ASSESSING THE ROLE OF ENVIRONMENTAL LAW IN DRIVING THE SHIFT TOWARDS ELECTRIC VEHICLE TO MITIGATE POLLUTION

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ABSTRACT

Environmental pollution is now a global problem. Toxic gas emissions from internal combustion engines are one of the major air pollutants. Electric vehicles (EVs) are being actively promoted around the world to reduce the impact of emissions from fossil fuels and address environmental issues (EC). Various governments are encouraging people to switch to electric vehicles by offering migration incentives. The Indian government has called for "only electric vehicles" to be on public roads by 2030. Electromobility is being investigated as a possible solution to reduce environmental pollution in the transport sector. However, there is much debate among scientists and practitioners about how well electric vehicles outperform internal combustion engine vehicles in terms of greenhouse gas emissions, especially the variables that influence this performance. To our knowledge, most research on this topic mainly focuses only on specific stages of the vehicle life cycle, such as: Manufacture and Use of Vehicles. Comprehensive assessments of greenhouse gas emissions over a vehicle& life cycle are rarely done. This paper therefore aims to develop a comprehensive assessment framework for assessing the environmental impacts associated with electric vehicles. A valuation framework is then employed to estimate the environmental impacts associated with electric vehicles. The results show that in all analysed scenarios, electric vehicles have lower CO2 emissions over their lifecycle than comparable vehicles with combustion engines. Furthermore, the analysis highlights the significant impact on vehicle CO2 emissions associated with the geographic location of the upper stages of the vehicle supply chain (mainly electric vehicles). The main impact of the use phase on his CO2 emissions of EVs, then vehicle and battery manufacturing. Both evidences support the impact of the energy mix on the environmental performance of electric vehicles, which is further confirmed by sensitivity analyses. This paper contributes to the existing literature by confirming the superior environmental performance of electric

vehicles compared to internal combustion engine vehicles in terms of life cycle CO2 emissions, and as a means of addressing environmental issues. It provides policy makers with useful suggestions for promoting electric vehicles.

Keywords: Environment, Electric vehicles, Pollution, Greenhouse Gas emissions, Combustion engines.

I. Introduction

Air pollution is a silent killer on a global scale. India has some of the worst air pollution in the world, which poses a serious danger to the health and economy of the nation. The 1.4 billion people who live in India are all subject to unsafe concentrations of ambient PM 2.5, the most dangerous pollutant, which come from a variety of sources. The diameter of these tiny particles, which is less than 2.5 microns, is equivalent to around one-thirtyth of a human hair. Lung cancer, stroke, and heart disease are just a few of the terrible conditions that exposure to PM 2.5 can bring on. India is addressing this issue by undertaking numerous key actions. The Indian government has recently tightened requirements for industrial and vehicular emissions, and it is planning to revise its criteria for ambient air quality.[1]

Importance of reducing pollution

Human Health: Exposure to pollution can cause several health problems, such as respiratory illnesses, heart disease, and cancer. It can also affect reproductive health, causing birth defects, low birth weight, and premature births.

Environmental Preservation: Pollution can harm natural resources, such as water bodies, soil, and air, affecting ecosystems' balance and biodiversity. It can lead to the extinction of species and the destruction of habitats.

Climate Change: Pollution contributes to climate change, which has severe consequences, such

[1] Catalyzing clean air in India World Bank. Available at: https://www.worldbank.org/en/country/india/publication/catalyzing-clean-air-in-india (Accessed: April 27, 2023).

as rising temperatures, sea levels, and more frequent and severe natural disasters.[2]

Economic Costs: Pollution can have significant economic impacts, such as loss of productivity due to health problems, the cost of healthcare, and the cost of environmental remediation. Reducing pollution is essential for several reasons:

Social Equity: Pollution often disproportionately affects vulnerable communities, such as low-income and minority populations. Reducing pollution can help promote social equity and justice.

History of electric vehicles

The concept of electric vehicles dates back to the 1830s when the first electric carriage was developed. However, due to limitations in battery technology, electric vehicles were not practical for widespread use.In the early 20th century, electric cars became more popular, particularly in urban areas, due to their quiet operation and lack of emissions. However, the mass production of gasoline-powered cars by companies like Ford in the early 1900s made electric cars less competitive and they gradually fell out of favor. In the 1970s, in response to the oil crisis, interest in electric vehicles renewed. Automakers, such as General Motors, Ford, and Toyota, developed electric vehicle prototypes and small-scale production models. However, the high cost of batteries and limited driving range hindered widespread adoption. In the 1990s, California introduced Zero Emission Vehicle (ZEV) regulations that required automakers to produce a certain percentage of electric vehicles to reduce air pollution. This led to the development of the first modern electric cars, such as the General Motors EV1 and the Toyota RAV4 EV. In the 2000s, advancements in battery technology led to longer driving ranges and the development of new electric vehicle models, such as the Tesla Roadster and Nissan Leaf. The introduction of government incentives, such as tax credits and rebates, also helped boost the popularity of electric vehicles.[3]

Battery electric cars (BEVs) and plug-in electric vehicles (PHEVs) make up the majority of EVs. BEVs are electric-powered vehicles that are recharged by plugging them into an electrical

[2] *Health impacts of Pollution World Health Organization*. World Health Organization. Available at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts (Accessed: April 27, 2023).
[3] *The history of the Electric Car Energy.gov*. Available at: https://www.energy.gov/articles/history-electric-car (Accessed: April 27, 2023).

outlet or the power grid. Batteries are used to store the energy. They don't use any fuels with a petroleum base. However, PHEVs have combustion engines that are powered by petroleum-based fuels and use batteries to store the electricity they get from the grid. ICEVs, which employ combustion engines, consume petroleum-based fuels, and hence generate greenhouse gases, might be thought of as an alternative to the widespread usage of EVs. EVs can be charged from the grid despite the fact that they don't emit any direct emissions. As a result, the principal source of electricity generation affects the emission reduction. When electricity produced from renewable energy sources (solar, wind, or hydropower) is utilised to charge EV batteries, the impressive emission reduction of EVs can be attained. The diffusion of EVs cannot be aided by a single policy; rather, a combination of enabling policies, taking into account the national contexts, are more likely to be successful. To address air pollution, such regulations should take into account critical factors including the expansion of EV charging infrastructure, increased purchase prices, tax breaks, and subsidies for EV purchases.

Electric vehicles (EV) are quickly replacing other forms of transportation as the whole transportation sector undergoes a major transformation marked by a definite preference for cleaner and greener cars. Through programmes like "FAME I and FAME II (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles)", India has also campaigned for EV requirements. Up until 2026, the nation's EV sales are expected to grow at a compound annual growth rate of 35%. Electric cars can have an influence on the environment depending on how they are made or charged, despite the fact that the majority of experts say they are a more environmentally friendly alternative than conventional cars. The question of whether environmental law and electric vehicles are compatible emerges, nevertheless, as electric cars and trucks gain popularity.

We will be analyzing the role of Environmental law in driving the shift towards electric vehicle to mitigate pollution.

II. Environmental Laws and Regulations

India has implemented several environmental laws and regulations related to vehicle emissions to address air pollution and improve public health. Here is an overview of some of the key laws and regulations:

1.Bharat Stage Emission Standards: India has implemented a set of emission standards known

as Bharat Stage (BS) emission standards, which are similar to Euro emission standards. The BS standards specify the maximum permissible levels of pollutants such as carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter that can be emitted by vehicles.[4]

2.Central Motor Vehicle Rules: The Central Motor Vehicle Rules specify the emission norms for different types of vehicles, including two-wheelers, three-wheelers, passenger cars, and commercial vehicles. These rules also specify the testing procedures and equipment required to measure vehicle emissions.[5]

3.Pollution Under Control Certificate: All vehicles in India are required to have a Pollution Under Control (PUC) certificate, which indicates that the vehicle meets the prescribed emission norms. The PUC certificate is issued after a vehicle passes an emissions test conducted at authorized testing centers.[6]

4.National Green Tribunal: The National Green Tribunal (NGT) is a specialized court that was established to handle cases related to environmental issues, including air pollution caused by vehicles. The NGT has the power to impose fines on polluters, including vehicle manufacturers and owners, and to order the closure of polluting industries.[7]

5.Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles: In 2015, the Indian government launched the Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) scheme, which provides incentives to manufacturers and buyers of electric vehicles to promote their adoption.[8]

Overall, these laws and regulations play a crucial role in controlling vehicle emissions and improving air quality in India. However, effective implementation and enforcement of these regulations are necessary to achieve their intended goals.

Environmental laws and the Motor Vehicle Act in India are designed to promote the use of electric vehicles by providing incentives to manufacturers and consumers alike. The Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) scheme, which is a

[4] Iea *Bharat Stage (BS) VI emission standards – policies*, *IEA*. Available at: https://www.iea.org/policies/7454-bharat-stage-bs-vi-emission-standards (Accessed: April 29, 2023).
[5] Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).
[6] Ibid
[7] Ibid
[8] Ibid

part of the National Electric Mobility Mission Plan (NEMMP), is a prime example of how the government is working to promote EVs in India.

The FAME scheme provides financial incentives to both manufacturers and consumers of EVs. For manufacturers, the scheme provides support for research and development of EV technology, as well as incentives for the production of EVs. For consumers, the scheme offers subsidies for purchasing EVs, as well as tax benefits and exemption from road tax and registration fees.[9]

Furthermore, the Motor Vehicle Act in India mandates that all new vehicles must meet certain emission standards. This encourages the production of cleaner vehicles and creates a more level playing field for EVs to compete with traditional gasoline vehicles. The government has also set a target for 30% of all new vehicles sold in India to be electric by 2030, which provides a strong signal to manufacturers and consumers that the government is serious about promoting EVs.

Environmental laws in India, such as the Air (Prevention and Control of Pollution) Act and the Water (Prevention and Control of Pollution) Act, also play a role in promoting the use of EVs. These laws are designed to reduce pollution and encourage the use of cleaner technologies like EVs. The government has also implemented various measures to increase the availability of charging infrastructure for EVs, such as providing subsidies to set up charging stations.[10]

In conclusion, environmental laws and the Motor Vehicle Act, along with policies like FAME, are playing a significant role in promoting the use of electric vehicles in India. By providing incentives for manufacturers and consumers and setting emission standards, the government is creating a framework for the growth and development of EV technology in India.

Case studies of countries or regions with effective environmental laws and regulations

There are several countries and regions that have implemented effective environmental laws and regulations to protect their natural resources and ecosystems. Here are a few examples:

[9] Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).
[10] Vaish, V. (2017) *Environment laws in india* , *Environment Laws In India - Waste Management - India*. Vaish Associates Advocates. Available at: https://www.mondaq.com/india/waste-management/624836/environment-laws-in-india (Accessed: April 29, 2023).

1.Costa Rica: Costa Rica is known for its progressive environmental policies, including the establishment of a national park system, reforestation efforts, and a commitment to sustainable tourism. In 2019, the country announced plans to become carbon neutral by 2050.

2.European Union: The EU has implemented a range of environmental laws and regulations to reduce greenhouse gas emissions, protect biodiversity, and promote sustainable development. These include the Renewable Energy Directive, which requires member states to increase their use of renewable energy sources, and the Birds and Habitats Directives, which protect threatened species and their habitats.[11]

3.Bhutan: Bhutan is known for its commitment to Gross National Happiness, a philosophy that emphasizes sustainable development and environmental conservation. The country has implemented policies to protect its forests and wildlife, including a ban on logging and hunting.[12]

4.Singapore: Singapore has implemented strict environmental laws and regulations to address pollution and waste management. The country has established a national recycling program and implemented a carbon tax to reduce greenhouse gas emissions.

5.Norway: Norway has implemented a range of environmental policies to protect its natural resources and ecosystems, including a ban on offshore oil drilling and investments in renewable energy. The country has also established a sovereign wealth fund that prioritizes investments in sustainable industries.[13]

III. Incentives for Electric Vehicles

In recent years, India has been taking significant steps towards promoting the use of electric vehicles (EVs) as a means of reducing air pollution and decreasing reliance on fossil fuels. Environmental laws and policies have played a crucial role in incentivizing the adoption of EVs in the country. Here is an overview of some of the incentives provided by environmental laws for electric vehicles in India:

[11] *Renewable energy directive Energy*. Available at: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en (Accessed: April 29, 2023).
[12] https://www.trade.gov/country-commercial-guides/offshore-energy-oil-gas-and-renewables
[13] Ibid

FAME India scheme: The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) India scheme was launched by the Government of India in 2015 to promote the adoption of EVs in the country. The scheme offers a range of incentives, including financial incentives for purchasing electric vehicles and a subsidy for setting up charging stations.

GST reduction: In 2019, the Goods and Services Tax (GST) on EVs was reduced from 12% to 5%, making them more affordable for consumers.

Income tax benefits: Under Section 80EEB of the Income Tax Act, individuals can claim a deduction of up to Rs. 1.5 lakh on the interest paid on loans taken to purchase electric vehicles.

Road tax exemption: Several states in India, including Delhi, Maharashtra, and Uttar Pradesh, have exempted electric vehicles from road tax to promote their adoption.

Priority parking: Many cities have reserved parking spaces for electric vehicles to encourage their use.

Toll exemption: Several states, including Delhi, Maharashtra, and Karnataka, have exempted electric vehicles from toll charges to promote their adoption.

No permits required: In 2018, the Ministry of Road Transport and Highways exempted electric vehicles from requiring permits to operate as commercial vehicles, making it easier for businesses to adopt EVs.[14]

Analysis of the effectiveness of incentives in promoting electric vehicle use

Incentives have been used worldwide to encourage the adoption of electric vehicles (EVs) by reducing the purchase price and operational costs of EVs, as well as by improving the availability of charging infrastructure. In India, the government has implemented several incentive programs to promote EVs, and while the impact of these programs is still being evaluated, here is a general analysis of the effectiveness of incentives in promoting EV use in India:

Financial Incentives: The government of India provides financial incentives to encourage the

[14] *Green highways | Ministry of Road Transport & Highways, Government of India* . Available at: https://morth.nic.in/green-highways (Accessed: April 28, 2023).

purchase of EVs. The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME) scheme provides subsidies ranging from 10% to 60% of the total vehicle cost, depending on the type of EV and battery capacity. This scheme has been instrumental in boosting EV sales, especially in the two-wheeler segment. However, the availability of funds for the scheme has been a major bottleneck in achieving its full potential.[15]

Charging Infrastructure Incentives: The government of India has launched various schemes to promote the installation of EV charging infrastructure. These schemes provide financial incentives to private and public entities for setting up charging stations. While the number of charging stations has increased, the pace of expansion has been slow, and the charging infrastructure remains inadequate, especially in smaller cities and towns.

Tax Incentives: The government of India provides several tax incentives to promote the adoption of EVs. For instance, EVs are exempted from road tax, and they attract a lower Goods and Services Tax (GST) rate of 5%, as opposed to the 28% GST rate for conventional vehicles. These incentives reduce the operational cost of EVs and make them more affordable for consumers.

Non-Financial Incentives: The government of India has also introduced non-financial incentives to promote EV adoption. For instance, EVs are allowed to use bus lanes in some cities, and they are exempted from the odd-even vehicle rule, which limits the use of private vehicles on alternate days. These incentives aim to improve the convenience and attractiveness of EVs for consumers.[16]

Overall, while incentives have played a crucial role in boosting the adoption of EVs in India, the impact of these incentives is limited by various factors such as the availability of funds, inadequate charging infrastructure, and limited consumer awareness. To maximize the effectiveness of incentives, the government needs to address these factors by providing sustained financial support, improving the charging infrastructure, and increasing consumer awareness of the benefits of EVs.

[15] *FAME India Scheme Fame India scheme*. Available at: https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377 (Accessed: April 29, 2023).
[16] *FAME India Scheme* (no date) *Fame India scheme*. Available at: https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377 (Accessed: April 29, 2023).

Comparison of incentive programs across different countries or regions

Electric vehicle (EV) incentive programs vary widely across different countries, including India. Here are some comparisons of EV incentive programs across different countries:

India: The Indian government has launched the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) scheme to promote the adoption of EVs. The scheme provides subsidies on the purchase of EVs, as well as charging infrastructure incentives.

United States: The federal government offers a tax credit of up to $7,500 for the purchase of EVs. Some states also offer additional incentives, such as tax credits, rebates, or exemptions from sales tax or vehicle registration fees. Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).[17]

China: The Chinese government offers significant incentives for the purchase of EVs, including subsidies and tax exemptions. However, the amount of incentives has decreased over the years due to concerns about fraud and overcapacity in the EV market.

Norway: Norway has one of the most generous EV incentive programs in the world. It includes tax exemptions, reduced tolls, and free parking and charging for EVs. As a result, EVs make up a significant portion of the country's new car sales.

France: The French government offers a bonus-malus system that rewards the purchase of EVs and punishes the purchase of high-emission vehicles. The bonus for EVs can be up to €7,000, while the malus for high-emission vehicles can be up to €20,000.[18]

IV. Mandates for Electric Vehicle Adoption

India does not have any nationwide mandates requiring a certain percentage of new vehicles sold to be electric. However, the Indian government has set a target for 30% of all new vehicles sold to be electric by 2030, and some states have implemented their own policies to promote EV adoption.

[17] Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).
[18] Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).

For example, the state of Delhi has mandated that 25% of all new vehicle registrations must be EVs by 2024, and the state of Maharashtra has set a target for 10% of all new vehicle registrations to be EVs by 2025. In addition, some cities such as Bengaluru and Hyderabad have introduced their own incentives for EVs, such as reduced road tax and registration fees.

The Indian government has also introduced various policies and schemes to promote EV adoption, such as the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) scheme, which provides financial incentives for the purchase of EVs and charging infrastructure, as well as other measures to support the development of the EV ecosystem in the country.

It's worth noting that India's current lack of nationwide mandates for electric vehicles does not necessarily mean that such mandates will not be introduced in the future. As the Indian government continues to prioritize efforts to reduce air pollution and combat climate change, it's possible that mandates or other policies to promote EV adoption could be implemented in the coming years.[19]

India has set an ambitious target of achieving 100% electric mobility by 2030. To achieve this goal, the Indian government has implemented several policies and mandates to encourage the adoption of electric vehicles (EVs) in the country. Here's an analysis of the impact of mandates on the adoption of EVs in India:

FAME II Scheme: In 2019, the Indian government launched the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME II) scheme, which aims to promote the adoption of EVs and reduce air pollution. Under this scheme, the government provides financial incentives to EV buyers and manufacturers. The scheme has had a positive impact on the adoption of EVs, as it has increased the demand for EVs in the country.[20]

EV Subsidies: The Indian government has also implemented several subsidies and incentives to encourage the adoption of EVs. For instance, the government offers a subsidy of up to INR 1.5 lakh (around $2,000) for EVs priced under INR 15 lakhs (around $20,000). This has helped

[19] *Battery capacity needed to power electric vehicles in India from 2020* . Available at: https://theicct.org/sites/default/files/publications/Battery-capacity-ev-india-feb2021.pdf (Accessed: April 28, 2023).
[20] *FAME India Scheme Fame India scheme*. Available at: https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377 (Accessed: April 29, 2023).

reduce the cost of EVs and made them more affordable for buyers, thus increasing their adopton.

Mandate for Public Transport: The Indian government has mandated that all new public transport vehicles should be electric by 2030. This mandate has had a significant impact on the adoption of EVs in the public transport sector. Several state governments have already started replacing their old diesel buses with EVs.

Mandate for Two-Wheeler Taxis: Several state governments have mandated that all two-wheeler taxis (auto-rickshaws) should be electric by a certain date. For instance, the state of Delhi has mandated that all auto-rickshaws in the city should be electric by 2023. This mandate has had a positive impact on the adoption of EVs in the two-wheeler taxi sector.

Mandate for Government Fleets: The Indian government has mandated that all new cars purchased by government departments should be electric. This mandate has had a positive impact on the adoption of EVs in the government sector.[21]

Challenges of implementing mandates

While the mandates implemented by the Indian government have had a positive impact on the adoption of electric vehicles (EVs) in the country, there are still several challenges that need to be addressed. Some of the challenges of implementing mandates on EVs in India are:

Lack of charging infrastructure: One of the biggest challenges for the adoption of EVs in India is the lack of adequate charging infrastructure. Most of the charging stations are concentrated in urban areas and are not easily accessible to people living in rural areas. This lack of infrastructure poses a significant challenge for EV users, who may have to travel long distances to find a charging station.[22]

High cost of EVs: Although the Indian government offers subsidies and incentives to encourage the adoption of EVs, the high initial cost of EVs remains a significant barrier to their adoption.

[21] Ibid
[22] *Charging infrastructure needs big push as EV adoption grows in India . The Economic Times*. Available at: https://economictimes.indiatimes.com/industry/renewables/charging-infrastructure-needs-big-push-as-ev-adoption-grows-in-india/articleshow/97223763.cms?from=mdr (Accessed: April 29, 2023).

This is especially true for low-income households, who may not be able to afford the high upfront cost of an EV, even with the government subsidies.

Limited range of EVs: Another challenge for the adoption of EVs in India is the limited range of EVs. Most EVs currently available in India have a range of around 100-150 kilometers, which may not be sufficient for long-distance travel. This limited range is a significant barrier for people who depend on their vehicles for daily commuting and long-distance travel.

Lack of awareness: Despite the government's efforts to promote the adoption of EVs, there is still a lack of awareness among the public about the benefits of EVs. Many people are not aware of the government subsidies and incentives available for EVs, and they may not understand the long-term benefits of owning an EV.

Limited availability of EVs: Although several automakers have started manufacturing EVs in India, the availability of EVs is still limited. This limits the options available to buyers, and they may have to wait for long periods to get their hands on an EV.

V. Investment in Charging Infrastructure

India has implemented various environmental laws and policies to promote the development of charging infrastructure for electric vehicles (EVs) in the country. Below are some of the key environmental laws that promote the development of charging infrastructure for electric vehicles in India:

National Electric Mobility Mission Plan (NEMMP) 2020: NEMMP 2020 is a flagship scheme launched by the government of India to promote the adoption of electric vehicles in the country. The mission plan aims to achieve 6-7 million electric/hybrid vehicles on Indian roads by 2020. One of the key objectives of NEMMP 2020 is to set up a robust charging infrastructure for EVs.[23]

Faster Adoption and Manufacturing of Electric Vehicles (FAME) India: The FAME India scheme was launched by the Indian government in 2015 to promote the adoption of electric

[23] Iea (no date) *National Electric Mobility Mission Plan 2020 – policies*, *IEA*. Available at: https://www.iea.org/policies/3151-national-electric-mobility-mission-plan-2020 (Accessed: April 29, 2023).

vehicles in the country. The scheme provides financial incentives to manufacturers and buyers of EVs, and also supports the development of charging infrastructure for EVs.

National Institution for Transforming India (NITI) Aayog's EV Policy: The NITI Aayog, which is India's premier think tank, has also released a policy on electric vehicles. The policy aims to promote the adoption of EVs in the country by providing incentives and support for the development of charging infrastructure.[24]

Indian Electricity Grid Code: The Indian Electricity Grid Code (IEGC) is a set of rules and regulations that govern the operation and management of the Indian electricity grid. The IEGC has provisions for the integration of renewable energy sources, including EV charging stations, into the grid.

Bureau of Indian Standards (BIS): The BIS is a national standards body that develops and promotes standards for various products and services in India. BIS has developed standards for EV charging infrastructure, which include specifications for the design and operation of charging stations.[25]

Energy Conservation Act: The Energy Conservation Act is an Indian law that aims to promote energy efficiency and conservation in the country. The Act has provisions for the promotion of energy-efficient technologies, including EVs and charging infrastructure.[26]

Case studies of countries or regions with successful charging infrastructure programs

Norway:

Norway is often cited as a leading example of successful EV adoption and charging infrastructure. The government has implemented policies that provide incentives for EV purchases and support the development of charging infrastructure. As a result, Norway has the highest per capita EV ownership in the world, and a comprehensive charging network that includes fast-charging stations along highways and urban areas.[27]

[24] *National level policy*. Available at: https://e-amrit.niti.gov.in/national-level-policy (Accessed: April 29, 2023).
[25] Ibid
[26]Ibid
[27] Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).

California, United States:

California has been a leader in EV adoption and charging infrastructure development in the US. The state has set aggressive targets for EV adoption and has provided financial incentives for EV purchases and charging infrastructure development. California has a network of over 25,000 charging stations, including fast-charging stations along major highways and urban areas.[28]

Amsterdam, Netherlands:

Amsterdam has been recognized as a global leader in sustainable transportation, including EVs and charging infrastructure. The city has implemented policies that encourage EV adoption and has developed a network of charging stations that includes over 3,000 public charging points and 400 fast-charging stations.[29]

China:

China is the world's largest market for EVs and has made significant investments in charging infrastructure. The government has provided financial incentives for EV purchases and has supported the development of a nationwide charging network. China has over 1 million charging points, including fast-charging stations along highways and urban areas.

Japan:

Japan has been a leader in EV adoption and charging infrastructure development, particularly in the area of rapid charging technology. The government has provided financial incentives for EV purchases and has supported the development of a nationwide charging network that includes over 30,000 charging points, including fast-charging stations along major highways and urban areas.[30]

VI. Research and Development

The Indian government has launched several research and development programs to promote the development and adoption of electric vehicles (EVs) in the country. Here's an overview of

[28] Iea *International Energy Agency*, *IEA*. Available at: https://www.iea.org/ (Accessed: April 29, 2023).
[29] Ibid
[30] Ibid

some of the major government-funded research and development programs for electric vehicles in India:

National Electric Mobility Mission Plan (NEMMP):

The NEMMP is a flagship program of the Indian government aimed at promoting the development and adoption of electric and hybrid vehicles in the country. The program was launched in 2013 and aims to achieve 6-7 million sales of hybrid and electric vehicles by 2020.[31]

FAME India Scheme:

The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) India scheme was launched in 2015 as part of the NEMMP. The program provides financial incentives to promote the adoption of electric and hybrid vehicles in the country.[32]

National Automotive Testing and R&D Infrastructure Project (NATRiP):

The NATRiP is a government-funded initiative aimed at developing testing and R&D infrastructure for the automotive industry in India. The program includes the development of a testing and certification center for electric and hybrid vehicles.[33]

Technology Platform for Electric Mobility (TPEM):

The TPEM is a collaborative research and development program launched in 2012 by the Department of Heavy Industry and the Ministry of New and Renewable Energy. The program focuses on developing advanced technologies for electric mobility in India.[34]

Electric Mobility Research Initiative (EMRI):

The EMRI is a research and development program launched by the Department of Science and

[31] Iea (no date) *National Electric Mobility Mission Plan (NEMMP) – policies*, *IEA*. Available at: https://www.iea.org/policies/6201-national-electric-mobility-mission-plan-nemmp (Accessed: April 29, 2023).
[32] [32] *FAME India Scheme Fame India scheme*. Available at: https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377 (Accessed: April 29, 2023).
[33] *Open source content management Home*. Available at: https://www.natrip.in/ (Accessed: April 29, 2023).
[34] *Dhi-DST technology platform for Electric Mobility (TPEM): Department of Science & Technology: Department of Science & Technology (DST)* (no date) *विज्ञान एवं प्रौद्योगिकी विभाग Department of Science & Technology (DST)*. Available at: https://dst.gov.in/dhi-dst-technology-platform-electric-mobility-tpem (Accessed: April 29, 2023).

Technology to support the development of technologies for electric mobility in India. The program aims to develop advanced battery technologies, charging infrastructure, and vehicle components.[35]

VII. Conclusion

There are several limitations and areas for future research for electric vehicles (EVs) in India. Some of them are:

Lack of charging infrastructure: The lack of charging infrastructure is a major limitation for the widespread adoption of EVs in India. There is a need for more charging stations, particularly in public places such as shopping malls, office complexes, and public parking lots.

High cost: The high cost of EVs is a significant barrier to their adoption in India. The cost of EVs needs to be reduced to make them more affordable for the average consumer.

Limited range: The limited range of EVs is also a significant limitation. EVs have a lower range than conventional vehicles, which makes them less practical for long-distance travel.

Battery technology: Battery technology is a critical area for future research. The development of more efficient and cost-effective batteries will help to reduce the cost and improve the performance of EVs.

Policy framework: There is a need for a comprehensive policy framework to support the adoption of EVs in India. This includes incentives for EV manufacturers, charging infrastructure development, and consumer subsidies.

Consumer awareness: There is a need to create more awareness among consumers about the benefits of EVs. This includes educating consumers about the cost savings, environmental benefits, and performance of EVs compared to conventional vehicles.

Supply chain: Building a robust and efficient supply chain for the production and distribution of EVs and their components is another critical area of research and development.

[35] *Why the Automotive Future Is Electric* (2021) *McKinsey & Company*. McKinsey & Company. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-the-automotive-future-is-electric (Accessed: April 29, 2023).

To address these challenges, future policies and programs for electric vehicles in India should consider the following:

Incentives and subsidies: The government should continue to offer incentives and subsidies to make EVs more affordable for consumers. This could include tax exemptions, reduced registration fees, and financial incentives for EV manufacturers.

Charging infrastructure: The government should prioritize the development of a robust charging infrastructure network across the country. This could involve collaborating with private companies to install charging stations at public locations, such as shopping malls and parking lots.

Public awareness campaigns: The government should launch public awareness campaigns to educate consumers about the benefits of EVs, such as reduced air pollution and lower operating costs. These campaigns could also include information on government incentives and the availability of charging infrastructure.

Battery recycling: The government should establish regulations and policies for the safe and environmentally-friendly disposal and recycling of EV batteries. This would help to mitigate the potential negative environmental impacts of EV battery waste.

Partnerships with industry: The government should partner with the private sector, including EV manufacturers, charging infrastructure companies, and battery recycling companies, to drive innovation and accelerate the adoption of EVs in India.