



THE TRUE IMPACTS OF ELECTRIC VEHICLES IN INDIA

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Abstract:

The global shift towards electric vehicles (EVs) as a sustainable alternative to traditional combustion engine vehicles is gaining significant attention and being implemented increasingly in recent years. India, as well, has embraced this global movement towards electric vehicles, amidst escalating concerns over carbon emissions and air pollution, in efforts to improve the condition and sustainability of our environment. However, this societal shift towards electric vehicles that is taking place with the goals for ultimate sustainability, needs to be reevaluated, particularly concerning the environmental impacts of EV battery production, usage, and disposal. This research paper aims to assess the extent of sustainability of India's rapid adoption of electric vehicles by examining the environmental and economic benefits, considering the government's role, and also analyzing the lifecycle environmental implications of EVs. Specifically, the implications in relation to battery manufacturing and disposal, power sources, and the challenges associated with integrating EVs into the current power grid infrastructure are examined. Based on the gathered data and analysis, solutions are proposed to further benefit environmental standards and financial sustainability within the available resources and budgets of the Government. These solutions advocate for a redefined role of the government, emphasizing the prioritization of converting heavy public transport to electric, particularly trains and buses, over advocating and spending on the electrification of private vehicles. Ultimately, this paper provides information into the various considerations necessary for achieving truly sustainable transport solutions in India.

1. Introduction

The rapid rise in adoption of electric vehicles (EVs) in the past two decades has presented the start of a revolution, where the days of combustion engines dominating our streets are soon to be gone. Electric vehicle (EV) adoption in India has been on the rise, with sales growing by 82% in March 2023 compared to the previous year. Overall sales increased by 157% from FY2022 to FY2023,^[1] showcasing a significant shift in consumer preferences towards

cleaner and more sustainable modes of transportation. Instead of the traditional combustion engines, we, now, turn to electric motors signaling a shift towards a cleaner, more sustainable mode of transportation; however, this notion is to be questioned. 75% of the world's total CO₂ emissions propelled in recent years by Asian economies come from road transportation wherein, India, alone, contributes about 2.91 crore tonnes of CO₂ out of the 7.95 crore tonnes emitted in Asian economies. CO₂ emissions from the transportation industry alone experienced a threefold increase in the last decade. As the world grapples with the urgent need to combat climate change and reduce greenhouse gas emissions, EVs have emerged as a one-stop-shop solution. Governments worldwide put in their best efforts in catalyzing the adoption through initiatives such as the Electric Vehicle Initiative (EVI), as demonstrated by the EV30@30 campaign in 2017. This campaign aims to accelerate the widespread use of electric vehicles (EVs) worldwide and achieve a collective deployment of 30% new electric vehicle sales in all major markets by 2030.

Nevertheless, despite the commendable efforts being made to switch to a more sustainable alternative, a critical question arises: To what extent is the rapid adoption of Electric cars in India truly sustainably beneficial? While the transition to EVs holds promise for mitigating environmental degradation and building a greener future, it is important to reevaluate our assumptions and interrogate whether this change we make as a society from our gas-fueled engines to "green" electric vehicles is indeed completely and optimally sustainable.

2. Background

Understanding the working and mechanism of electric vehicles (EVs) and their battery technology is fundamental for evaluating their sustainability and potential environmental impact.

2.1.Types of Electric Vehicles

Electric car batteries function by storing electrical energy in a chemical form, which can then be utilized to power the vehicle's electric motor. There are different types of electric cars that are segregated based on their energy sources and powertrain configurations:

- **Battery Electric Vehicle (BEV):** BEVs are fully powered by electricity, utilizing a battery-powered electric drivetrain. They do not have an internal combustion engine, are powered exclusively by electric motors, and are charged by plugging into the electricity grid.
- **Hybrid Electric Vehicle (HEV):** HEVs utilize both an internal combustion engine and an electric motor powered by a battery pack. The engine and motor work together to drive the vehicle, and the battery is recharged through regenerative braking or engine power.

- **Plug-in Hybrid Electric Vehicle (PHEV):** PHEVs feature both an internal combustion engine and a battery charged from an external source. This allows the vehicle to be charged with electricity rather than relying solely on the engine.
- **Fuel Cell Electric Vehicle (FCEV):** FCEVs produce electric energy from chemical energy, primarily hydrogen gas. These vehicles utilize a fuel cell stack to convert hydrogen and oxygen into electricity, emitting only water vapor as a byproduct. This happens through an electrochemical reaction within a fuel cell stack, where hydrogen molecules are split into protons and electrons. The protons travel through an electrolyte membrane, while the electrons flow through an external circuit, generating electrical current. At the cathode, oxygen from the air combines with the protons and electrons to produce water vapor as the only byproduct, making FCEVs emissions-free during operation. FCEVs offer zero-emission mobility with the potential for rapid refueling and long driving ranges, making them a promising solution for sustainable transportation.

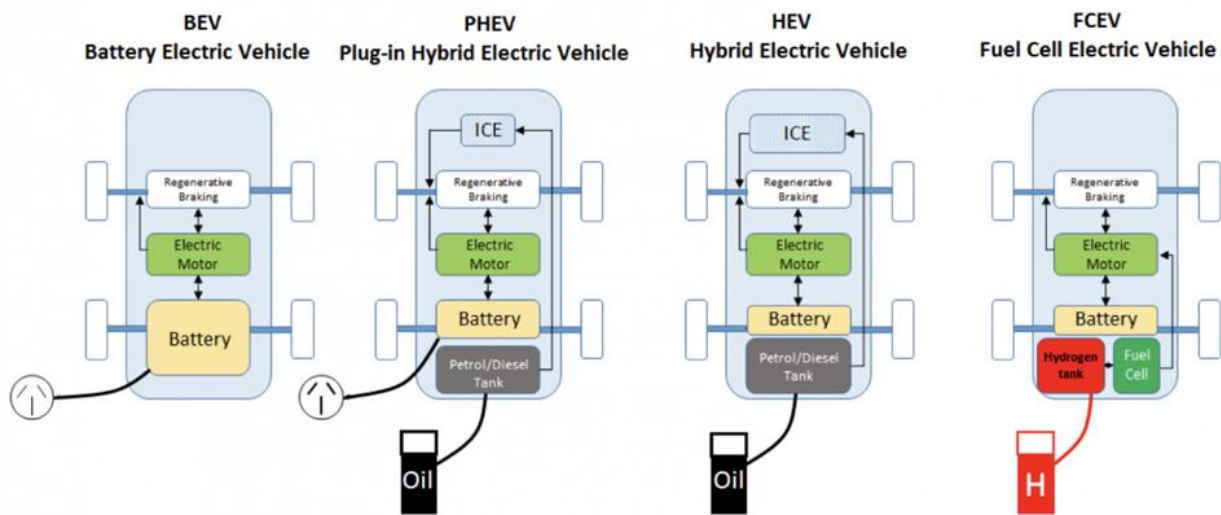


Fig 1. Types of Electric Vehicles. Gaton, B. (2020, May 22).

2.2. How the battery work:

Electric vehicle batteries consist of multiple individual cells that undergo a chemical reaction to create a flow of electrons, which are used to power the vehicle. These batteries are made of various different compositions including the lithium-ion, nickel-metal hydride, and solid-state batteries, out of which the lithium-ion is most commonly used due its lightweight nature, high energy density, and extended lifespan.

The chemical reaction taking place in each cell comprises the primary components- two electrodes and electrolyte. In the lithium cobalt oxide cell, specifically, the electrodes consist of an anode made of graphite and a cathode made of lithium cobalt oxide (LiCoO₂). An electrolyte solution, typically composed of lithium salts dissolved in an organic

solvent, facilitates the movement of lithium ions between the electrodes during the charging and discharging processes.

The battery's operation involves chemical reactions driven by the transfer of lithium ions between the anode and cathode. During discharge, lithium ions migrate from the anode to the cathode, producing an electric current that powers the vehicle's motor. Conversely, during charging, lithium ions move from the cathode back to the anode, replenishing the battery's stored energy. These fundamental processes enable electric vehicle batteries to efficiently store and release electrical energy.

LITHIUM-ION BATTERY

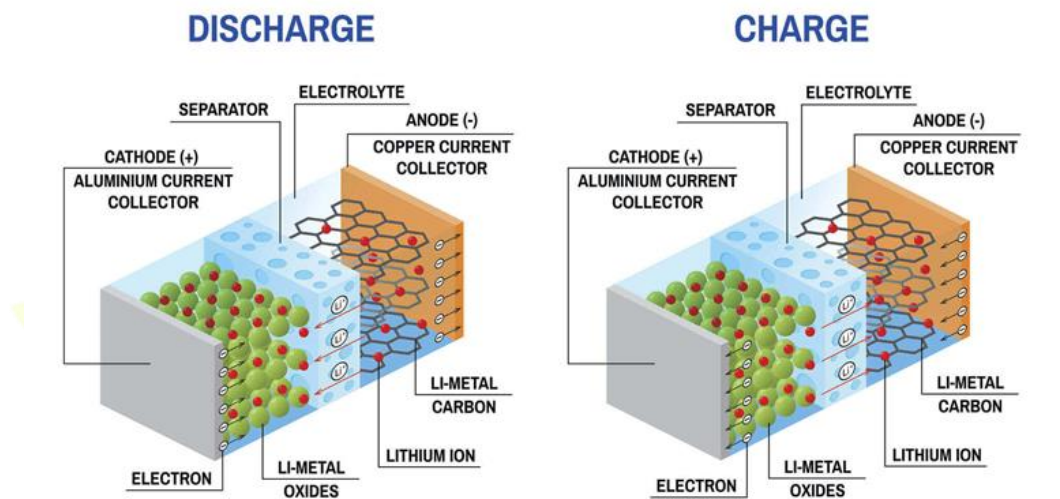


Fig 2. Reaction process of Lithium-ion battery. Layosa, C. (2021, November 2).

3. The Appeal of an Electric Vehicle

3.1. Environmental Sustainability

Electric vehicles (EVs) have become increasingly prominent in today's world due to several factors, with the primary concern it is made to address being environmental concerns. With growing awareness about climate change and air pollution, there's a greater emphasis on reducing greenhouse gas emissions. Therefore, the feature of EVs producing zero tailpipe emissions make them a much more alluring alternative to traditional internal combustion engine vehicles, by significantly reducing harmful pollutants released into the atmosphere.

3.2. Technological developments in EV

Additionally, technological advancements in the electric energy sector have significantly improved the performance and affordability of EVs. In India, significant development has been made in battery technology, particularly in the development of more efficient and durable lithium-ion batteries. Indian companies like Exide Industries and Amara Raja Batteries have been actively involved in research and innovation efforts aimed at improving energy density, reducing charging times, and enhancing overall battery performance, which have led to the development of batteries with higher energy densities, longer lifespans, and improved safety features in EVs. Furthermore, Indian companies, including Mahindra Electric and Tata Motors, have been at the forefront of developing advanced electric drivetrain systems and power electronics- Mahindra Electric has developed indigenous electric drivetrains for its electric vehicles, optimizing efficiency and performance while reducing dependence on imported components, further supporting the national economy, while, similarly, Tata Motors has made significant strides in developing electric powertrains for its passenger and commercial vehicles.

3.3. Consumer Economics

From a consumer financial standpoint, while the initial investment for EVs may still be higher compared to traditional vehicles, the long-term cost savings are substantial. Electricity, the primary fuel source for EVs, is generally cheaper than gasoline, resulting in lower operating costs over the vehicle's lifetime. Moreover, EVs have fewer moving parts than internal combustion engine vehicles, leading to reduced maintenance expenses and overall cost efficiency.

Furthermore, The Indian Government has been the greatest driving force in the transition, offering consumers financial incentives including subsidies, tax savings and other financial benefits. This is done as part of the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles scheme, phase 2 (FAME II) launched in April 2019. As part of the scheme, consumers receive incentives up to Rs. 15,000 per kWh for two-wheeler EVs, up to Rs. 10,000 per kWh for four-wheeler EVs, and an e-vehicle subsidy cap that is set at 40% of the vehicle's cost.^[2]

3.4. The Government's Role

Given the multitude of benefits electric vehicles (EVs) offer, particularly in addressing environmental concerns, the Government of India prioritizes promoting the rapid adoption of EVs. The Government has consistently been taking drastic measures and initiatives in implementing electric vehicle (EV) transportation with the ambitious goal to become the global leader in the EV sector by 2030. As part of this vision, the Faster Adoption Electric and Hybrid Vehicles in India (FAME) scheme Phase 2 was introduced in 2019^[3], an initiative under the National Electric Mobility Mission Plan (NEMMP), aimed to incentivize EV infrastructure providers and manufacturers through the

provision of subsidies as well as provide tax incentives to consumers. This scheme had launched with a budget outlay of Rs. 10,000 crores with an additional outlay of Rs. 500 crores to cover incentives for electric two-wheelers and four-wheelers, that will hold up till March 2024, a 3 year period.

Furthermore, the Ministry of Heavy Industries has proposed the introduction of FAME-III, with a proposed budget of Rs. 12,600 crores, scheduled for implementation in July 2024. This scheme is expected to build on FAME II and further incentivize the adoption of EVs across different vehicle segments.

Financial incentives provided to consumers under these schemes include purchase incentives, road tax exemptions, registration fee waivers, and income tax benefits. For instance, under FAME II, the Electric Mobility Promotion Scheme 2024 (EMPS 2024) offers subsidies of Rs. 15,000 per kWh for two-wheeler EVs, Rs. 10,000 for three-wheeler EVs, and up to Rs. 1.5 lakhs for four-wheeler EVs priced below Rs. 15 lakhs. [4] Additionally, the scheme covers incentives for electric buses, with the aim to subsidize a significant number of electric vehicles across various categories.

These initiatives have significantly contributed to driving technological innovation and market penetration of EVs. They provide a favorable environment for local EV companies and manufacturers to further develop their technologies and produce improved products, facilitating the transition to cleaner and more efficient modes of transportation. Moreover, by promoting domestic manufacturing of EV components and vehicles, these initiatives bolster India's self-reliance in the EV sector, while also fostering job creation and stimulating economic growth.



Fig. 3. Timeline for various initiatives in relation to Electric vehicles taken by policymakers and regulators in India. E-AMRIT. National level policy. <https://e-amrit.niti.gov.in/national-level-policy>

Overall, electric vehicles are increasingly being seen, by consumers, as a more viable and sustainable transportation solution in today's world, offering environmental benefits, cost savings, and technological advancements that continue to drive their adoption.

As we continue to promote EVs and acknowledge their benefits, it becomes imperative to pause and reflect: Is this truly the most optimal path to a sustainable future, both environmentally and otherwise? While the promises of zero tailpipe emissions and reduced operational costs do hold a great advantage, we must delve deeper into the environmental implications and long-term sustainability of this transition.

4. The Other Side

Despite the commendable efforts put in by the government to transition towards more sustainable transportation alternatives, it is important to reconsider our knowledge and analyze whether this change we make as a society from our gas fuel engines to “green” electric vehicles is the most environmentally sustainably optimal option for our society. Electric vehicles have been marketed to be the one-stop-solution to ultimate sustainability, which needs to be reevaluated. The major environmental concerns brought by EVs, which will be broken down and evaluated, include the production of lithium-ion batteries -covering manufacturing, transportation, and disposal - as well as battery powering.

4.1. Production of Batteries in Electric Vehicles

Electric vehicles (EVs) use rechargeable batteries to convert stored electrical energy into mechanical energy, thereby producing zero tailpipe emissions. However, the composition of these batteries, predominantly comprising non-renewable resources, as well as improper battery reusable technology pose significant environmental threats to the sustainability of resources. Despite the benefits EVs offer in reducing greenhouse gas emissions and air pollution, their reliance on finite resources and the environmental impacts associated with battery production and disposal emphasize the need for further technological innovations and sustainable practices within the electric vehicle industry.

4.1.1. Natural resource depletion

Various types of batteries power electric vehicles including lithium-ion, nickel-metal hydride, and solid-state batteries, with lithium-ion batteries being the most prevalent in India due to their high energy-density and extended lifespan. These batteries rely on rare earth metals such as lithium, cobalt, and nickel, all of which are non-renewable and susceptible to depletion over time. The composition of the lithium-ion batteries differs with every vehicle, which

can include lithium cobalt oxide, Lithium iron phosphate, Lithium Nickel Manganese Cobalt, Lithium Manganese Oxide, etc. A typical EV battery contains approximately 8 kilograms of lithium, along with approximately 14 kilograms of cobalt, and 20 kilograms of manganese, depending on the battery size. According to estimates, by 2025, 11 million tons of waste lithium-ion batteries will flood our market without a system to deal with them. Moreover, India, lacking significant lithium reserves, relies entirely on imports, with over 95% sourced from China and Hong Kong. This also increases India's dependency on China for raw materials, mineral processing, and battery production.

4.1.2. Carbon emissions from mining/ extraction

India, lacking significant lithium reserves, relies entirely on imports, with over 95% sourced from China and Hong Kong. Moreover, approximately 77% of the global supply of lithium-ion batteries is manufactured in China^[5], primarily fueled by coal energy, thereby raising environmental concerns. For example, A 2021 study published by Ricardo^[6] comparing EV and ICE emissions, an average medium-sized car will produce around 42 tonnes of CO₂ during its life cycle, while an electric vehicle (EV) will produce around 18 tonnes over its life. This means that 46% of an EV's total carbon footprint is generated at the factory itself. Almost 4 tonnes of CO₂ are released during the production process of a single electric car, and in order to break even, the vehicle must be used for at least 8 years to offset the initial emissions by 0.5 tonnes of prevented emissions annually. The extraction of these materials involves environmentally damaging processes, including the release of toxic fumes and the intensive use of water resources.

The composition of lithium-ion batteries differs with every vehicle, which can include lithium cobalt oxide, lithium iron phosphate, lithium nickel manganese cobalt, lithium manganese oxide, etc. A typical EV battery contains approximately 8 kilograms of lithium, along with approximately 14 kilograms of cobalt and 20 kilograms of manganese, depending on the battery size. The extraction of these materials results in substantial CO₂ emissions, particularly evident in hard rock mining, where 15 tonnes of CO₂ are emitted for every tonne of lithium mined^[7]. Moreover, concerns regarding human rights violations, such as child labour, persist in regions like the Democratic Republic of the Congo, which supplies 60% of the world's cobalt. For instance, a Tesla Model S battery contains up to 62.6 kg of lithium, with manufacturing processes emitting between 2400 kg to 16,000 kg of CO₂ per battery. This equates to the emissions of a typical gas-powered car over approximately 4,000 kilometers of driving.

4.1.3. Water depletion

Aside from resource depletion and carbon emissions, lithium production requires vast amounts of water, worsening the water scarcity issues. For instance, producing one tonne of lithium requires approximately 20 lakh tonnes of water, making battery production highly water-intensive. This has already led to significant water depletion in regions such as the South American Lithium triangle, comprising Chile, Argentina, and Bolivia, where 65% of the region's water was utilized for lithium extraction. Similar concerns regarding water scarcity may emerge in India if proactive measures are not implemented.

4.1.4. Disposal

The disposal of EV batteries presents significant challenges due to their composition and lack of efficient recycling infrastructure in India. Despite the fact that up to 95% of lithium-ion batteries can be retrieved, only 5% of EV batteries are currently being recycled.^[8] Batteries differ widely in chemistry and construction, which makes it difficult to create efficient recycling systems. This is because current EV batteries are not designed for easy recycling, leading to economic barriers as it's often cheaper to use freshly mined metals than recycled materials. Additionally, the escalating demand for lithium batteries exacerbates the issue, with recycling costs surpassing those of the batteries themselves.

Furthermore, the disposal of lithium-ion batteries poses environmental and health risks. The disposed batteries end up in landfill where damaged batteries can emit toxic fumes and may cause fires, endangering human health and the environment. High lithium concentrations in waste batteries also threaten human nervous and endocrine systems. Additionally, when the battery is damaged, it will generate a lot of heat and cause a fire, and it will release incredibly toxic gas.

Despite the potential for secondary use, such as in energy storage or electric vehicles, transitioning retired batteries requires effective recycling processes. Cascade utilization^[9] is one such process that involves repurposing retired batteries after their primary use in electric vehicles. Retired batteries may still have significant capacity left, but not sufficient for powering vehicles. Instead of discarding them, this process allows them to be repurposed to perform secondary applications like energy storage. This provides a solution to this issue, however, is held back by economic constraints and inadequate infrastructure.

4.2. Regular Battery Powering

Electric vehicles (EVs) are often said to be environmentally friendly alternatives to internal combustion engine vehicles due to their lack of tailpipe emissions. However, this sustainability depends upon the source of electricity used to power the EVs, particularly in countries like India where the majority of power generation relies on non-renewable sources, predominantly coal-fired power plants. This raises concerns about the environmental impact of regularly recharging EV batteries, as the electricity generation process emits carbon dioxide (CO₂) and consumes significant amounts of water.

A typical passenger vehicle emits about 4.6 metric tons (**4600 kg**) of CO₂ per year. This assumes the average gasoline vehicle on the road today has a fuel economy of about 9.4 kilometers per liter and drives around 18,500 kilometers per year.^[10]

Using the average EV's energy consumption, a home EV charger would use around 11.81 kWh per day to charge the car to replenish the range driven. This translates to about 353.3 kWh per month and 4,310.65 kWh per year. This data has been used to calculate the specific carbon emissions, water wastage and other pollution that comes from using coal fired power to recharge the EVs.

4.2.1. Carbon Emissions:

India's power generation landscape heavily relies on thermal sources, particularly coal, which accounts for 61% of the country's electricity as of 2021. Coal-fired power plants emit approximately 0.9 to 1.1 kilograms of CO₂-equivalent per kilowatt-hour (kWh) of electricity generated, considering both direct emissions from combustion and indirect emissions associated with mining, transportation, and plant operations. Consequently, recharging EV batteries with electricity sourced from coal-fired power plants leads to an estimated emission of 4310 kilograms of CO₂ per year per EV.

4.2.2. Water Wastage

Additionally, coal-fired power plants consume substantial amounts of water for various purposes, including cooling and steam generation. On average, these plants withdraw approximately 75 to 230 liters of water per kWh of electricity generated, resulting in significant water wastage ranging from 326,000 to 978,000 liters per year per EV, depending on the specific technology used for cooling and water availability in the region. However, the actual water consumption can vary widely depending on the specific technology used for cooling (e.g., once-through cooling vs. closed-loop cooling) and the availability of water resources in the area.

Therefore, comparing the carbon emissions and other external factors like water wastage that comes with refueling a gas-vehicle vs. an EV, as seen, a gas vehicle approximately produces 4600 kg of tailpipe carbon emissions per year, apart from the fossil fuels like petrol and diesel, while EVs produce 4310 kg with recharging the battery, along with the water wastage of 326,000 to 978,000 liters per year that comes with it, for the repowering the battery of an EV. This shows that quantifiably, though the EV is better in terms of carbon emissions, it is not as clean and undamaged as assumed.

4.2.3. Impact on Power grid

The widespread adoption of electric vehicles (EVs) in India poses significant challenges to the country's existing power grid infrastructure.

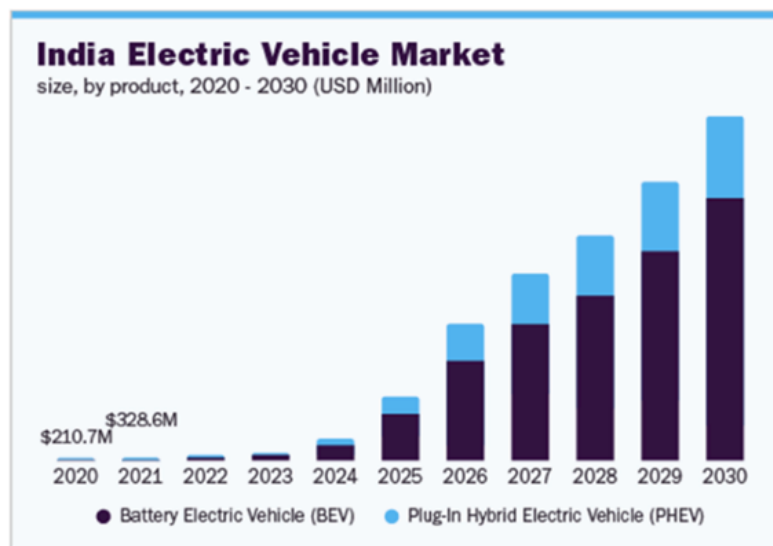


Fig 4. Indian EV Market Growth Scenario. Banothu, C. S., Gorantla, S. R., Rakada, V. B. A., & Evuri, G. R. (2024b, May 2). Impacts of wireless charging system for electric vehicles on Power Grid. *e-Prime - Advances in Electrical Engineering, Electronics and Energy*.

As illustrated by the exponential growth projected in the EV industry which is expected to reach \$152.21 billion by 2030 with a compound annual growth rate of 94.4% from 2021 to 2030, it is imperative to address the technical and logistical concerns associated with this transition.

- **Increased power demand:** The widespread use of electric vehicles translates to a surge in electricity demand. This sudden spike can strain the existing energy grid, especially during peak charging times. To meet this rising demand, there is a need for substantial upgrades in the capacity and efficiency of the electricity generation and distribution systems.

- **Grid Stability:** The intermittent nature of renewable energy sources used for power generation, such as solar and wind, can pose challenges to grid stability. EV charging, if not managed efficiently, may intensify this issue by causing fluctuations in demand that the grid must adapt to quickly.
- **Charging Infrastructure:** The development of a reliable EV charging infrastructure is crucial for effectively and successfully performing the transition. The existing infrastructure in India requires substantial expansion and improvement to support the growing number of electric vehicles on the roads.
- **Intermittency of Renewable Energy:** India's push towards renewable energy sources for power generation, such as solar and wind, is commendable. However, the intermittent nature of these sources poses challenges to grid stability. Integrating EV charging with renewable energy requires smart solutions to manage the fluctuations in power generation.



To address these challenges, distribution system operators must prepare for the rise in demand from EV charging and incorporate it into their strategies for enhancing the capacity of the distribution network. This entails conducting power flow grid impact analyzes to assess the thermal constraints of lines and the nominal power of transformers, ensuring that the local grids of every area and locality can support the deployment of rapid inductive charging stations.

The power flow analysis can be used to ensure that voltage levels at each node remain within acceptable limits, preventing interruptions in the charging process. Simulation methods play a crucial role in evaluating the performance of inductive charging infrastructure and optimizing the energy profile of distribution lines, as demonstrated in the case of Telangana, India.

PROPOSED CHARGING STATIONS: OPTIMIZING THE CATCHMENT

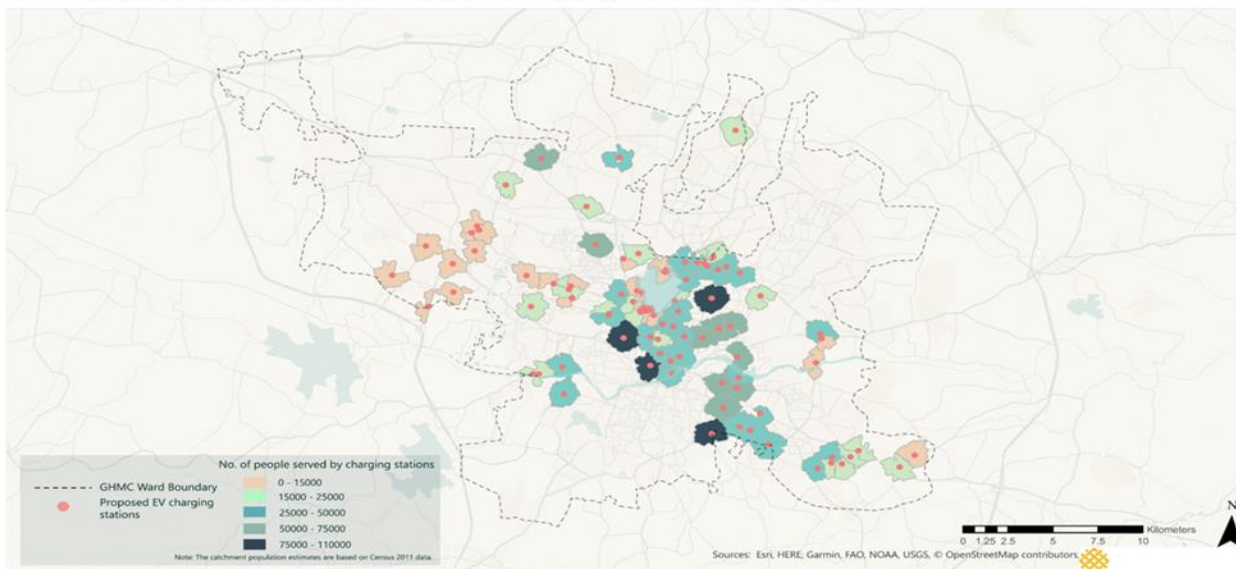


Fig. 5. MV distribution line in the area of India Telangana (TSREDCO).

In conclusion, the rise of EVs in India presents both opportunities and challenges for the power grid. Addressing these challenges requires proactive planning, investment in infrastructure, and the implementation of smart grid technologies to ensure the safe and reliable operation of the grid amidst the growing demand for electric transportation.

5. Using Electric Vehicles Sustainably

Therefore, the question arises: what is the solution to improve sustainable transport in the future? Despite these various environmentally harmful and degrading impacts associated with electric vehicles, EVs still hold benefits and potential when implemented strategically in specific scenarios.

5.1. Light-Duty Vehicles (LDV) vs. Heavy Duty vehicles (HDV)

The environmental cost of manufacturing EV batteries may not always offset the emissions saved from tailpipe pollution in small-scale private vehicles. As presented, the production and disposal of lithium-ion batteries in EVs contribute to carbon emissions and resource depletion. The production of a single electric car results in approximately 4 tonnes of CO₂ emissions, which the vehicle must be used for at least 8 years to offset the initial emissions and break even by 0.5 tonnes of prevented emissions annually. Moreover, the limited recycling of lithium-ion batteries poses a significant challenge, with only 5% of EV batteries being recycled currently. By 2025, an estimated 11 million tons of waste lithium-ion batteries are expected to accumulate without adequate recycling systems in place. Therefore, despite the benefits of EVs in reducing tailpipe emissions, this amount of pollution and damage caused by the production of EV batteries does not outweigh the emissions saved in light-duty vehicles like private 4-wheelers or 3-wheelers, especially considering their shorter mileage and lifespan.

Alternatively, this environmental burden of EV battery production is less significant for heavy-duty vehicles like buses, trains, and trucks. Public transport like trains and buses emit a much higher range of tailpipe carbon emissions when compared with that produced in the production of electric batteries. This is seen in the table below that presents the difference in emission levels of light-duty vs. heavy-duty vehicles.

Categories	CO ₂	CO	NO _x	CH ₄	SO ₂	PM	HC
Bus	28 748.16	207.26	679.73	5.02	79.24	31.36	51.72
Omni buses	8508.42	60.94	200.53	1.49	23.45	9.28	15.11
Two wheelers	8701.08	719.64	62.15	58.88	4.25	16.36	464.49
Light motor vehicles (passenger)	4378.10	370.29	92.93	13.07	2.11	14.52	10.16
Cars and jeeps	23 901.22	212.30	22.14	18.17	5.67	3.22	28.01
Taxi	2367.08	10.23	5.68	0.11	117.05	0.80	1.48
Trucks and lorries	70 288.92	491.15	859.51	12.28	193.73	38.20	118.69
Light motor vehicles (goods)	44 654.58	442.04	110.94	7.80	123.08	17.33	12.13
Trailers and tractors	46 563.85	460.94	115.69	8.13	128.34	18.08	12.65
Others	5705.22	57.41	64.54	1.83	32.19	3.98	8.96

Fig 6. Emissions from different types of ICE vehicles in India. Ramachandra, T. V., & Kashyap, S. (2009, November). *Emissions from India's transport sector: Statewise synthesis*. Research Gate.

The emissions calculated for different types of road transport vehicles are summarized in Fig 6. This shows that trucks and lorries contribute to 28.8% of CO₂(70.29 Tg), 39% NO_x (0.86 Tg), 27.3% SO₂ (0.19 Tg), and 25% PM (0.03 Tg), constituting 25% of the total vehicular emission of India^[11]. This displays the disproportionate impact that HDV have on carbon emissions compared to their relatively small numbers. Globally, on average, a pickup truck emits 2,040 kilograms more CO₂ per year than a car. Therefore, transitioning heavy-duty vehicles to electric power presents a promising avenue for reducing pollution.

Moreover, heavy-duty vehicles typically have greater mileage and longer life spans compared to LDVs. This means that the environmental cost associated with producing electric vehicle batteries is more easily offset with a greater mileage. Given these factors, prioritizing the electrification of public heavy-duty transport, such as trains, buses, and cargo trucks, emerges as a strategically optimal approach for curbing emissions. By focusing on these sectors, the government can most effectively target sources of pollution that contribute significantly to environmental degradation while promoting the adoption of sustainable transportation alternatives.

5.2. Government Initiatives and Incentives

The Indian government is playing a crucial role in promoting the adoption of EVs by offering incentives and subsidies to both manufacturers and consumers, primarily targeting private LDVs like 4-wheelers and 3-wheelers EVs. It has already launched a budget outlay of Rs. 10,000 crores with an additional outlay of Rs. 500 crores to cover incentives for electric two-wheelers and four-wheelers, that was held up till March 2024, as part of the Faster Adoption Electric and Hybrid Vehicles in India (FAME) scheme Phase 2. However, the government should prioritize transitioning public transport vehicles like buses, trains, metros, and trucks from ICE to electric-powered. By investing in electrifying heavy-duty vehicles and developing charging infrastructure, governments can create a more sustainable impact on reducing emissions. Rather than providing subsidies and incentives to citizens who buy electric cars, which may not be as impactful in terms of emissions reduction, financial resources should be allocated towards electrifying heavy-duty vehicles and constructing and developing charging infrastructure, as well as advancing EV battery technology to make public transport electric.

5.3. Investment in Charging Infrastructure and Battery Technology

Governments must invest in the development of charging infrastructure. This includes installing charging stations at depots, terminals, and along transit routes to ensure adequate charging capabilities for electric vehicles. Additionally, distribution system operators must prepare for the increased demand from EV charging and incorporate it into their strategies for enhancing the capacity of the distribution network. This involves ensuring that the local grids of every

area and locality can support the deployment of rapid inductive charging stations. Research and development efforts should focus on improving battery technology to enhance the range, efficiency, and lifespan of electric public transport vehicles.

5.4. An Alternative approach

Fuel cell electric vehicles (FCEVs) are another more sustainable alternative. FCEVs are powered by hydrogen fuel cells, which produce electric energy from chemical energy stored in hydrogen gas. Unlike traditional EVs, FCEVs emit only water vapor as a byproduct, making them environmentally friendly. However, the technology for FCEVs is still under development, as hydrogen is highly combustible. Despite its potential, further advancements are needed to ensure safety and efficiency.

5.5. Clean power production

Instead of incentivizing private vehicles, the government should allocate funds towards cleaner sources of power, such as solar or green hydrogen energy. This will reduce emissions generated from powering and recharging EV batteries and minimize current carbon emissions. Alternatives like green hydrogen energy or biofuels should be explored to contribute to this effort.

Citation

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