteries has to be mined and then refined for use. Both these processes emit greenhouse gases.

An electric vehicle requires about six times the amount of minerals as compared to a regular car. The minerals and metals used in the battery are rare and found only in a few places. The essential components for batteries, including lithium, cobalt, nickel, and manganese, must be extracted from the depths of the earth. Mining practices followed are generally detrimental to the ecology around them. Loss of biodiversity, rising temperature, soil cover loss, water shortages, and destruction of ecosystems are some of the detrimental effects of mining.

Lithium, often hailed as the next oil, requires approximately 2.2 million litres of water from the ground to mine a metric ton of lithium. This makes lithium mining a huge drain on water resources. Groundwater is pumped at a much faster rate than it can be replenished. In South America, lithium deposits are found in dry areas where access to water is hard to come by and thus groundwater becomes an essential source of survival for only the human population but also the flora and fauna of the region.

When an area is identified for mining, it loses its natural forests. With the loss of tree cover, the main source of carbon fixation is lost. With more CO_2 released into the environment, global temperatures rise, thus defeating the purpose of shifting to electric vehicles for the benefit of climate. Chile has lost around 56.8 kilo hectares of its forest cover in 2021 roughly estimating to 28.5 metric tons of CO_2 emissions. Australia lost 231 kilo hectares of its forest cover by 2021, estimating carbon emissions to the tune of over 90.5 metric tons. Moreover, the fear that some of the world's most invaluable ecosystems might get destroyed due to what is being done in the name of good for the global climate is fast growing. Already population of two species of Flamingos has greatly reduced in Chile due to lithium mining and is threatening the existence of a rare wildflower, Tiehm's buckwheat. Scientists are also exploring the possibility of deep sea-bed mining, which could lead to the destruction of the surrounding sensitive flora and fauna.

Waste generated from mining generally percolate in the local environment, leading to contaminated water resources, low yields, and health issues among other things, greatly impacting the local communities. There is no established protocol to measure the social costs of the same. Neither they have been tabulated.

Lithium-ion batteries are considered to be better as they not only store more power, but they have a longer life too, making it the obvious choice for environmentalists. But the hidden fact is that the production of lithium-ion batteries is dependent on fossil fuels which increases their total carbon footprint. Also, China is the major producer of these batteries. China depends majorly on coal as an energy source which accounts for a large carbon footprint. Subsequently, batteries produced by China have a significant carbon footprint.

When it comes to labour, the working conditions are poor and highly dangerous, physically very demanding and the pay is not enough. There are even noises being made about the use of child labour for mining. The exploitation of the worst kind is fueling the supply boom of batteries.

4. THE USE PHASE

The capacity of lithium-ion batteries in modern electric vehicles is around 30 kWh – 200 kWh. This capacity speaks of the hours that the vehicle can run after a full charge. On an approximate basis, a car with a 30-kWh battery can keep running for around 30 hours. These figures might change depending on the type of vehicle and model of the car. Below is a chart with different lithium-ion batteries and estimates for CO_2-eq emissions. These emissions vary not just with the type of car and model but also the place where it is driven among other factors.

Table -1: Battery Capacity and Carbon Emissions

Battery Capacity	Low Range	Medium Range	High Range
General - 1kWh	40 kilograms of CO_2-eq	150 kilograms of CO_2-eq	200 kilograms of CO_2-eq
EV – 30 kWh	1.2 metric tonnes of CO_2-eq	4.5 metric tonnes of CO_2-eq	6 metric tonnes of CO_2-eq
EV – 60 kWh	2.4 metric tonnes of CO_2-eq	9 metric tonnes of CO_2-eq	12 metric tonnes of CO_2-eq
EV – 80 kWh	3.2 metric tonnes of CO_2-eq	10.2 metric tonnes of CO_2-eq	16 metric tonnes of CO_2-eq
EV – 160 kWh	6.4 metric tonnes of CO_2-eq	24 metric tonnes of CO_2-eq	32 metric tonnes of CO_2-eq
EV – 200 kWh	8 metric tonnes of CO_2-eq	30 metric tonnes of CO_2-eq	40 metric tonnes of CO_2-eq

When the car is being used emissions are either upstream emissions or tailpipe emissions. In a petrol /diesel car both types of emissions are released, i.e., upstream emissions and tailpipe emissions. Whereas in an electric vehicle only upstream emissions are involved, which depend on the material used to produce electricity, i.e., either renewable sources or fossil fuels.

Tailpipe emissions: Smoke released from a fossil-fueled car contains particulates. These particulates contain toxic chemicals which can go deep into our lungs and make us sick. Carbon monoxide is an odorless poisonous gas known to cause a variety of health issues. Nitrous oxide is also known to cause respiratory problems and the formation of smog. If the car is old or runs on diesel, then the presence of these particulates is heightened. According to a report, about 4.6 metric tons of carbon dioxide is released every year by a regular car, which is the leading greenhouse gas responsible for global warming.

Upstream emissions: Upstream emissions happen when the fuel that powers the car is produced. In electric vehicles, upstream emissions depend on the country's electricity generation mix, whether electricity is coal generated leading to a big carbon footprint or produced from low-carbon sources. In electric vehicles, batteries need to be charged regularly. So, the electricity mix is the major source of emissions in electric vehicles. Most countries rely heavily on coal-generated electricity. This increases emission numbers substantially. Very few countries draw most of their energy from renewable sources giving a small carbon footprint to electric vehicles like Norway. Apart from the energy used, carbon emissions also depend upon the area that it is being driven in.

As an example, Australia and New Zealand are being considered. They have different electricity mixes. In New Zealand, about 84% of electricity is produced from renewable sources as opposed to only 21% in Australia. (Figures are for the year 2018). Estimates based on this data show that upstream emissions of an electric vehicle in Australia will be around 170 g of CO_2 per km and of an electric vehicle in New Zealand will be approximately 25 g of CO_2 per km. Driving an electric vehicle in New Zealand is far better than driving in Australia. From a regular car, the upstream emissions will be around 251 g of CO_2 per km. It is quite evident that driving electric vehicles in these countries is a much better choice than fossil fuel cars as the emissions are much higher than electric vehicles in both countries.

The environmental impact of electric vehicles can be decreased considerably by using renewable energy for charging their batteries. Electricity produced using coal releases approximately 800-850 grams of CO_2 per kWh. When energy sources like solar panels or wind turbines are used, the statistics significantly decline to about 36g CO_2 per kWh.

5. THE RECYCLING PHASE

Transition to e-vehicles is being incentivized everywhere. However, the environmental consequences of the same are still under consideration.

The components of any car recycling involve its dismantling, recycling of its parts, recycling of battery, and recovery of the material. When electric vehicles are taken out of commission, it is battery disposal/recycling which is a major cause of concern.

In electric vehicles, lithium-ion batteries start degrading from the first cycle of discharge and charge, till they reach a point where they are unable to perform. After being used for 5-8 years, the batteries do not generate enough power to achieve the required range in an electric vehicle. These batteries have a serviceable life of less than ten years. In U.S. around 200,000 and 500,000 electric vehicle batteries were decommissioned in the late 2010s, each year. Extrapolating on these figures, by 2025, around one million units will be retired annually, and around two million units by 2040.

There are five options available for batteries once they have exhausted their capacity. Recycle, reuse, restore, dispose, or incinerate. The lithium-ion cells form the core of the electric vehicle battery along with additional raw materials like cobalt, nickel, graphite, and other rare earth elements. After the battery life is exhausted, the waste includes massive amounts of these chemical components. Out of which, only cobalt is worth recycling. This leaves nickel, graphite, manganese, and other substances, recycling of these is not economical and involves substantial costs for any additional processing. Recycling batteries is labour-intensive and not safe. Even the transport costs to transport these batteries for recycling incurred are quite high as shipping and transport companies adhere to some very strict guidelines and end up charging extra for these batteries. They are estimated to be almost as high as 40% of the total recycling costs. Due to increased costs, there are not many players in the recycling business, and for the want of buyers for lithium and manganese. The effect of these leftover materials is ruinous for the environment. Lithium is known to react spontaneously with the moisture in the environment. If dumped, this can result in the possibility of huge landfill explosions too. The toxic water that enters the water sources due to reckless disposal of batteries, not just reduces water fit for consumption but also destroys the flora and fauna of the region.

According to a study conducted in China, emissions on an estimate for an electric vehicle is 2.4 tonnes as opposed to 1.8 tonnes for a regular car. The high emission rate of an electric vehicle is mostly due to battery recycling, which is approximately around 0.7 tonnes.

The battery may be reused either directly or refurbished to be used for some other applications such as for storing energy for homes or businesses or in other vehicles such as public buses. Reuse also requires less processing than recycling. Restoring is mid-way between recycling and reusing, in which the cathode materials are reinstated without further processing. Under incineration, materials inside the battery are used as fuel for other processes. However, it has the added risk of releasing toxic gases into the air.

6. SURVEY ON THE PERCEPTION OF INDIANS REGARDING ELECTRIC VEHICLES

To gain valuable insights into public perceptions and attitudes toward electric cars and their environmental impact, we conducted a survey. In this endeavor, we collected and analyzed responses from a diverse range of participants. Through this survey, our aim was to delve into various aspects related to electric vehicles, such as awareness levels, perceived benefits and drawbacks, and barriers to adoption and to check how green are these vehicles perceived by the Indian population.

The survey pool comprises 49% participants of in the age group 20-40 years and 51% in the age group 40-60 years, out of which 62.7% were male and the rest females. By analyzing the responses, we gained a comprehensive understanding of public sentiments, concerns, and preferences in relation to electric vehicles. According to the collected data, 27.7% were thinking of buying an electric car soon, 44.6% a hybrid car, and the rest a conventional car. 76.5% were aware of the battery life installed in the electric vehicle but only 8.8% were aware of the real-time required to charge an electric vehicle battery fully. 56.9% of participants were aware that electric vehicle batteries have a longer life than conventional car batteries. However, more than 30% believe that the raw material to make these batteries is available in India and they are manufactured in India. 41.65% believe that these batteries can be easily recycled and 38.6% are aware that India does not have a proper disposal system in place. Only 48% were aware of different charging stations in their city. A whopping 68.6% believed that electric vehicles are green in the Indian context, despite the fact 65.7% are aware that coal is the major source of power in India.

The responses have helped us identify trends, patterns, and key insights regarding public attitudes toward electric cars. According to the survey responses, there is a noticeable interest in electric vehicles in India. This is partly due to the global shift toward sustainable and eco-friendly transportation options, as well as government initiatives to promote electric vehicle

adoption. But since electric cars often have greater upfront costs than conventional petrol or diesel cars, pricing is still a major concern for many Indians. The Indian consumers are not fully aware of all facets of electric vehicles and there are concerns about the performance and range limitations of electric vehicles. Overall, the perception of electric vehicles among the Indian population is quite positive.

7. THE INDIAN PICTURE

Transforming transport industry in India has to transverse quite a few economic blocks. India is overly dependent on the import of lithium and has very limited capacity of battery production and refining capacities at the moment. This is going to stress the Import bill a lot. Imports from China have increased from 19.79% in 2019 to 32.05% in 2021. India can hope to access the advantages offered by electric vehicles only if it achieves self-reliance in these aspects, which is still quite a distant dream.

In India, the energy mix is heavily dependent on fossil fuels. Estimates based on data collected by IPCC and EU project only a slight improvement in decreasing CO_2 levels with electric vehicles on the road. On one hand, regular cars emit 253g of CO_2 per km and 52.9 tonnes of CO_2 over their lifetime, and on the other electric vehicles would emit 235 gm of CO_2 per km and 57 tonnes of CO_2 over their lifetime in India, resulting in a paltry saving of 7% only. With fuel efficiency improving regular cars to 15 km per litre, then they will account for 227 gm of CO_2, thereby becoming more efficient than electric vehicles. On the other hand, manufacturers are also innovating to improve the efficiency of electric cars.

Energy saving throughout India varies greatly across states and regions depending on the electric mix of that place. On an estimate, the northeastern part of India will witness the maximum savings of CO_2 from electric vehicles (around 36%), Whereas the western and eastern states fare badly. Delhi will be able to save around 13% of its carbon emissions while Haryana is more coal-reliant, only 4%. In Uttar Pradesh, both types of cars will release the same carbon emissions and in Chhattisgarh, a petrol car will be more efficient than an electric car. Similarly in Jharkhand and West Bengal petrol run cars will be more efficient. Additionally, a petrol car would become 23% more efficient than an electric vehicle, if the fuel efficiency rises to 19km per litre, in the case of sub-compact cars, which are a majority in India.

India's electricity mix is highly skewed in favour of power through fossil fuels. This greatly reduces the efficiency of electric vehicles. A major shift to more renewable sources of electricity production is needed. Unless it is achieved, electric cars in India won't help in attaining any substantial environmental benefits.

When it comes to e-waste, India is woefully inadequate in dealing with it, with most of it ending up in landfill. Even legislation regarding the illegitimate dumping of used lithium batteries is lacking. In the present laws, the E-waste (Management and Handling) Rules, 2011, E-waste (Management and Handling) Rules, 2016, and E-waste (Management) Amendment Rules, 2018, there is no reference to recycling or treatment of disposed lithium batteries. India might end up being a dumping ground for such batteries. That is a very scary picture to comprehend as the toxins are hazardous to both human life and the environment if not treated properly.

The recycling sector in India is largely unorganised with most of it being in isolated rural areas where adequate controls are missing. Recycling cost is quite high, amounting to approximately ₹9200 per kg lithium-ion battery. Setting up a recycling facility involves high investments and huge transportation and handling costs, while profit margins are comparatively low. On an estimate to recover cost and start earning profits, it takes about 5 years. At present battery disposal and recycling in India mostly comprises of dismantling the battery to extract copper aluminium and black powder (black powder collectively contains lithium graphite cobalt and others). Government policies are urgently needed even in this regard.

Standards for reusing existing electric vehicle batteries are also necessary to deploy electric vehicle batteries effectively in stationary applications such as renewable energy and others. A circular economy for lithium-ion batteries will benefit domestic electric vehicles and the storage industry. By 2030, recycled components from old batteries might support India's generation of 60 GWh of Li-ion batteries. This may boost the government's Aatma Nirbhar Bharat initiative, lessen India's dependency on imports, and open new markets for Li-cell manufacturers. A study found that using recycled materials might cut CO_2 emissions as much as 90%. Numerous businesses have already begun recycling lithium-ion batteries on a limited scale.

Table -2: Installed Generation Capacity (Fuelwise) as on 31.01.2023

CATEGORY	INSTALLED GENERSTION CAPACITY (MW)	% OF SHARE IN TOTAL
Fossil Fuel		
Coal	2,04,435	49.7%
Lignite	6,620	1.6%
Gas	24,824	6.1%
Diesel	589	0.1%
Total Fossil Fuel	**2,36,469**	**57.4%**
Non-Fossil Fuel RES (Incl. Hydro)	**1,68,400**	**40.9%**
Hydro	46,850	11.4%
Wind, Solar & Other RE	1,21,550	29.5%
Wind	41,983	10.2%
Solar	63,894	15.1%
BM Power/Cogen	10,210	2.5%
Waste to Energy	523	0.1%
Small Hydro Power	4,940	1.2%
Nuclear	6,780	1.6%
Total Non-Fossil Fuel	**1,75,180**	**42.5%**
Total Installed Capacity (Fossil Fuel & Non-Fossil Fuel)	**4,11,649**	**100%**

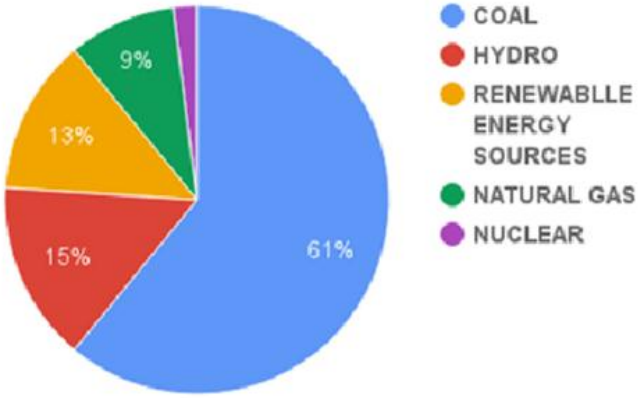

Chart -1: Sources of Electricity in India by Installed Capacity

8. POSSIBLE SOLUTIONS

Certain measures can aid in reducing the environmental impact of the manufacture and disposal of lithium batteries.

Carbon offset credit: A company causing pollution purchases carbon credit to offset the pollution caused by it. The sum is used to undertake measures to either prevent carbon emissions or eliminate the same amount of carbon emissions from the air.

Collaborative research between different countries for finding ways to extract lithium using seawater.

Shallow Cycling of Batteries at a 50% charge can lead to a longer life cycle of lithium batteries, thereby reducing CO_2 emissions over its life cycle. This will also reduce the impact of producing these on the environment as a lesser number of batteries will be required.

Proper Disposal of Batteries only at selected centers of collection and more recycling initiatives need to be undertaken.

Encouraging the use of hybrid cars as they have a quicker means of emission reduction. A study conducted by Toyota shows that if we use the limited amount of lithium batteries available in hybrids, rather than electric vehicles, then it is possible to achieve better emission reductions. An electric vehicle uses around 80-100kWH of battery as opposed to 3-5kWH in an electric vehicle. With a limited supply of lithium fewer electric vehicles will be built, but more hybrids can be built with the same supply. This would probably help in achieving reduced emissions as compared to electric vehicles.

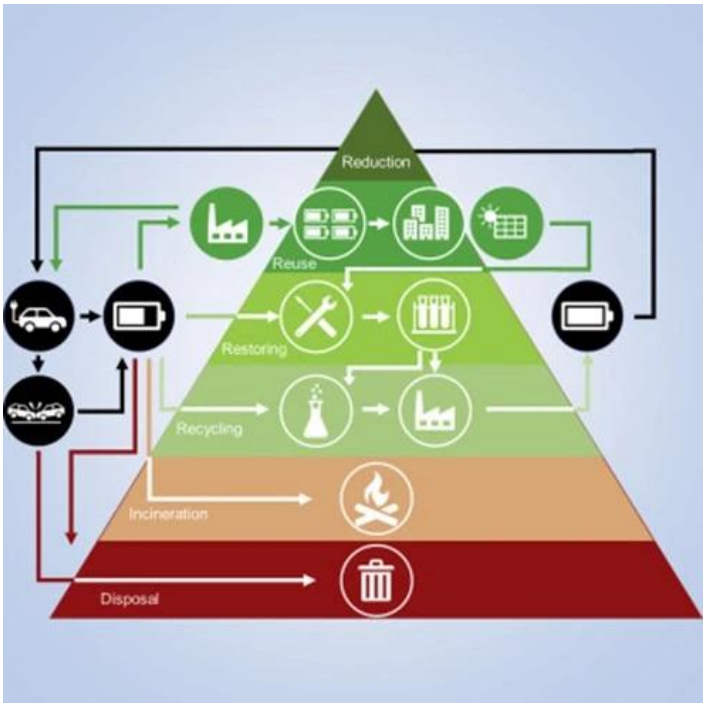

Fig -2: Pyramid of five major pathways of batteries used in electric vehicles

There are five major pathways — excluding reduction, which is expected — for dead electric vehicle batteries, all with their own risks and advantages. Sustainability requires innovations in recycling technology, though the process is expensive and hazardous.

9. CONCLUSION

Electric vehicles are the cars of the future. They can play a very integral role in the transport industry. Electric vehicles may, if technology continues to advance and become more sustainable, prove to be the answer to the world's climate change problems. At present at least according to our research, they are not the answer to India's problem of energy and climate change. The current electrical grids need to be more efficient and reduce their reliance on fossil fuels and increase renewable energy production. Technology must be developed so that the need to mine for new materials is reduced and proper recycling and disposal methods should be put in place to start accruing the benefits of electric vehicles. The industry needs to address the issues mentioned above along with requisite government policies before they make the environment greener and cleaner in the Indian context.

9.1 ANNEXURE 1 (SURVEY RESULTS)

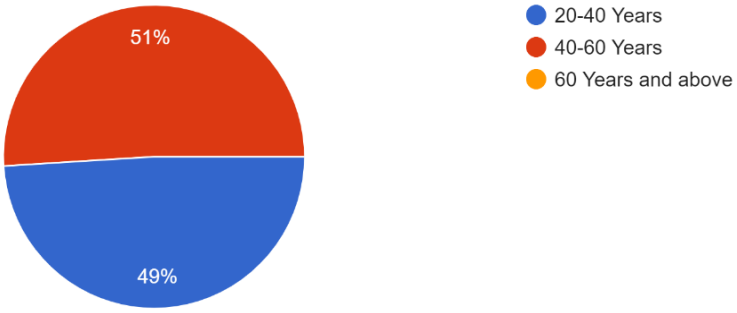

Fig -3: Age Group (102 Responses)

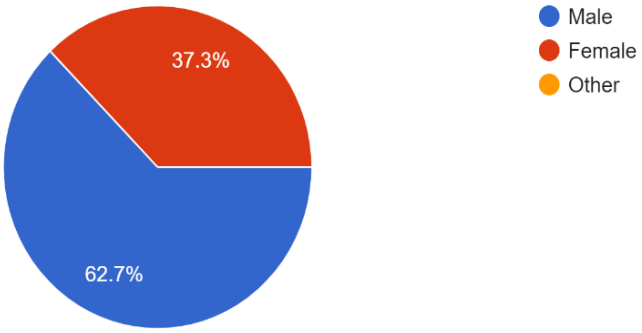

Fig -4: Sex (102 Responses)

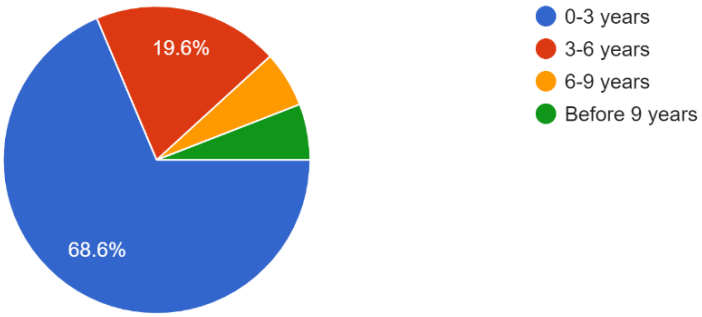

Fig -5: When did you last buy a car? (102 Responses)

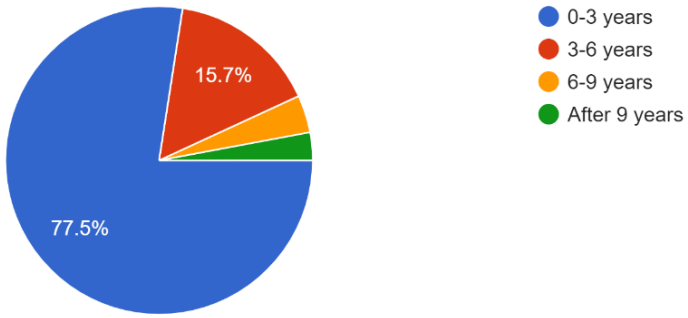

Fig -6: When do you plan to buy the next car? (102 Responses)

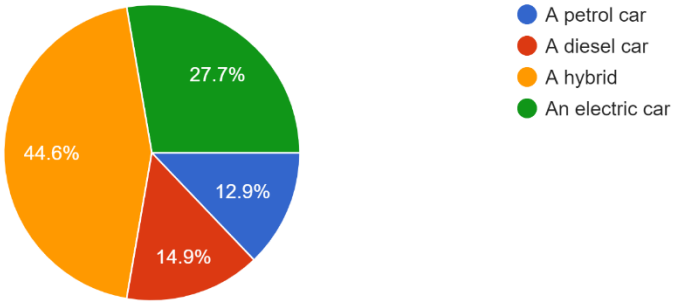

Fig -7: What kind of vehicle are you planning to buy? (101 Responses)

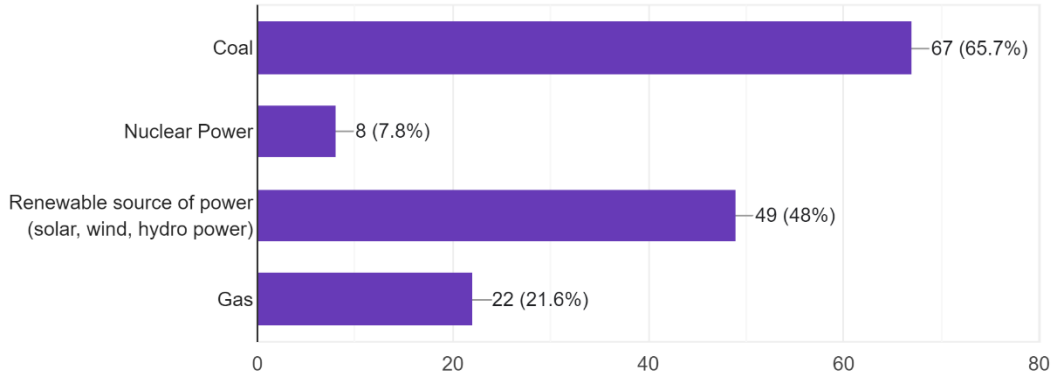

Fig -8: What do you think are the major sources of power in India? (102 Responses)

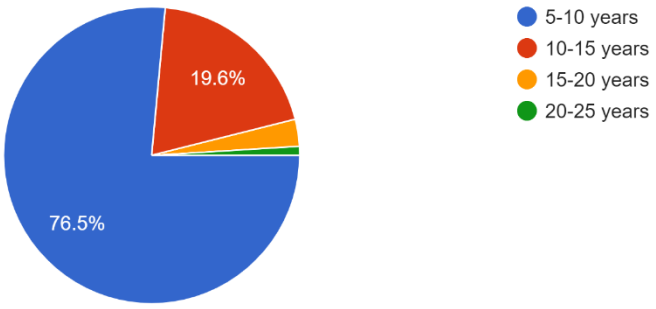

Fig -9: According to you what is the life of an electric vehicle battery? (102 Responses)

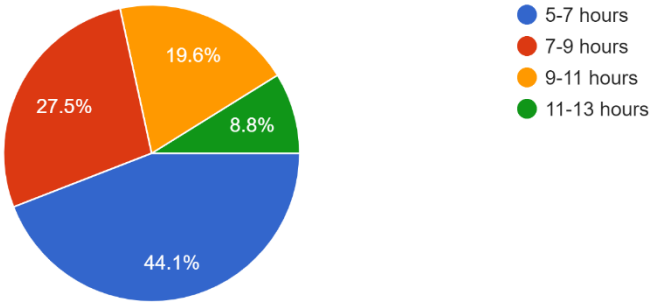

Fig -10: How long does it take to completely change an electric vehicle battery? (102 Responses)

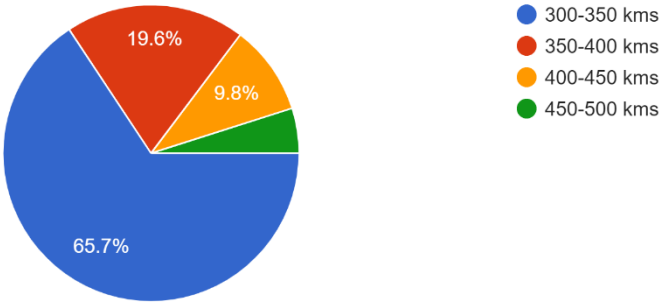

Fig -11: How far can an electric vehicle travel on a fully charged battery on average? (102 Responses)

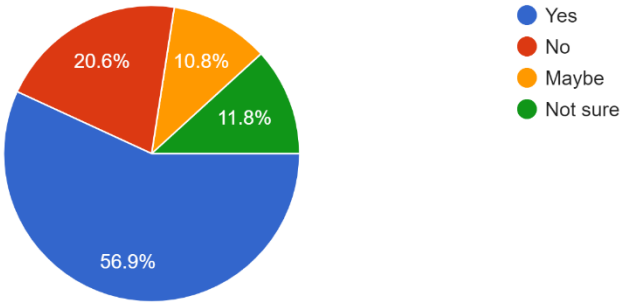

Fig -12: Do you think electric vehicle batteries have a longer life than regular car batteries? (102 Responses)

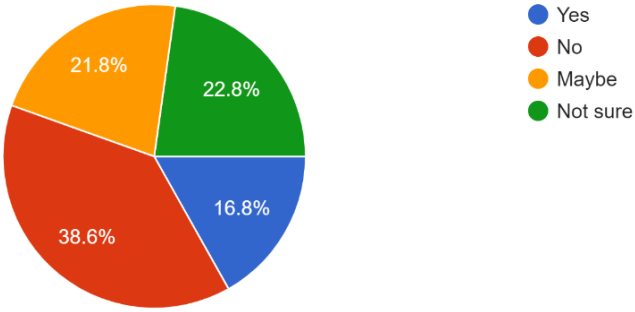

Fig -13: Do you think India has electric vehicle battery disposal arrangement? (102 Responses)

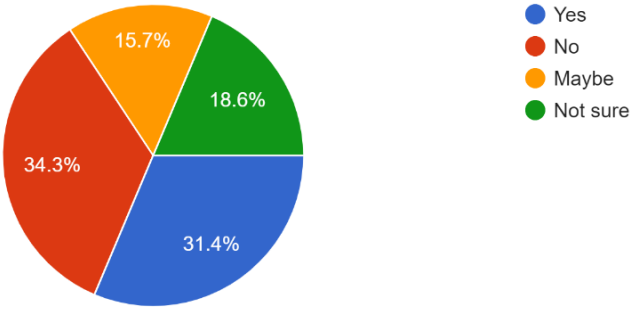

Fig -14: Does India produce its own electric vehicle battery? (102 Responses)

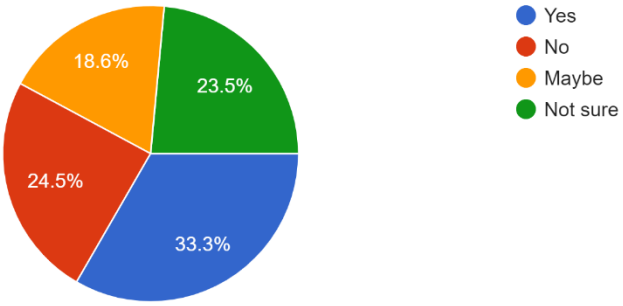

Fig -15: Is the raw material needed for electric vehicle battery available in India? (102 Responses)

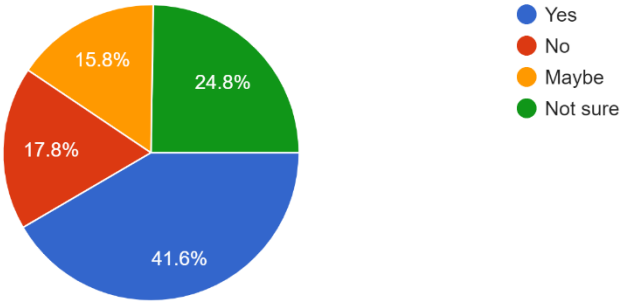

Fig -16: Can the batteries be recycled? (102 Responses)

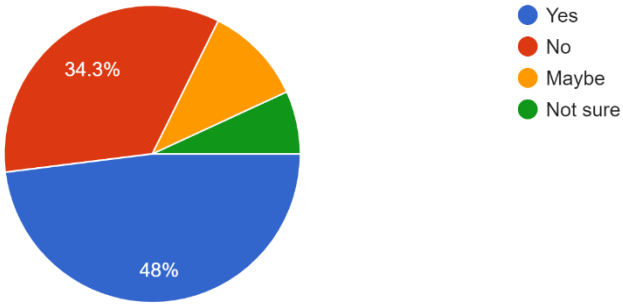

Fig -17: Are there different charging stations available in your city? (102 Responses)

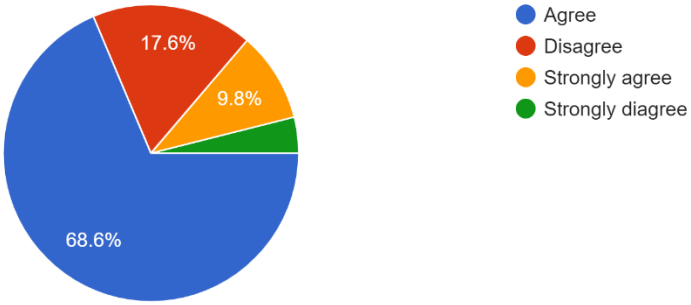

Fig -18: Are electric vehicles green in Indian context? (102 Responses)

REFERENCES

[1] https://www.eetimes.com

[2] http://timesofindia.indiatimes.com/

[3] https://e-vehicleinfo.com/

[4] https://www.eetimes.com/

[5] https://climate.mit.edu/

[6] https://www.nature.com/

BIOGRAPHIES

Ananya Chowdhery
Science Enthusiast with a Creative Bent of Mind
Student of Grade 12
Sat Paul Mittal School, Ludhiana

Samarthya Bindlish
Car Afficionado with a Scientific Bent of Mind
Student of Grade 10
Vivek High School, Chandigarh