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MARKET POTENTIAL AND ENVIRONMENTAL IMPACT OF ELECTRIC VEHICLE FOR SUSTAINABLE MOBILITY IN INDIA

By

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Declaration by the Guide

This is to certify that the Mr. Bhushan Rajkumar Khade, a student of MBA Power Management, SAP ID 500058282 of UPES has successfully completed this dissertation report on "**Market Potential and Environmental Impact of Electric Vehicle for Sustainable Mobility in India**" under my supervision. Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of MBA.

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Table of Contents

List of Figures

List of Table

Chapter 1: Introduction

This chapter outlines the overview, background of the project, objectives or purpose of the study, theme, necessity of project.

1.1 Overview

Electric vehicles are the way forward for India and we must move towards self-sufficient electric vehicles that can replace fossil fuel-based ones. With the scale of pollution in India and alarming projections of worsening climatic conditions in the future, the only way to move forward in our quest to achieve environmental sustainability and clean air to breathe is to rapidly move towards electric mobility. Around the world, countries are rapidly adopting electric vehicle-related technologies and gradually phasing out fossil fuel-based vehicles as a part of their concerted plan to combat climate change and rising pollution in cities. For instance, some European countries plan to phase out all fossil fuel-based cars by 2025 and some intend to stop manufacture of such cars. This initiative is expected see more than a million electric cars on road by 2030. In this scenario, India should consider the best interest of health and environment-related considerations in the country. It needs to device an implementable roadmap and put together the right infrastructure and conducive policy structure required for electric vehicles to meet the needs of the humongous Indian automotive market and public transport system. While the benefits of electric vehicles are obvious, their adoption rate is minimal in India. Therefore, to push the e-Mobility initiative, the Government needs to provide adequate incentives for adoption of electric vehicles. This will lead to cities seeing a surge in the demand for power. To meet this demand, the Government will need to develop innovative solutions, for instance, by using the rooftops of fuel pump stations to generate solar power across India. These fuel stations could initially double up as solar power based electric vehicle-charging stations. This will not only augment the earnings of the owners of fuel station, but also facilitate the smooth transition from traditional fuel-based mobility solutions to renewable and clean energy-based ones. Electric vehicles have to be an integral part of an environmentally sustainable future for us, and the sooner we realise this, the faster will be our progress towards mobility of clean and green electricity in the country. Public electric vehicles are however only one part of a much broader approach that needs to be taken towards sustainable mobility. Apart from public transport systems, privately owned cars and other vehicles should also become climate-neutral. Use of such vehicles will play a major role in India meeting its environment and sustainability goals, and drastically reduce pollution levels in the country.

Figure 1: Electric Vehicle & Charging Infrastructure

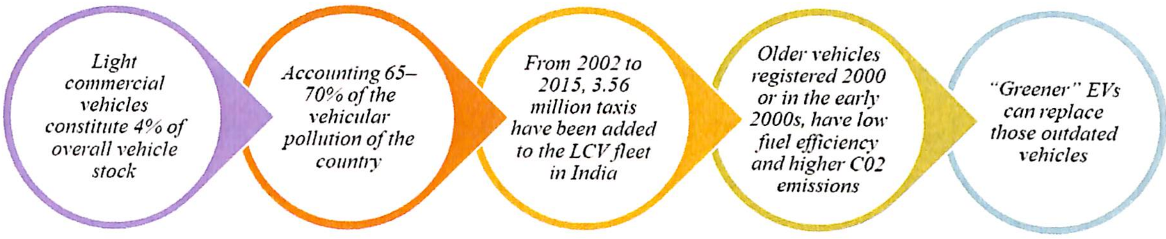

Figure 2: Electric vehicle track

1.2 Background

The Indian government has a clear agenda of moving to an Electric Vehicles (EV) only regime, with a complete phasing out of vehicles that are driven by Internal Combustion Engines (ICEs). The Ministry of Heavy Industries and Public Enterprises had also launched the FAME scheme (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) in 2015 under the National Electric Mobility Mission Plan 2020 (NEMMP 2020) to promote faster transformation from ICE to EVs. The FAME scheme focuses on a three phased approach to achieve the target of introducing six to seven million electrified vehicles on Indian roads by 2020. Subsequently, multiple state governments have been providing incentives to attract electric vehicle (EV) manufacturing in their states, and to fast-track adoption of EVs. Karnataka became the first state of the country to notify an EV policy. Telangana and Andhra Pradesh are expected to release their respective policies in due course. In addition, NITI Aayog's 'Three Year Action Agenda is to be implemented by 2019-20 also emphasises the need to migrate from ICE to eco-friendly automobiles. There are multiple factors that drive the policy objectives. Key drivers are:

Vehicular pollution: Ten Indian cities are among the world's twenty most polluted cities of the world according to the Global Urban Ambient Air Pollution database, 2016. ICEs are one of the major contributors to air pollution emitting high levels of sulphur dioxide and suspended particulate matter amongst other pollutants such as carbon monoxide, ozone, oxides of nitrogen and hydrocarbons.

Impact on health in the congested Indian cities: According to State of Global Air 2017 report, India accounts for the second highest number of premature deaths due to air pollution in the world. The Lancet Commission 2017 also ranked India as no.1 in pollution related deaths with air pollution being the biggest contributor. The pollutants emitted from ICE directly affect the respiratory and cardiovascular systems and indirectly result in increased mortality, morbidity and impaired pulmonary function.

Impact on balance of payment as oil is the largest imported commodity in India: Of the total oil consumption in the country, nearly 70 per cent of diesel sales and 99.6 per cent of petrol sales occur in the transport sector. The growth in energy demand from this sector outpaces growth in all other sectors and is estimated to reach 280Mtoe (Million tonnes of oil equivalent) in 2040, if the present trend continues. Transition to electric mobility can significantly ease out the pressures of balance of payment.

Improved energy security: As per the present trend, India would require nearly 1,600 million metric tonnes oil equivalent of petrol and diesel to fuel its passenger mobility sector between 2017 and 2030. India can save 64 per cent of energy demand from motorised vehicles by pursuing a shared, electric and connected mobility regime resulting in reduction of 876 million metric tonnes oil equivalent of oil consumption by the year 2030. This could save India more than half of the cost of oil imports by transforming passenger ICE vehicles to EVs by 2030.

Mechanism to better utilise cheap solar energy, through the government's National Solar Mission policy: India has set up a 100GW solar power target by 2022. The large-scale push is part of the government's 175GW power generation target from renewable sources of energy by 2022. Solar power's duck curve challenge – mismatch between peak demand and solar power production – poses a serious threat to its sustainability. Electric vehicles can be crucial to solar power's success in India. Solar power is only generated during day time and would require a storage mechanism, and that is where lithium-ion batteries of EVs become important. The stored electricity can provide grid stability as solar power generated can be used during peak hours without pushing the grid stability. Further, extensive public charging infrastructure can also increase the demand during the duck 'belly' hours.

Among the above issues, pollution and health impact appears to be a key driving factor for adopting polices for rapidly moving away from ICE based vehicles and embracing EVs. Therefore, the Government of India has initiated a recent policy effort under the National Health Policy 2017 of Ministry of Health and Family Welfare to target reduction of outdoor air pollution. It is necessary to have a stronger push towards retrofitting existing vehicles into becoming EV/hybrid and having more hybrid vehicles among the new vehicles that are to be sold, in order to significantly reduce increasing pollution that is impacting human life. The initial thrust towards hybrids is necessary as higher costs have been deterring customers from buying EVs and cost parity is yet to be achieved. Higher price (chiefly attributable to imported batteries), lack of public charging infrastructure and fewer consumer choices have kept the market penetration for electric vehicles considerably low. Currently, electric vehicles penetration is barely 0.1 per cent in the personal vehicles segment and about 0.2 per cent in the two-wheelers segment.

While the ecosystem for pure electric vehicles is at a nascent stage, hybrid vehicles have a better developed ecosystem. Hybrids essentially utilise the same technology and components as pure electric vehicles. Given this, focus on the hybrid vehicles segment becomes even more important transitioning towards a pure EV regime. Additionally, hybrids have the following to their advantage:

- Cheaper due to smaller batteries being used
- No range anxiety as they are not dependent on public charging infrastructure which is hardly present as of now
- Fuel efficiency because they use battery power intermittently
- Cleaner technology in comparison to ICE

Targeting new vehicle sales to consist of EV/hybrids, the existing on-road vehicles must also be retrofitted to mitigate ill-effects of ICE with immediate effect. A convenient approach to retrofitting is through installation of hybrid retrofit kits. Hybrid retrofits are fast becoming economically affordable with easy installation mechanisms that offer significant savings to the consumers reducing the total cost of ownership. Through considerable improvement in mileage, the capital costs of these devices are usually recovered in less than a year. Economic benefits are combined with nearly 20 per cent reduction in carbon dioxide emissions and considerable decline in overall tailpipe emissions. As less gasoline is used per mile, retrofitted vehicles emit less particulate matters (PM), nitrogen oxides (NOx), and carbon dioxide (CO2) than conventional cars. The cleaner nature of retrofitted vehicles makes hybrid retrofits an ideal transitory technology when moving into a fully electric vehicle regime.

Sustainable mobility is not just about replacing fossil fuel-powered vehicles with modes of transportation propelled by electricity. It requires a drastic reduction in the number of personal vehicles in the country in favour of public transport, even if cars run on renewable electricity. We also need to keep in mind that today a growing number of young urban professionals do not consider cars a status symbol, but just hire a car when necessary. We would all do well to follow suit. It is all about a shift in cultural thinking, coupled with the global technical revolution around e-Thinking in transport systems.

1.3 Purpose of the Study

Continuous increase in the world's population has caused an increase in demands for fossil fuel, in order to support growing energy needs for social and economic developments. This has resulted in numerous environmental problems associated with burnings of fossil fuel such as pollutions, water contaminations, global warming, etc. With energy demand expected to increase even further, the problems are expected to be exacerbated, bringing more environmental headaches. The transportation sector, encompassing land, air and sea transports, represents one of the biggest consumers of fossil fuel, particularly oil; contributing significantly to our environmental problems.

- Market potential
- Analysis of Total vehicle ownership cost of Electric Vehicle (EV) compare with the cost of conventional vehicles
- Economic Analysis of EV as public transportation services
- EV Sustainable mobility services (e-mobility)
- Challenges in Electric Vehicle Charging Infrastructure
- Impact of Electric Vehicle on Environment

1.4 Research Hypotheses

India has a lot to gain by converting its ICE vehicles to EVs at the earliest. Its oil-import bill would considerably reduce. ICE vehicles are a major contributor to pollution in cities and their replacement with EVs will definitely improve air quality. There is a considerable possibility that we can become leaders in small and public electric vehicles. India has over 170 million two-wheelers. If we assume that each of these vehicles uses a little more than half a litre of petrol per day or about 200 litres per year, the total amount of petrol used by such vehicles is about 34 billion litres. At ₹70 per litre, this would cost about ₹2.4 lakh crores. Even if we assume that 50% of this is the cost of imported crude (as tax and other may be 50%), one may save ₹1.2 lakh crores worth of imported oil. There is a real possibility of getting this done in the next five to seven years. Keeping in mind, the expected outcome of the study states about the market potential of electric vehicle in the Indian market. Apart from this, the transportation sector is one of the major contributors to CO_2 emissions. Moreover, with rapid urbanization in developing economies such as India and China, CO_2 emission by urban transport is increasing rapidly. Therefore, there is an onus on these economies to act immediately and combat climate change through a constant focus on innovation in industry and infrastructure, and by building sustainable smart cities. A lot of efforts have been made to reduce environmental effect associated with the transportation sector. This study also states about the environmental impact of electric vehicle. The main change will come in the form of e-Vehicles, which can take the industry to new and wider horizons and reimagine our vision of a sustainable future.

Chapter 2: Literature Review

2.1 Electric Vehicle Market in India

Driven by powerful environmental, macroeconomic and technological factors, the global transportation sector is undergoing a historical period of transition. New business models like Mobility as a Service and the increasing economic viability of technologies like Electric Vehicles (EVs) will soon reshape how we travel. According to research by the International Energy Agency (IEA), the global EV parc has increased from just five thousand vehicles in 2008 to more than two million by 2016. This has been driven by key underlying trends including mounting environmental concerns, decreasing Lithium-ion battery prices and increasing availability of charging infrastructure [1]. All this has led experts to predict a rapid growth in EV adoption in the next decade – current year on year growth projections range from 27% to 33% until 2030.

By many metrics, China is leading the world's EV revolution. China's share of the global EV parc grew to 32% in 2016, overtaking the US for the first time. Its share was only 11% in 2011. Private investment is pouring into China from major auto manufacturers like Daimler, BYD, Honda, Toyota and Ford, all of whom are actively exploring how to capitalize on China's expanding market.

In contrast, the India EV story has been underwhelming so far. Absence of charging infrastructure, inconsistent government support and early product failures have all resulted in stagnant growth in recent years [2]. However, 2017 may have marked a turning point in India's EV journey - a clear and ambitious goal of 100% EV adoption by 2030 has been laid out by the government, and the country's leading government think tank, NITI Aayog, has set the contours for a comprehensive, long-term mobility strategy. This has already led to concrete steps being taken to help spur EV growth [3].

Energy Efficiency Services Limited (EESL) launched a tender for 10,000 4-wheeler EVs in 2017, the world's largest single EV procurement to date. In the 3-wheeler and bus segments, the government is looking to introduce battery swapping to decouple battery costs from vehicle costs and ease the re-charging process. Standards for the first generation of public EV chargers have been set, and a second generation is in the pipeline [4].

The strategy for EV growth in India revolves around two core assumptions that demand aggregation from the likes of EESL can help quickly grow scale, and that the battery swapping model can help reduce upfront EV costs and improve the charging experience. While both assumptions are tenable, they each have their own complexities and potential hurdles. EESL has shown, with its Ujala Program for LED bulbs, that it can be an effective demand aggregator and market maker. However, replicating this success for EVs would involve overcoming a host of challenges. These include the significantly higher upfront costs of EVs as compared to LED bulbs, the dependency on charging infrastructure for increased adoption, complex distribution structures for vehicles like e-Rickshaws, to name a few. A subscription-based battery swapping model is likely to be adopted in some form for 3-wheelers and buses, though it faces a more tenuous future with 4-wheelers and 2-wheelers, where manufacturers are unlikely to accept common battery specifications [5].

If both demand aggregation and battery swapping are successfully implemented, we project India reaching EV sales of more than 1.6 million vehicles in FY23. This is an overall Compound Annual Growth Rate (CAGR) of 35% from FY17. Government procurement and public transport will be the major drivers of this growth, through procurement of vehicles for Government use and 3-wheelers and buses for public transportation. Growth in the 4-wheeler space is also likely to be driven by investments by private fleet operators like Ola and Uber, where higher daily running makes EVs more economically viable. The 2-wheeler space will be largely private ownership and subsidy driven, and will be characterized by a migration from Lead Acid to Lithium-ion batteries and from low speed to high speed vehicles.

Despite this promising growth, **we expect that the government's targets for 2030 are ambitious and are likely to be missed due to the industry and consumers not being ready to adopt rapidly, given the relative economics.** Our growth projections suggest that EVs will account for less than 2% of total vehicle sales by 2023. From that position, reaching the government's goal of 100% penetration by 2030 seems far from achievable [6].

Even if India does reach its 2030 ambitions, **it would not necessarily result in a significant reduction in our import dependency.** While cumulative oil imports for the automotive industry from 2017-30 in a "Business as Usual" scenario are expected to amount to INR 40 Lakh Cr, India would still have an import bill of INR 15 Lakh Cr for Lithium-ion cells and INR 17 Lakh Cr for oil in case it completes its transition to EVs. This results in a savings of INR 8 Lakh Cr.

While India has a long way to go to achieve its EV ambitions, it is clear that EVs do present a short-term high growth opportunity in key segments and will, no doubt, be an inevitable disruption in the long-run; one that requires a cohesive strategy at both - the government and corporate level.

2.2 Electric Vehicle Policy

India, being on the verge of transition from developing to a developed economy, is targeting GDP growth rate of more than 7.2 % in the next five years. This will subsequently lead to increase in consumption of crude oil and oil products. With transport sector being one of the biggest consumers of oil and oil products, increased consumption along with import dependency will not only increase GHG emission but will also have substantial impact on the energy security scenario of the country. Therefore, transportation sector needs to undergo a significant transformation from oil-based system to a more environment friendly electric based system. Considering this, Government of India launched National Electric Mobility Mission Plan (NEMMP) 2020 which envisages introduction of about 6-7 million electric/hybrid vehicles in India by the year 2020. Under this NEMMP, Faster Adoption and Manufacturing of Electric Vehicles (FAME) India scheme was introduced in 2015, with the objective to support hybrid/electric vehicles market development and manufacturing eco-system. The FAME scheme was extended in the form of the FAME-II in 2019 with a total outlay of INR 100 billion. Eight states have released draft and final versions of electric vehicle (EV) policies for their respective states; while many other states are working on their EV policies. Few states have also introduced separate electricity tariff for charging of EVs [3] – [6].

National mission on e-mobility has been launched, India has yet to issue a national level EV policy. But eight states such as Andhra Pradesh, Delhi, Karnataka, Kerala, Maharashtra, Telangana, Uttarakhand and Uttar Pradesh have designed individual state level EV policies to cater to their respective requirements based on available resources. The state of Karnataka was the first in India to release an EV policy titled "Karnataka Electric Vehicle and Energy Storage Policy" in September, 2017. Government of Kerala, was the last in this list that issued their final version of the EV policy in June, 2019.

Karnataka, Telangana, Uttar Pradesh, Andhra Pradesh, Kerala and Delhi have set clear targets in terms of number of EVs and charging stations/battery swapping stations deployment during the policy period. Karnataka has committed to 100% e-mobility for most vehicle segments in the city of Bangalore by 2030. Telangana has set the ambitious goal of 100% EV migration by 2030. Uttar Pradesh has decided to adopt hybrid EVs (HEV) during the transition phase up to 2022. Andhra Pradesh has included hydrogen powered vehicles with fuel cells and other alternate fuels as part of its e-mobility plan. Kerala has included electric ferries to be deployed as part of its e-mobility goals. Similarly, Delhi has focused on making 25% of all new vehicle registrations by 2023 to be EVs. Primary focus in most states is on public transport, followed by government vehicles and private transport and then goods transport vehicles. In terms of charging station and battery swapping station deployment, most of the states have promised to encourage charging infrastructure along highways, government offices, shopping complexes, malls, parking spaces etc. Karnataka and Uttar Pradesh have proposed to build 5000 MWh and 2000 MWh battery manufacturing/assembling capacity during the policy period.

Hydrogen powered fuel cells and solar powered cells manufacturing are included in Uttar Pradesh's target. Maharashtra has stated its intent to invest INR 250 billion in EV and its components manufacturing/assembling. The states have also listed a range of supply-side and demand-side incentives such as capital subsidies, incentive subsidies, registration charge exemptions, interest-free loans, free parking, toll exemptions, electricity duty exemptions, etc. to EV buyers, EV and component manufactures/assemblers and EV charging station owners. Telangana will provide government land in Hyderabad on long-term lease at subsidised interest and two years moratorium period for setting up charging/battery swapping stations. Telangana will also allow private companies to utilise corporate social responsibility (CSR) funds for company buses for employee commute. Maharashtra has allowed petrol pumps to install charging infrastructure, subject to safety regulations. Uttarakhand has however added a caveat to their policy – 70% of staff in the EV enterprise must be from Uttarakhand for the enterprise to avail policy incentives.

Many states have placed importance for "Ease of Doing Business" in their state policies e.g. Karnataka Udyog Mitra for expediting clearance processes. Telangana, Uttar Pradesh, Andhra Pradesh and Maharashtra have put forward the idea of creating EV manufacturing hubs, clusters or EV automotive parks. Incentives for research and development and training have also been incorporated in the EV policies in some states to ensure improvement in indigenous EV technology and capacity building. Telangana has also added an exit strategy mechanism to its policy that would be developed by the state government and the central government to facilitate EV enterprises within the state to extricate themselves if the situation arises. Telangana has also put forward the idea of listing the EV industry as a 'public utility' within the state, which would help to prevent flash strikes. Delhi and Andhra Pradesh have also mentioned measures for battery recycling, battery reusing and end-of-life battery usage. While a number of points overlap for the EV policies, the newer policies have been broader in their scope and have added more forward-looking points. Future policies can be devised based on building on these policies.

Table 1: Electric Vehicle policies in various states in India

Sr. No.	State	Key features
1	**Karnataka:** Karnataka was the first state in the country to introduce a policy dedicated to electric vehicles. The Karnataka Electric & Energy Storage Policy, 2017, operational for five years, is expected to give the necessary impetus to the electric mobility sector in the state, and attract investments. The Government of Karnataka intends to make Bengaluru the Electrical Vehicle Capital of India.	1. Attract investments of Rs 31,000 crore and create 55,000 jobs - both from supply and demand side. 2. Create a conducive environment for transition to EVs from the Internal Combustion (IC) engines. 3. Focus on developing R&D, and special initiatives for EV manufacturing such as making industrial land available to create EV manufacturing zones. 4. Support for charging infrastructure, and research development and skill development incentives and concessions. 5. A startup incubation centre for EVs, and startups will be encouraged to develop business models focused on EVs. 6. A venture capital fund for research in EV mobility. 7. All electric vehicles, including e-rickshaws and e-carts, are already exempted from GoK payment of taxes. 8. Policy to provide incentive to shift auto rickshaws, cab aggregators, corporate fleets and public transport systems into EVs.
2	**Delhi:** Delhi the city, which has the unwanted reputation of being one of the most-polluted cities in the world, is striving hard towards a cleaner environment. The draft EV policy was introduced by the Delhi government in 2018, and it seeks to drive rapid adoption of Battery Electric Vehicles (BEVs) so that they contribute to 25 percent of all new vehicle registrations by 2023.	1. Policy to incentivize purchase of EVs and support electrification of public and shared transport. 2. Road tax, registration charges, one-time parking fee, and auto rickshaw permit fees to be waived for e-autos. 3. App-based aggregators and ride-hailing service providers to be encouraged to create fleet of e-vehicles. 4. Public transport to have 50 percent electric buses by 2023. 5. Policy to encourage adoption of electric three-wheeler goods carriers. 6. Charging infrastructure in private and public places. 7. Petrol and diesel-powered vehicle users to pay a 'pollution cess' on fuel (higher cess on diesel) starting April 2019.

3	**Maharashtra**: Maharashtra the state introduced its EV policy in 2018 with the aim to make Maharashtra among the most-preferred EV investment destinations for global investors through promotional strategies, combined with developing a competitive and sustainable investment environment.	1. Increase the number of registered EVs to five lakhs. 2. To generate an investment of Rs 25,000 crore for EVs and EV infrastructure, and create jobs for 1,00,000 people. 3. Provide fiscal and non-fiscal incentives to increase viability of EVs. 4. Promote creation of dedicated EV charging infrastructure through subsidized investment. 5. Promotion of R&D and innovation. 6. Petrol pumps will be allowed to set up charging stations freely, subject to regulations. 7. To promote EVs in public transport in six cities, i.e. Mumbai, Pune, Aurangabad, Thane, Nagpur, and Nashik. 8. The first 1,000 private/public passenger electric bus buyers will be eligible for user subsidy for five years, and the first 100,000 EVs across categories will get end-user subsidy for five years. 9. Exemption from road tax and registration fees.
4	**Uttar Pradesh:** Lucknow, the capital of Uttar Pradesh, is one among the 10 cities identified for pilot project of Multi-Modal Electric Public Transport, under the Faster Adoption and Manufacturing of Electric Vehicles in India (FAME) scheme. Keeping this in mind, the state government came out with the Uttar Pradesh Electric Vehicles Policy, 2018.	1. To establish UP as a preferred destination for attracting investments in EV manufacturing. 2. Create employment opportunities. 3. Create a conducive environment to shift from internal combustion (IC) engines to EVs. 4. Encourage use of Hybrid EVs during the transition phase. 5. Develop human capital and augment the power capacity to meet the needs of the industry. 6. Promote EVs in public transport by introducing 1,000 EV buses in phases by 2030. This will also introduce green routes in select destinations. 7. Promote EV battery and charging equipment manufacturing, and incentivize manufacturing of Hydrogen-powered fuel cells and solar-powered cells. 8. Ensure quality infrastructure to develop the state as EV manufacturing hub. 9. Setting up EV incubation centres at IIT-Kanpur and other leading engineering institutions to encourage business models on EVs. 10. 100 percent road tax exemption on EVs purchased within the state.

5	**Telangana:** The state of Telangana introduced its EV policy in 2018 to showcase a model of international standards for electric vehicle adoption across segments, supported by world-class infrastructure and ecosystem.	1. To attract investments worth $3 billion and create employment for 50,000 people by 2022. 2. Provide ecosystem and infrastructure to make Telangana the EV hub of India. 3. Develop a proving ground for viable business models through accelerated demand for EVs. 4. Promote innovation in EVs and other trends such as autonomous/connected mobility. 5. Creating a pool of skilled workforce for the industry. 6. Create a conducive environment for industry and research institutions to focus on EV technologies. 7. Roadmap for developing charging infrastructure. 8. Mandating use of EVs at an institutional level. 9. Establishing a startup ecosystem to nurture innovation in EV technology space. 10. Road tax exemption for all electric vehicles till 2025. 11. 100 percent electric buses by 2030 for intra-city, intercity, and interstate transport. 12. A separate power tariff will be created for EV Charging, both public and private. 13. A mobility engineering cluster (on the lines of the MCity at University of Michigan, US) will be developed. 14. An innovation fund will be created to offer financial support to EV OEMS, ancillaries, and startups for research and innovation in battery technologies.
6	**Andhra Pradesh:** The Government of Andhra Pradesh has the ambitious plan of putting 10 lakh EVs on the road in the next five years, which will be aided by fiscal incentives to become one of the important hubs for this segment in the country. The state launched its Electric Mobility Policy in 2018.	1. To attract investments of Rs 30,000 crore by 2030. 2. Create employment for 60,000 people. 3. Battery manufacturing units in Amaravati. 4. Advanced battery manufacturing units of 10 GWh. 5. One lakh EV charging stations will be built by 2024. 6. All government buses and commercial vehicles will be made electric by 2024. 7. Stamp duty and GST reimbursements on purchase or lease of land for EV manufacturing in Amaravati, and no registration fee on electric vehicles. 8. Development of EV manufacturing hubs.

7	**Kerala:** Kerala also came out with an electric vehicle policy in 2018, which seeks to reduce the number of vehicles running on fossil fuels with the introduction of electric buses in public transport and e-autorickshaws. It is aiming for full electrification of all types of motor vehicles by 2030.	1. To have one million EVs in the state by 2022. 2. Pilot EV fleet of 200,000 two-wheelers, 50,000 three-wheelers, 1,000 goods carriers, 3,000 buses, and 100 ferry boats. 3. To attract investments in power electronics and battery pack assembly, which will also provide employment opportunities. 4. Targeting over 6,000 electric buses in public transport by 2025. 5. Creating common charging infrastructure that will be interoperable with several models of EVs. 6. Create awareness and promotion of shared mobility. 7. Building human resources in the area of EV, which would also mean reskilling.
8	**Uttarakhand:** The hilly state of Uttarakhand came out with its EV policy in 2018. The state wants to create a conducive atmosphere to support manufacturers, and reduce vehicular pollution. It is also looking to create jobs in the state.	1. To waive off motor vehicle tax for the first 100,000 customers purchasing EVs for a period of five years. 2. The first 100,000 customers purchasing commercial EVs or electric stage carriages will also be able to avail exemption from tax. 3. Investors in the EV segment will be entitled to have 100 percent electricity duty exemption.

2.3 Adoption of Electric Vehicles - Gap Analysis & Total Cost of Ownership (TCO)

It is important to understand the consumers' outlook and concerns as to why growth of market for electric vehicles has been sluggish. It is important to study the gaps for the electric vehicles vis-à-vis conventional vehicles. The single major factor for slow penetration of EVs is their high price which is around 2 to 2.5 times more than a comparable conventional vehicle. The other important concern of EVs is their range per charge. To offer a higher range, higher battery capacity in the vehicle is needed which lead to increase in the EV price roughly proportionately and increases the price gap. At the same time, however, EV offer a significant advantage on operating cost (running plus maintenance cost) which could be as low as 1/4th of that of a conventional vehicle [7].

As compared to a personal vehicle, commercial vehicles like taxi fleets, bus fleets, 3-wheelers run 4 to 5 times longer distance per day. Therefore, for such higher mileage vehicles savings on operating cost will pay-back the initial high purchase price faster than low mileage vehicles. Attractive power tariff can play a significant role to offset capital cost of buying EV with lower operating cost at faster pace. Most of the personal vehicle buyers consider upfront purchase price, fuel efficiency, maintenance and service cost, comfort features as the key buying criteria. However, commercial vehicle buyers consider capex plus opex cost economics as the most important buying criteria [8].

In India, affordability index is lower than developed economies due to lower per capita income. Therefore, manufacturers will have to offer medium range electric vehicles so that the cost of the vehicles remain affordable for the masses. This would in turn would need more frequent charging, especially for commercial fleets where the vehicle would run for up to 200~250 kilometres per day. Charging infrastructure for fleet application would require more of fast charging stations to minimise the turnaround time of the vehicles. For personal vehicles where the usage would be up to 50 kilometres per day, slow chargers at home, workplaces, opportunity places like shopping malls, cinemas etc. would be adequate [9].

It is a complex scenario of multiple factors. Based on this broad narrative, the gap analysis for various segments are provided in the following sections.

- **Two-Wheelers**

Today, more than 18 million gasoline 2-wheelers i.e. scooters and motorcycles, are sold annually in India. Majority (84%) of the 18 million two-wheelers sold have engine capacity between 100 and 125 cubic capacity. These two wheelers are available in the range of Rs 60,000 – 90,000 (both scooter and motorcycle). This segment is popularly known as the commuter segment. Currently, in India, the total vehicle parc of electric 2-wheelers is about 210,000. Out of these, more than 98% are low powered and low speed variants (maximum power not exceeding 250 Watts and maximum speed not exceeding 25 kilometres per hour). These vehicles are deemed as non-motorized vehicles and are thus exempted from various requirements under the Indian Central Motor Vehicle Rules (CMVR) viz. type approval, conformity of production, registration plate, driver's license etc. These low speed electric 2-wheelers by their basic design have limited performance like drivability, acceleration, gradeability etc. Even today, price of such low speed electric 2-Wheeler (before incentive) is in the range of Rs 30,000 - 50,000 which is quite low as compared to the conventional gasoline 2-wheeler. Still, because of sub-par performance as stated above, such low speed electric 2-Wheelers have not been accepted by the consumers at large. At best, such electric 2-wheelers would remain a niche segment and might not enable large scale penetration into the market to replace the conventional 2-wheelers. It would be necessary that comparable or near equal electric 2-wheelers are developed to make an impact for a sustainable marketplace and achieve economies of scale for the creation of a robust manufacturing eco-system.

A viability analysis of a comparable electric 2-wheeler vis-à-vis a gasoline 2-wheeler with different battery prices as a variable (starting from current cost at around 300 USD/KWh down to 73 USD/KWh). Two scenarios are analysed – commercial application (150~200 Km/day) and personal mobility (30~50 Km/day). An electric 2-wheeler is not economically comparable (at capex level) even if the battery price falls to 73 USD/KWh, however, the total cost of ownership viability could be achieved in 2 to 5 years at different battery prices for a commercial application. However, in personal mobility use, due to shorter commuting distance, the payback within 3 to 4 years is only possible when the battery price falls to 73 USD/KWh.

- **Three-Wheelers**

India is world's largest market for Three wheelers. These 3-Wheelers or Auto-Rickshaws are being used seamlessly in tandem with public transportation and for intra-city good movement. Majority (78%) of the Passenger 3Ws are configured for less than 4 seats and another 21% have more than 4 seats configuration. At current cost levels, any electric 3W with near equal performance to IC engine will be at least twice in price. Moreover, limited range and inadequate charging infrastructure will lead to downtime resulting in revenue loss. For 3-wheelers, battery swapping may be encouraged to strengthen the possibility of overcoming range limitations in inner cities. Government authority could play a pivotal role in defining standard specs for swappable batteries for 3 – wheelers.

The current total cost of ownership (TCO) would become positive if the battery prices fall to below USD 150 per KWH. With phased mandates in cities over time, 3-wheelers could be one of the biggest opportunities to move to pure electric vehicle technology. With such a policy measure, the vision for 100% electric vehicles for public fleets in 2030 would be achievable for 3-wheelers.

- **Passenger Cars, Vans & Utility Vehicles**

Majority (99%) of the passenger cars sold in India belong to the small or mid-size segment. Due to the addition of incremental EV powertrain components such as battery, traction motor, control unit and charging point, the initial increase in the purchase price of an equivalent EV over an entry level sedan is ~70%. Due to the moderate mileage clocked by PVs for personal use (40 to 50 km per day), electric cars are rendered unviable even for a 7 years ownership period. This scenario holds true even if the battery costs fall to 50 USD/KWh. For the fleet application, due to longer commuting (~200 km per day), the viability gap reduces substantially. If the battery price falls below 150 USD per KWh, fleet operators can recover the additional investments by 4 years.

➢ **Buses**

Majority of the buses sold in India belong to the 7.5-12 tonnes category. Of all the buses sold, ~7% are run by the STUs. Buses employ a larger battery pack (optimal capacity at around 120 Kwh) leading to higher increase in the initial capex of 1.7~2.5 times a diesel bus. With bigger battery, there could be a weight penalty in terms of payload and lead to inefficiency. However, with smaller battery, there would be an operational gap for meeting daily mileage requirement of around 250 Kms per day. Therefore, an optimal electric range per charge, which is proportional to the battery capacity in the vehicle, is an important requirement.

In other vehicles segments, where life of a battery is expected to be 10 years or more and would be good for the lifetime of a vehicle. However, in the bus segment with today's battery technology, the life of the battery may not be more than 5~6 years due to strenuous operating conditions in the city and the need for fast charging at regular intervals. Cost of replacement of batteries in the middle of the life of the bus will have a direct impact on the TCO for buses. At the current price level, for an electric bus with 120 KWh of battery pack and with power tariff of Rs 7 per kwh, the viability gap is estimated at around Rs 4,00,000~500,000 per annum for 10 years of operation. A battery replacement cost that will incur midway at around 5th year will increase the viability gap at that point of time. With power tariff at preferential rates, the viability gap per annum can be reduced [10].

To bring operational convenience of running longer distance per day, operators and vehicle manufacturers could also consider battery swapping as one of the possible mechanisms. Battery swapping in buses, to replace a discharged battery with a charged battery, could be as low as 10 to 15 minutes. Further, spare batteries for swapping could have a longer life span if such batteries are subject to slow and climatic controlled charging at a swapping station. With additional spare batteries to be available for swapping, commercial feasibility for such a mechanism are to be kept in mind [11].

2.4 Factors critical to success of study

Following are the factors critical for faster adoption of Electric Vehicle in Indian Market

- Environmental Concerns
- Government Support
- Charging Infrastructure
- Supply Chain Distribution
- Customer Acceptance

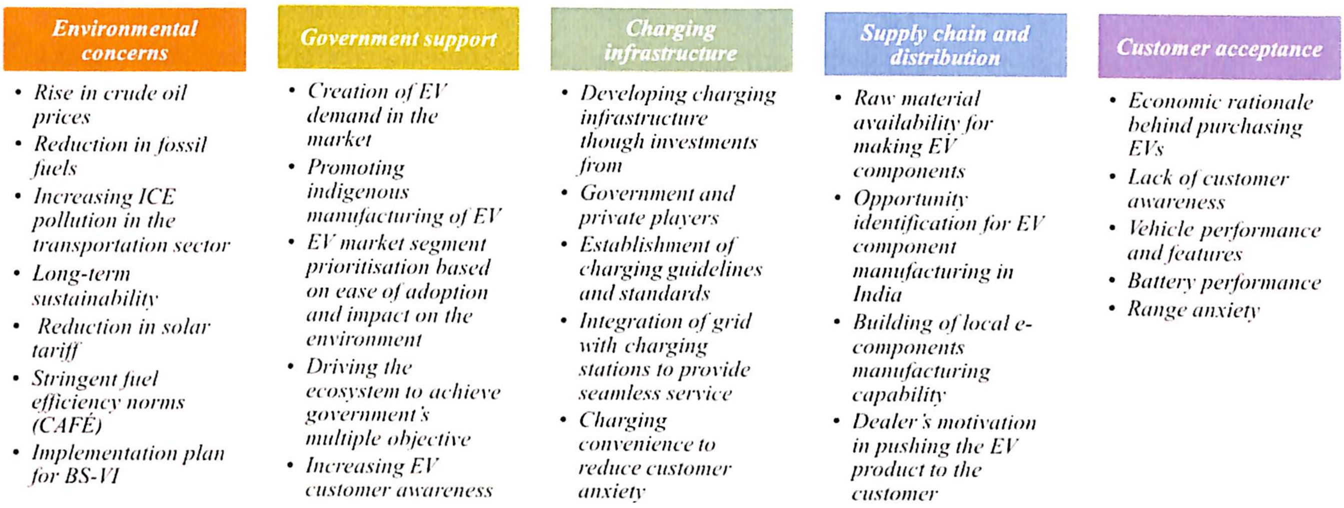

Figure 3: Key Drivers: shaping the development of the EV market in India

Chapter 3: Research Design, Methodology and Plan

3.1 Data Sources

A comprehensive secondary research can be conducted to develop an understanding of the India electric vehicle market. The objective of the desk research was to instigate the fundamental analysis of the market through gathering information on the market dynamics. Mutually exclusive and collectively exhaustive study was conducted to cover the entire scope of the study. Several publicly-available data sources, industry associations, trade unions, online newspapers, journals, and analyst coverage were accessed to gather industry/business related information to develop an understanding on India electric vehicle market.

Over the last decade, there's been an increase in the purchasing of electric vehicles (EV). There are many reasons why one might consider making the switch to an EV – electric cars are higher efficient than gas-powered cars, can reduce your dependence on fossil fuels and require less maintenance than most cars, to name three popular reasons. From Environmental impact point of view, need to go through various databases available on various public and paid data sources. Apart from these, there are four factors to consider when evaluating the impact of electric cars on the environment: tailpipe emissions, well-to-wheel emissions, the energy source that charges the battery, and the car's efficiency.

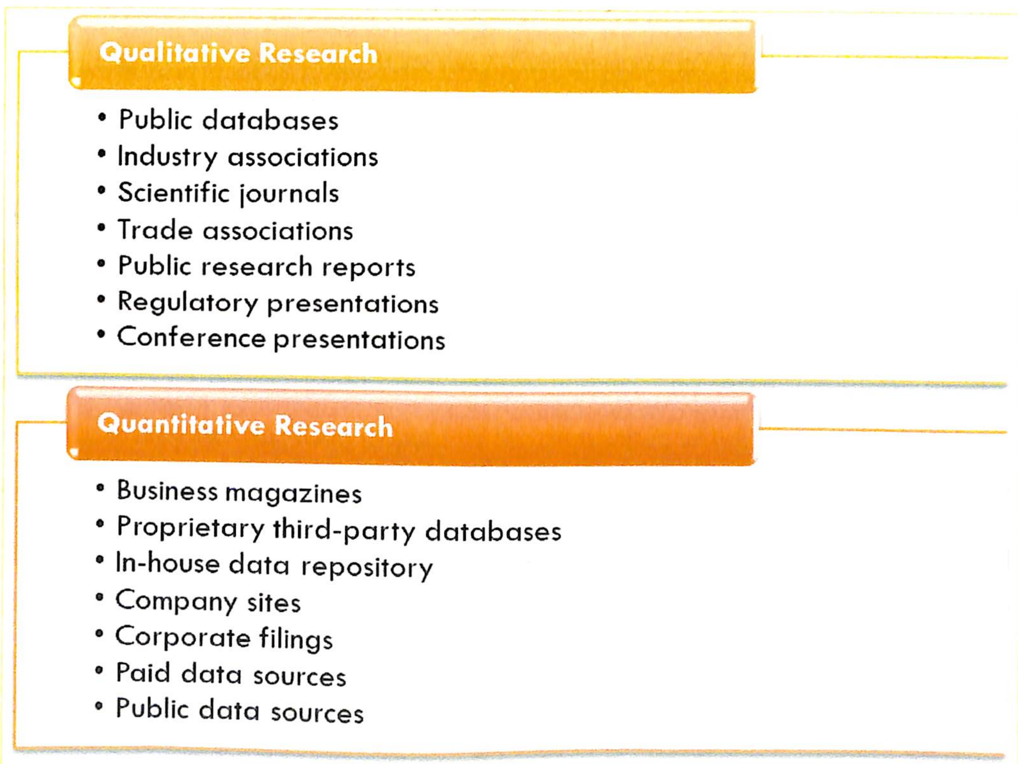

Figure 4: Qualitative & Quantitative Research

Figure 5: Key objectives of EV policies for faster adoption of EV In India

3.2 Research Design

Electric Vehicles can be considered as a Sustainable Solution For City Centres. The increasing concentration of population and wealth to cities is likely to continue-especially in the developing world. With further global population increase and urbanization on the horizon congestion will exacerbate the negative impact of the manner in which the automobiles will be driven and on the overall energy consumption. It will not be possible to tackle global automotive energy consumption and green-house gas emissions effectively without a radical change in thinking with respect to urban transport. For over a century, the automobile has offered affordable freedom of movement within urban areas. Currently, however, a typical automobile is larger and heavier than it needs to be to provide personal urban transport.

Worldwide, 18 million barrels of oil is consumed each day by the automobile sector. Annually the vehicles emit 2.7 billion tonnes of CO_2 and claim 1.2 million lives via accidents. Within city centres, the average vehicular speeds hardly ever exceed 16 kmph. One solution to tackle the problem of congestion and pollution within city centres around the world is to use electricity ultra-compact cars weigh 450 kg and occupy less than two third length of a conventional compact car. Battery electric vehicles (EVs) were quiet, clean and simple to operate, but their batteries took a long time to recharge, were expensive to replace and had limited range. Research and development is being carried out into manufacturing affordable electric automobiles that offer an improved overall thermodynamic efficiency.

3.3 SWOT analysis of electric vehicle industry in India

SWOT Analysis: Stands for "strength, weaknesses, opportunities and threats." It can be done to find out the "strengths and weaknesses and opportunities and threats" that may affect the sector in the external environment. It takes the gathering of data and analyzing all the data of all the 'internal and external factors" that help or hurt a business. Strengths will help a organiztion take advantage of the markets. A weakness is judged as a factor that the competitor has and the firm does not or something that is detrimental. Opportunity is a factor that is of advantage to the firm; something important that the competitor cannot get or have. Threats are unfavourable events or factors that can affect the firm negatively.

The strengths and weaknesses can be directly managed by some change in an organization it is the forecasting of these external and internal factors that will help first; and a suitable reaction to counter an unfavourable factors can be taken. The tool is universally accepted and easy to use, because of its simplicity and use of key issues that affect the firm. The Necessary strengths and weaknesses that are needed to counter threats or utilize opportunities need to be identified properly in a particular application.

SWOT analysis is done in a simple way. Key strengths and weaknesses are listed and grouped after brainstorming. Similarly all the threats and opportunities are listed separately. Strength can be identified as something which is advantageous in a venture. A weakness is something the firm has to catch up with, that another firm may possess at the moment of study. Some strengths and weaknesses can be listed from external or internal factors of: land resource, equipment and technology advancements, patents, knowledge and company learning, skilled cheap labour, brand equity, Core competencies, capable workers, training, Management tools, Human resources, capital, easy access to loans, expertise in research, the work culture (and number of years) and others. A clear definition of what the way an external internal factor affects the firm is need. For marketing image, if the firm has a bad image it is a weakness if the image is good it is strength. Another criterion for accurate results is comparing an external factor with the competitor's strength or weakness. For example if a company has 100 million in reserves for research it may be a strength only if the competitor has 50 million; if the competitor has 250 million then the benchmark analysis leads one to say that we have a weakness. Valuable rare external or internal factors are an advantage and are strengths.

An opportunity or threat may arise from some change in the external environment (macro conditions) it is uncontrollable at times. Hence, companies need to keep looking for them in advance so they can counter or take advantage of them as soon as possible. A change in the market conditions, a new law passage, a new technology for sale, can open a new market. Companies have to be aware of these as well. A certain market niche may become profitable due to a external change also. If a company wants to gain revenue it must invest in a suitable real time assessment all the time. The threat or opportunity should be judged accordingly to what impact it has on the firm.

An advance SWOT is one which can overcome the limitations of a conventional analysis. Here the various threats and weakness or opportunities and strengths are prioritized first. The aim is to get the most important factors that will affect your firm and not a crowd of different factors. Prioritization is done by first listing all the strengths and weaknesses then assigning a value to strength or weakness from 1 to 3 to the list. 1 for strength means it is not important 3 means major importance; likewise 3 for weakness means major weakness and 1 is a minor one. After assigning the rating a degree of importance is assigned the value is 1 to 0 and all the values must add up to 1. The degree to which it will impact the firm is multiplied by the rating to give a score. The strength or weaknesses with the highest score are counted in the SWOT analysis as the finalists.

Prioritizing threats and opportunities is done slightly different. The total importance of threats and opportunities is equal to 1; so it can be from 0 to 1. 0 means no impact 1 is high impact. Next the probability of an event impacting the firm from 1 to 3 low probabilities to high probability is listed. The importance and probability numbers are multiplied to give a score, which can determines which threats and opportunities are relevant to the situation and most affecting the firm.

Some of the strength, weaknesses opportunities and threats in electric vehicle industry in India are listed below:

Strengths

- Low running cost for maintenance & recharge
- Most Energy Efficient
- No Tailpipe Emissions & Environmental friendliness
- Smooth driving experience
- Reduce dependence on foreign oil imports
- EVs can charged at night, when electricity is cheapest to generate, can decrease utility prices
- Manufacturing facilities of conventional cars can be used
- Government rebates
- Can facilitate to earn stronger revenues & profit

Weaknesses

- High initial price (around 30% more than equivalent conventional cars)
- Range of conventional cars approx. 900kms on one full tank
- Range of most modern Electric cars around 150 to 200 kms
- Recharging time is high
- Shortage of spare parts as compared to conventional cars' part
- Limited car design

Opportunities

- Greater Opportunities for R&D
- Create more job opportunities
- Availability of skilful labour at cheaper prices
- Provide training to dealers & launch more EVs in the market
- Optimize production process to minimize losses
- Improve the governmental aim schemes for EVs & strengthen infrastructure
- Provide smaller incentives for a longer duration to improve acceptability

Threats

- Lack of collaboration between EV manufacturers (e.g.: Different charging plugs used by different manufacturers)
- Lack of Charging Infrastructure
- Lack of manufacturing facilities hence most EVs being imported which adds to the cost
- Lack of competition for the segment hence lack of choices
- Decreasing gasoline prices which compete to the EVs sales
- Improvements in public transportation

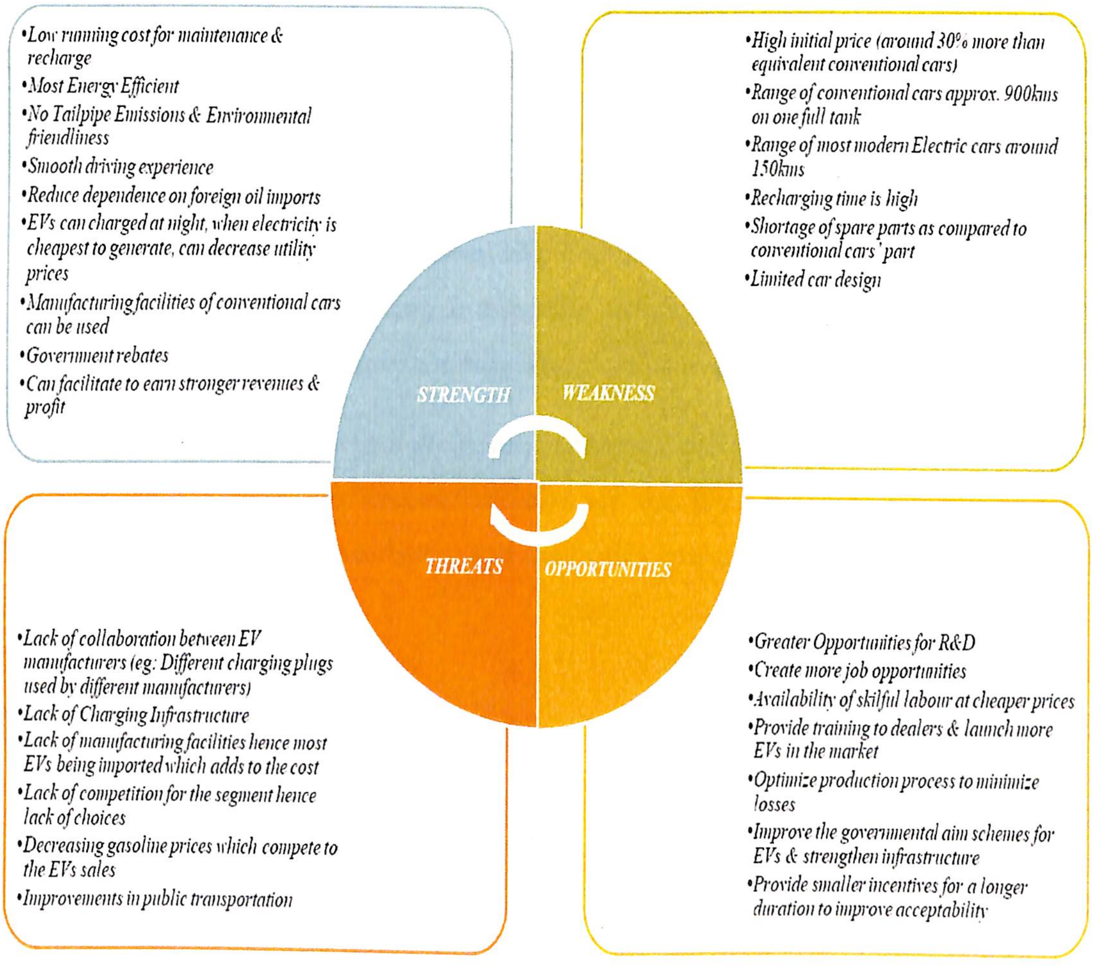

Figure 6: SWOT analysis of electric vehicle industry in India

3.4 PESTEL analysis of electric vehicle industry in India

India is facing unique environmental challenges and the companies are responsible both for the production of goods/services and the sustainable development. The PESTEL analysis is chosen in this case because it analyses the external macro environment in which the business operates. The PESTEL analysis takes into account the changes, keeps the companies on track with them and is very useful when a new product/service is started. It will assist the electric vehicles being a new technology for their faster adaptation on the automotive market. The subject of the PESTEL analysis should be clear. In this case it is a product (the electric vehicles) looking at its market (the Indian electric vehicle market). The PESTEL analysis consists of analysis of the political, economic, social, technological, environmental and legal factors which can influence the introduction and performance of the electric vehicles in Indian market.

Political: The political factors consist of the current and future support for the electric vehicles, grants and funding initiatives.

- Government continuously slashing tax rates
- Government has launched schemes like FAME, NEMMP, etc.
- Automatic approval for FDI in automobile sector
- Government aims to achieve carbon reduction as every other nation

Economical: The economic factors are related to the overall economic situation in the automotive market. The sales of electric vehicles are steadily increasing, but are not yet meeting the expectations of the industry and the policy makers in India.

- Stable economic policies
- Easy availability of finance
- Proximity of major export market
- Most automobile companies are present in India with their offerings in every segment
- Economic incentives by local & state government should be easily available
- Low duties & taxes
- Buying capacities of individuals are increasing
- Acceptability for new technologies is increasing at a good rate

Social: The social factors represent the attitudes of the Indian consumers towards the electric vehicles. Many of the test users reached the conclusions that if the charging could fit into their daily routines the electric vehicles could reach the same level of satisfaction as conventional cars. Additional planning of the trip was not needed, the driving style didn't change, the little noise that the electric vehicles produced is not dangerous for the pedestrians and the ability to reaching the final destination was satisfactory.

- Lucrative market in rural India
- Rapid urbanization & income level
- Skilled labour costs among the lowest in the world
- Buying EV can be depicted as a status symbol or care for mother nature
- Many social initiatives are being taken up to improve the living standards

Technological: The technological factors consist of the relevant current and future technological innovations. The main challenges that the electric vehicles face are the limitations within their range (the distance they can go with one charge). The distance, which an electric vehicle can pass with one charge, is on average around 150-200 km, while an average sized conventional car can pass more than 600-900 km. Another challenge is the establishment of effective charging infrastructure. The number of charging stations is expected to increase. The battery is another obstacle because it increases the price of the vehicle, but still needs to be technologically suitable. However, the technological development and market deployment of the electric vehicles will cope with both problems.

- Lakhs of Engineers pass out every year which can add to the strength for the segment
- Credible local suppliers of high-quality components
- India emerging as a hub for auto manufacturing & research
- Availability of skilful labour
- Modern population is technically sound & the acceptability to newer products increasing

Environmental: The environmental factors concern the level of pollution created by the electric vehicles and the attitudes to the environment from the consumers and the governments. The electric vehicles have the potential to decrease the air pollution. Since the air pollution can be global, regional and local attention should be paid to the local pollution as being a result if the activities of people in an area. It is necessary to determine which kinds of air pollution can be eliminated through the use of electric vehicles and which cannot. The electric vehicles can decrease the levels of COx, NOx and SOx emissions on a local level. However, renewable energy sources should be used for the production of the electricity for the electric vehicles. Otherwise, the energy plants from which the electric vehicles obtain electricity will create pollution, which will influence the environment despite the reduction of local air pollution in the cities. The climate changes in the future will influence the environment and the society in a way, which could lead to making electric vehicles the preferable option in an urban environment and perhaps at one point the only alternative.

- Indian automotive regulations are closely aligned to world standards on emission & safety
- EVs help to reduce carbon emissions into the environment
- Government initiatives for attaining sustainable development

Legal: The successful implementation of the electric vehicles in Indian market largely depends on the changes in the national regulations so that the process can be supported at local level. In some cities electric vehicles have been granted permissions to enter the pedestrian zones. In some cities, special lanes and parking space for electric vehicles are determined.

- Weighted tax deduction up to 150% on in house R&D
- Relatively high import duties
- Car manufacturers are not legally bound to provide basic safety equipment like airbags, anti-lock braking systems, etc. as standard which is present in other nations

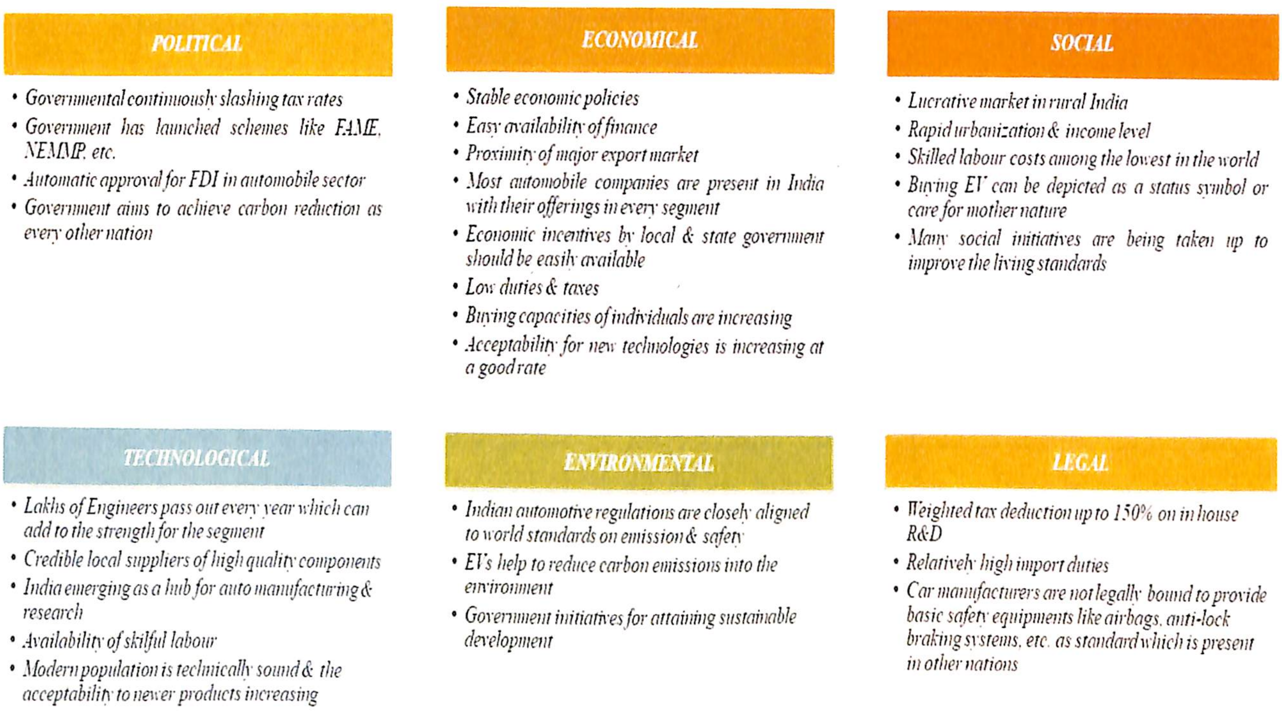

Figure 7: PESTEL analysis of electric vehicle industry in India

3.5 PORTERS'S five force analysis of electric vehicle industry in India

The underlying competitive structure in the electric vehicle industry in India is analysed by a `Five Forces Industry Analysis` (based on Michael Porters Model). It shows the key forces and their impact on the industry attractiveness and long-run profitability.

Threat of New Entrants: There is a high number of barriers to enter the e-Mobility industry. The electric vehicle industry has various barriers to entry. For example, the manufacturing of electric vehicles requires high investments in production lines, machinery and technology. Besides that, expertise in the automotive business is needed, in order to invest efficiently. Since the cost for technology (e.g. batteries) is still very high, the margins on electric vehicles are reduced. These barriers result in high fixed costs once investments have been done, which requires additional investment capital to secure a market share in the beginning especially for new competitors. Because of that, the growth in the e-Mobility industry will for the most part come from conventional automotive manufacturers, who already have the knowledge about processes and the needed infrastructure.

- Indian Government has introduced many schemes & incentives to promote EV market
- However, failure on the schemes & incentives, lack of infrastructure & optimum business models can deter entry of new players

Bargaining Power of Buyers: Customers have the choice; brand loyalty can help to mitigate the power of buyers. The demand for cars is very high. Cars are a commodity for private customers as well as businesses. An increased environmental awareness and the benefit of long-term savings on fuel costs, motivates more customers to switch from a conventional car to an electric vehicle. However, due to a strong competition and substitution in the industry, the power is with the buyers. Another factor that increases the power of the buyers is the limited switching costs. To switch from one model to another has little to no costs for the customer. Therefore, buyers tend to choose their model based on quality, price and service. An answer to mitigate the power of buyers is a better customer service and a stronger focus on brand loyalty.

- EVs are considered as a rich man's toy
- Though scooters are available at cheaper price, cars are still expensive compared to traditional cars
- Customers are ready to buy EVs, however after sales services, battery stations, fuel efficiency & performance are some of the hindrances for buying an EV

Bargaining Power of Suppliers: Suppliers hold comparatively little power. There is a large number of companies supplying the conventional as well as the electric automotive industry. In addition to that, the automotive industry is a key market for the most suppliers. Innovations happen more often on the side of the manufacturer than on the side of the supplying vendors. All these factors result in a comparatively low threat of suppliers.

- High technology costs Indian leading to higher pricing of electric vehicle compared to traditional vehicles especially cars
- Lack of technology infrastructure and support from Government for promotion of clean technology
- Alternative fuels like CNG, LPG

Competitive rivalry or Competition: Key automotive companies are highly competitive and maintain an intense rivalry. There are various automotive companies who fight for potential buyers of electric vehicles. A strong competition and a high power of buyers results in an intense rivalry in the electric vehicle industry. This is further increased, by a strong growth rate and a huge market prediction in the upcoming 2-5 years. Because of that, new companies are entering the industry, which leads to an even stronger competition. As an answer to that, existing key players in the automotive industry are willing to invest a large budget to make the switch from conventional cars to electric vehicles in time.

- EV directly compete with well-established business model of traditional vehicles
- With more players entering the market, especially the traditional manufacturers, competition is expected to get intense

Threat of Substitute: Intense competition and emerging mobility concepts make the threat of substitutes very real. The e-mobility industry has a similar competition structure as the traditional automotive industry. Even though the model mix of electric vehicles is not as broad as it is for conventional cars, the threat of substitutes is still tremendous. Emerging mobility concepts (such as mobility on demand, rideshare, autonomous driving, etc.) as well as traditional alternatives of transportation (e.g. bus, train, plain, etc.) are a serious threat to electric vehicles. In addition to that, the still high price difference of an electric vehicle compared to a conventional car, also adds conventional cars to the list of substitutes for EVs.

- Hybrids might enter Indian market sooner & more easily than EV because hybrids do not require new refueling infrastructure

- CNG & LPG are already making inroads in the automobile market

Conclusion and Forecast: The e-Mobility industry is currently in its early phase and is expected to grow during each of the five upcoming years. This growth is expected for several reasons. Investments from key automotive companies, new technological development, and a strong support from governments all over the world are positive factors that support a growth in the industry. Environmental awareness and long-term savings from electric vehicles will drive demand and with that sales figures higher. The automotive industry is one of the largest industries and if only a medium number of customers will switch from conventional cars to electric vehicles in the next 5 years, then this will lead to an enormous growth in the e-Mobility industry. One could see the trend of new mobility concepts as a threat for the growth of EV sales. The reality however is, even ride share options or autonomous driving require an efficient automotive. Electric vehicles will become the foundation of new businesses founded from new mobility concepts, because of lower variable costs.

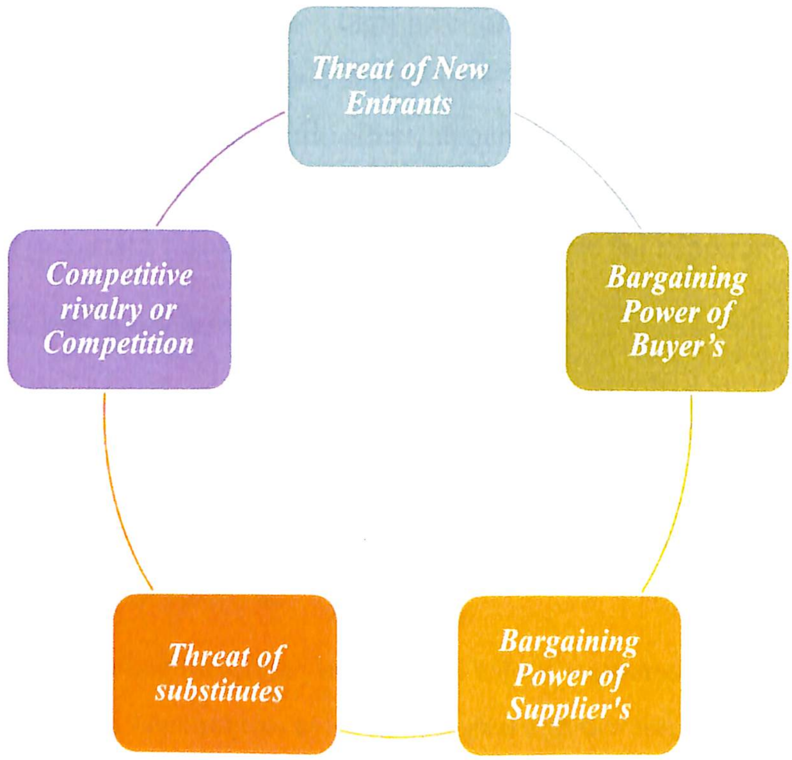

Figure 8: PORTERS'S five force analysis of electric vehicle industry in India

3.6 Shared Mobility

The rise of internet and digital tools has enabled the sharing economy to spread across multiple industries including mobility. Privately owned vehicle has an inherently low asset utilization, which can be improved through ride sourcing, ride sharing and carpooling. Shared mobility reduces the number of private vehicles on the road, thus tackling both congestion and pollution. This theme focuses on an approach to enable India to effectively harness the advantages of shared mobility at scale. Asset utilization today on private cars today is just ~5%. Further, there is lower utilization of seats in 2-5 seater category of cars. Various privately run, digitally powered, private aggregator platforms have emerged with healthy levels of adoption in India, which address this issue through different offerings (E.g. ride sourcing, ride splitting, ride sharing). However, two service offerings have seen increased traction:

- Ride sourcing e.g. Ola, Uber
- Ride sharing e.g. Ola Share, Uber pool

Ride sourcing and ride sharing achieve a high level of efficiency due to multiple advantages inherent in their business model: flexible supply base, smart communication system through smart phones, dynamic pricing, network effect, dynamic routing, demand pooling (for ride share), and digital feedback and management systems. Addressing safety concerns in ride source/share is an important factor, which can further improve the adoption.

Potential Options and Associated Strategic Levers

In order to address the challenges through a concerted effort, the proposed solutions are organized across a set of two core themes as following:

- Encourage ride-sharing and ride-sourcing through digital means
- Enable private vehicle sharing

Each theme and its supporting initiatives are outlined below, supported by the required strategic levers and relevant global benchmarks across developed and developing economies.

Theme 1: Encourage ride-sharing and ride-sourcing through digital means

Address safety concern with regards to shared mobility by designing clear guidelines for various stakeholders

- Strategic lever: There is a need to define a holistic safety framework encompassing needs of all stakeholders.

- Global example: All incidents that come to the light of Aggregator Company are to be reported to police, as has been instituted for Uber in London.

Provide a clear transition roadmap for existing closed-license taxi owners to compete effectively

- Strategic lever: An enabling ecosystem for existing closed-license taxi owners must be defined. Existing initiatives from Digital India could be leveraged towards this.
- Global example: A hardship fund to be funnelled towards closed-license taxi drivers was proposed by Uber in New York City. In Los Angeles, the process was democratized as all taxi drivers were asked to use an app allowing customers to hail a cab from their phones.

Theme 2: Enable private vehicle sharing

Introduce high occupancy lanes to encourage car pooling

- Strategic lever: A detailed policy framework needs to be laid out by central Government to help local authorities decide routes and pilot the initiative. Certain trunk routes for work should be identified for rolling out HOV and encouraging carpooling.
- Global example: US, UK (Leeds), Netherlands (Amsterdam), Spain (Madrid), New Zealand, Australia, Indonesia (Jakarta) have well defined lanes for the use of HOV, with minimum occupancy of 2 or 3, designed to discourage single or low occupancy car use. Jakarta had implemented the concept of HOV in 1992 for specific roads, specific hours. However, after rolling back the policy in 2016 (due to jockeys who rode along for a small fee) – Jakarta's peak hour traffic speed declined from 17 mph to 12 mph in mornings and from 13 to 7 mph in evenings. Travel delays worsened by 46% in morning rush hour and 87% in evening rush hour.

3.7 Green Mobility Technologies

Given the core issues of global warming and pollution across the world, green technologies have emerged as a potential solution. In this context, it is imperative for India to enable the growth of zero emission technologies to target these issues. Green mobility technology has significantly matured over the last few years.

Potential Options and Associated Strategic Levers

It is imperative to acknowledge that select policy initiatives have been designed and pilots have been rolled out in order to support the adoption of green mobility technologies. Most notable among them, is the FAME India Scheme aimed at supporting hybrid and electric vehicles' market development and manufacturing ecosystem. Pilots across cities by both public and private stakeholders such as Indian Oil, Ola have been attempted as well to develop charging infrastructure and promote adoption of green mobility technology. These initial steps are crucial to absorb lessons from, so that a holistic, comprehensive approach may be designed for active promotion and adoption of green mobility technologies. In order to address the challenges through a concerted effort, the proposed solutions are organized across a set of two core themes as following:

- Enforce supply-side restrictions to promote clean technology
- Provide supporting infrastructure

Each theme and its supporting initiatives are outlined below, supported by the required strategic levers and relevant global benchmarks across developed and developing economies.

Theme 1: Devise pollution control norms to promote clean technologies

Impose supply side regulations on OEMs to increase production of zero emission vehicles through market-based incentives like Corporate average fuel economy (CAFÉ) and ZEV (Zero Emission Vehicle) production credits.

- Strategic lever: Align with CAFE norms by developing regulations to penalize OEMs not adhering to the norms.
- Global example: Most Western countries are adopting enforceable CAFE norms to ensure supply of EVs; China has mandated OEMs to produce minimum of 10% EVs.

Use feebate mechanism to incentivize use of green mobility technologies

- Strategic lever: Identify potential mechanisms and develop regulation for incentivizing green mobility technologies with a feebate mechanism.
- Global example: London city imposes congestion charges during weekday working hours to vehicles entering the city centre.

Theme 2: Provide supporting infrastructure to drive adoption

Set up public charging infrastructure

- Strategic lever: Government to facilitate the setting up of public charging infrastructure – an important enabler for adoption of green mobility technologies (Ministry of Power has already initiated action in this respect). PPP in this space and utilization of existing infrastructure like petrol pumps are also being explored.
- Global example: Globally, public charging infrastructure is subsidized by the government while the utilities are the primary owners. The Chinese Government set up 16,000 charging points across the country in 2012 to drive adoption with the help of State Grid Corporation of China (SGCC); China also has plans to set up 4.8 Mn charging points with USD 18-20 Bn investment outlay by 2020.

3.8 FAME: Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles

The FAME India (Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles) Scheme is an incentive scheme for the promotion of electric and hybrid vehicles in the country. Ultimate objective of the scheme is to promote electric mobility and the scheme gives financial incentives for enhancing electric vehicle production and creation of electric transportation infrastructure. Basically, the incentive is provided in the form of subsidies to manufactures of electric vehicles and infrastructure providers of electric vehicles. FAME was launched by the Ministry of Heavy Industries and Public Enterprises in 2015 to incentivize the production and promotion of eco-friendly vehicles including electric vehicles and hybrid vehicles.

The Scheme operates in two phases:

- Phase I: started in 2015 and was completed on March 31st, 2019.
- Phase II: started from April 1st, 2019, will be completed by March 31st, 2022.

Features of FAME: FAME India is a part of the National Electric Mobility Mission Plan. Main thrust of FAME is to encourage electric vehicles by providing subsidies. Under the NEMMP scheme, the government aimed to invest Rs 14000 crore in creating infrastructure and promoting the use of electric vehicles. Vehicles in most segments – two wheelers, three wheelers, electric and hybrid cars and electric buses obtained the subsidy benefit of the scheme.

Focus areas of FAME: The scheme covers Electric and Hybrid technologies like Mild Hybrid, Strong Hybrid, Plug in Hybrid & Battery Electric Vehicles. FAME focuses on 4 areas i.e. Technology development, Demand Creation, Pilot Projects and Charging Infrastructure.

Phase I of FAME: Phase I of the FAME-India Scheme was launched on April 1st, 2015 and extended to March 31, 2019. Its original time period was two years. The scheme was implemented with an outlay of Rs 895 crore. Approximately 2,18,625 Electric Vehicles were 'promoted' by FAME I till July 2018. The mother programme of FAME- the National Electric Mobility Mission Plan (NEMMP) 2020 was launched in 2013 to achieve sales of six-seven million units of electric vehicles and thus to realise fossil fuel saving of 2.2 to 2.5 million tonnes. Such a promotion of electric vehicles will substantially lower vehicular emissions and decrease in carbon dioxide emissions by up to 1.5% by 2020. In early 2018, the Ministry of Power launched the new National Electric Mobility Programme with broad objectives. Here, the focus is for establishing the electric charging infrastructure and a policy framework to set realise more than 30% electric vehicles by 2030.

Phase II of FAME: The second phase is an expanded version of the first phase. FAME India Phase II has a total outlay of Rs 10000 Crores over the period of three years from 1st April 2019 to 2022. Allocation for the scheme for 2019-20 is estimated to be at Rs 1,500-crore; Rs 5,000 crore in 2020-21 and Rs 3,500 crore in 2021-22. FAME-II will cover buses using EV technology; electric, plug-in hybrid and strong hybrid four wheelers; electric three-wheelers including e-rickshaws and electric two-wheelers. For the overall monitoring, sanctioning and implementation of the scheme, an inter-ministerial empowered committee – 'Project Implementation and Sanctioning Committee' (PISC) that is headed by the heavy industry secretary, shall be constituted.

Following are the incentives given to various categories of vehicles under FAME-II. Incentives will be given on the basis of prescribed ex-factory price limits.

Electric two wheelers: Incentives will be provided for 10 lakh registered electric two-wheelers of Rs 20,000 each.

e-rickshaws: Incentives to 5 lakh e-rickshaws of Rs 50,000 each.

Electric four wheelers: An incentive of Rs 1.5 lakh each to 35,000 electric four-wheelers with an ex-factory price of up to Rs 15 lakh.

Hybrid four wheelers: An incentive of Rs 13,000 each to 20,000 strong hybrid four-wheelers with ex-factory price of up to Rs 15 lakh.

e-buses: Support to 7,090 e-buses with an incentive of up to Rs 50 lakh each having an ex-factory price of up to Rs 2 crore.

Electric charging infrastructure: The scheme proposes for establishing charging infrastructure and for this about 2700 charging stations will be established in metros, other million plus cities, smart cities and cities of Hilly states across the country. Objective is to create at least one charging station in a grid of 3 km x 3 km. Similarly, establishment of charging stations are also proposed on major highways connecting major city clusters. On the highways, charging stations will be established on both sides of the road at an interval of about 25 km each. Of the total allocation, Rs 1,000 crore has been allocated for setting up charging stations for electric vehicles in India.

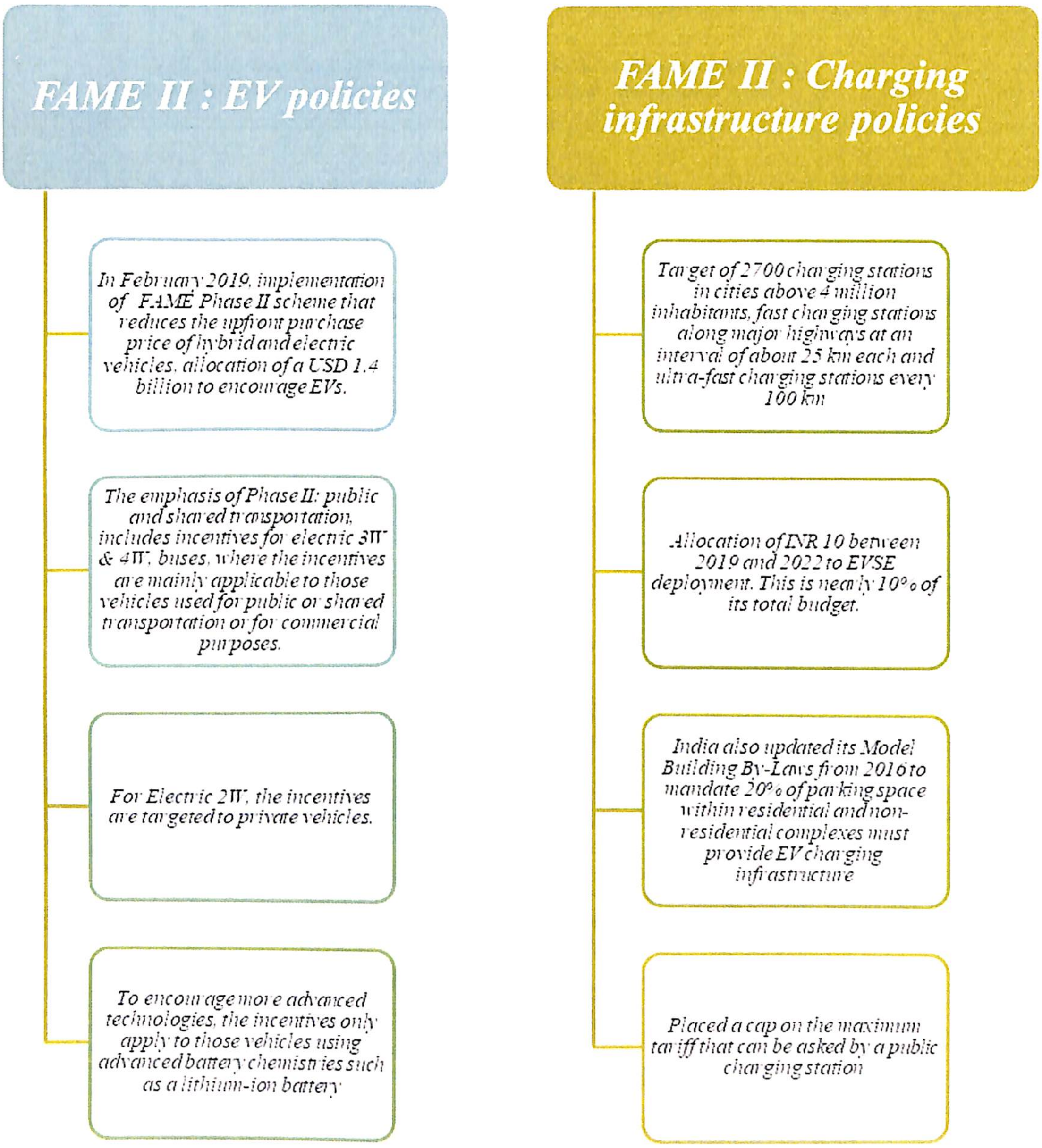

Figure 9: FAME policy in India

Chapter 4: Findings and Analysis

4.1 Descriptive Statistics

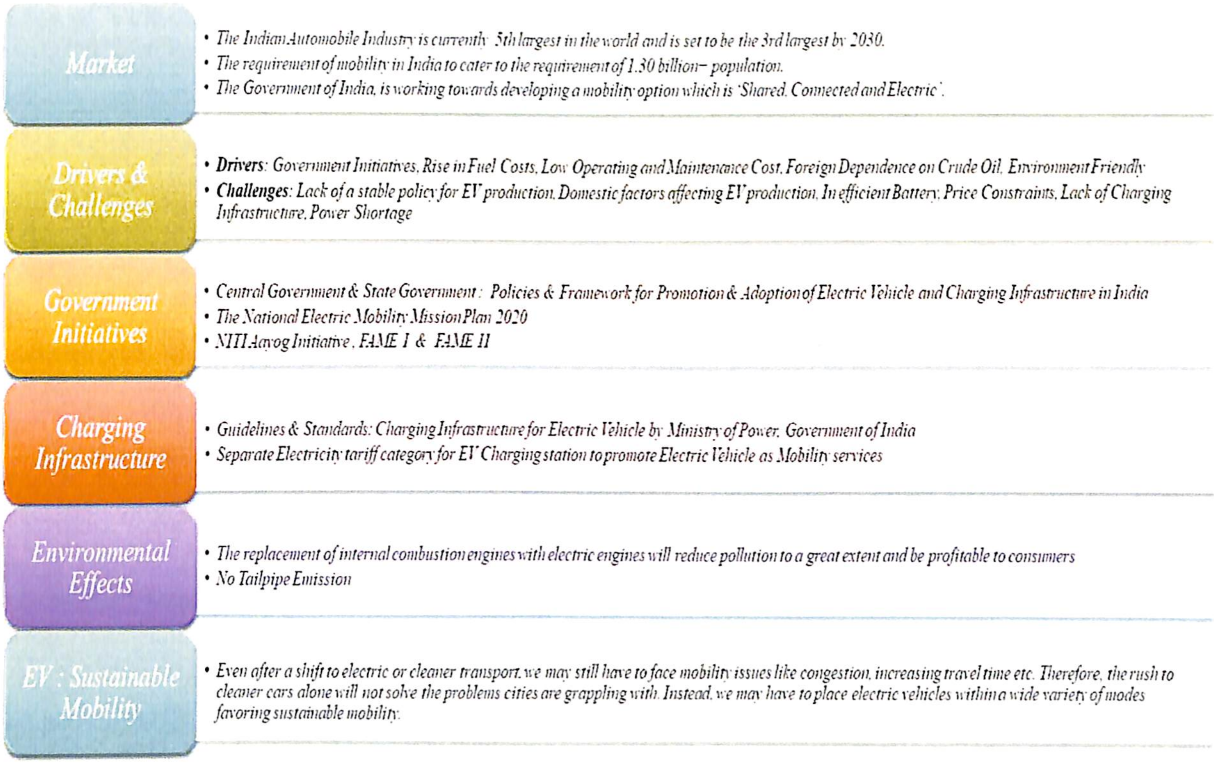

Figure 10: Electric Vehicle Components: Drivers, Challenges, Initiatives, Infrastructure, Effects, Sustainable mobility

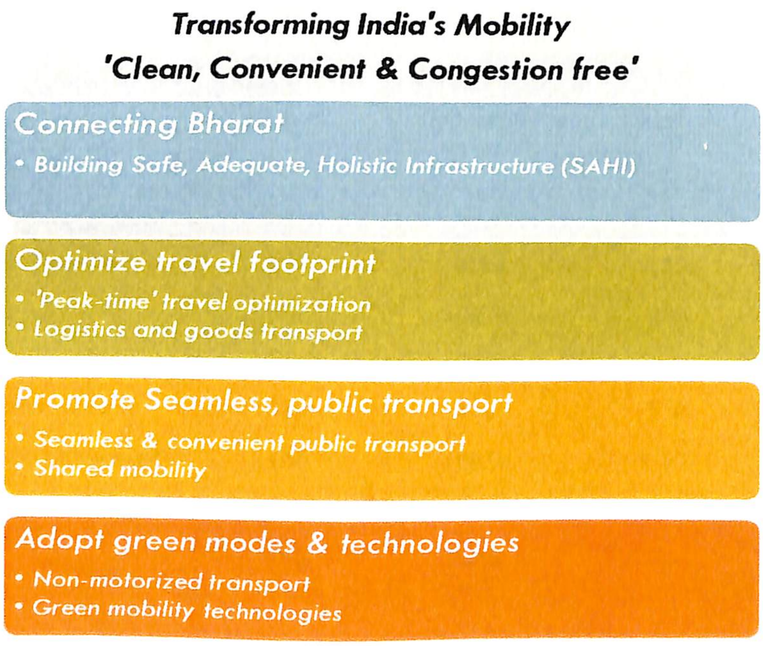

Figure 11: Electric Vehicle as sustainable mobility services

Approach to Future EV Market Estimation

Auto Industry body, Society of Automobile Manufacturers (SIAM) had predicted the 2026 sales of Vehicles in India based on the average GDP growth of 5.8%.

Table 2: Future Projections for Electric Vehicle

2016-17 revised classification as per Niti Aayog	2016-17 domestic sales	2026 SIAM Projections (Min.)	2026 SIAM Projections (Max.)	2026 SIAM Projections (median)
Passenger Vehicles - Personal	2,132,709	5,170,000	7,370,000	6,270,000
Passenger Vehicles – Commercial/fleet	914,018	4,230,000	6,030,000	5,130,000
Commercial Vehicles - Goods	616,106	1,700,000	3,315,000	2,507,500
Commercial Vehicles -Passenger	98,126	300,000	585,000	442,500
Three Wheelers	511,658	1,200,000	1,500,000	1,350,000
Two Wheelers	17,589,511	50,600,000	55,600,000	53,100,000
Overall vehicles	**21,862,128**	**63,200,000**	**74,400,000**	**68,800,000**

To arrive at the 2026 penetration numbers of the EV, assumptions were considered on the 2030 penetration levels These assumptions were taken into consideration based on the Vehicle type and the current ground realities surrounding each of these assumptions as shown below:

Table 3: Estimates based on NITI Aayog's plan

	Niti Aayog EV Plan 2030		Assumption on the Niti Aayog Plan	
2016-17 revised classification as per Niti Aayog	**2030 Business As usual (BAU)**	**2030 Transformative**	**2026 Business As usual (BAU)**	**2030 Transformative**
Passenger Vehicles -Personal	1%	40%	0.5%	20%
Passenger Vehicles - Commercial / fleet	5%	100%	2%	60%
Commercial Vehicles - Goods	0%	0%	0%	0%
Commercial Vehicles -Passenger	1%	100%	0.5%	60%
Three Wheelers	5%	100%	2%	50%
Two Wheelers	5%	40%	2%	20%

Table 4: Likely future market for EVs in India

	SIAM DATA	Feedback estimate	Feedback projection based on the explanation earlier	
2016-17 revised classification as per Niti Aayog	**2016-17 domestic sales (all types)**	**2016-17 domestic sales (only EVs)**	**2026 Business As usual (BAU)**	**2026 Transformative**
Passenger Vehicles -Personal	2,132,709	2,000	31,350	1,254,000
Passenger Vehicles - Commercial / fleet	914,018		102,600	3,078,000
Commercial Vehicles - Goods	616,106			
Commercial Vehicles -Passenger	98,126	20	2,213	265,500
Three Wheelers	511,658	50	27,000	675,000
Two Wheelers	17,589,511	22,000	1,062,000	10,620,000
Overall vehicles	**21,862,128**	**24,070**	**1,225,163**	**15,892,500**

Table 5: Likely future market for EV Chargers in India

	2017-18	2018-19	2019-21	2021-25	Cumulative potential upto 2026
No of EV Charging stations likely to be set up	1,000	5,000	50,000	350,000	406,000
Norms of EV Chargers likely to be installed	4	4	6	6	
Total EV Chargers likely to be installed	4,000	20,000	300,000	2,100,000	2,424,000
% of AC Slow chargers likely	90%	80%	80%	70%	
% of DC Fast chargers likely	10%	20%	20%	30%	
No of AC Slow chargers likely to be installed	3,600	16,000	240,000	1,470,000	1,729,600
No of DC Fast Chargers likely to be installed	400	4,000	60,000	630,000	694,400

4.2 Planned approach to mobility transformation

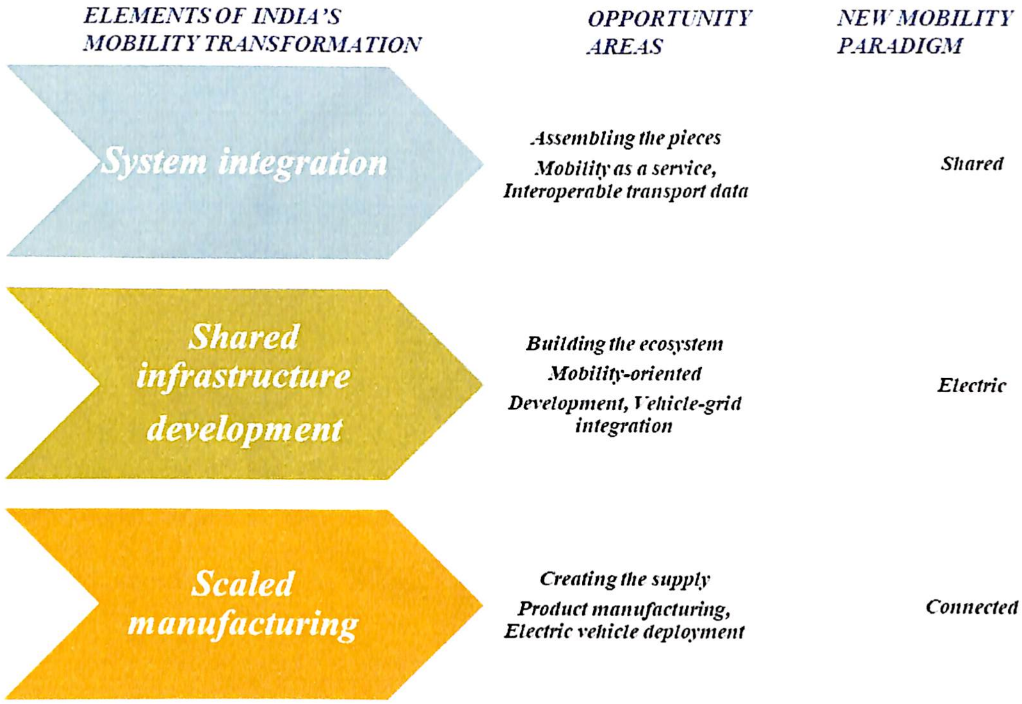

Figure 12: Government of India Initiative for faster adoption & manufacturing of EV

- **Systems integration:** Enabling wide-scale adoption of mobility solutions through ubiquitous availability and sharing of interoperable transport data (ITD).

- **Shared infrastructure development:** Better urban design, where a larger fraction of mobility demand is met by nonmotorized transit and public

- **Scaled manufacturing:** Facilitating market creation through policies and mechanisms that enable manufacturing of electric vehicles (EVs) and necessary components in successive segments based on their market readiness.

4.3 Battery Swapping

Figure 13: Charging infrastructure: Battery Swapping

Significant consideration has been given by the government on battery swapping as a mechanism to mitigate the issues of (a) cost of ownership and (b) range anxiety faced with electric vehicles. A Battery Swapping Infrastructure essentially supports swapping of discharged batteries in a vehicle with fully charged batteries from a shelf. A key advantage of battery swapping is the reduced time for energy replenishment in EVs as battery swap can be possible within 5-15 minutes compared to up to 6-8 hours required for charging a battery. This strategy of providing widespread battery swapping model is also expected to contribute to reducing the upfront cost of EVs as vehicles can be sold with a battery available on lease.

- Battery packs have been a major cost driver for EVs since their inception. Technological developments, widening application base, and economies of scale have pushed down their prices substantially.
- Intense price competition is further fuelling technological advancement efforts in form of development of new formulations and improved processes that are further expected to decrease the lithium-ion battery prices to USD 109/KWh and USD 73/ KWh by 2025 and 2030 respectively.

- Charging technology has improved by leaps and bounds since the first electric car was launched in India at the cusp of the new millennium. As technology evolves further, charging time is expected to become less than the time required to refill a petrol tank in a current combustion engine vehicle.

While, the above policy measures support India's movement towards cleaner mobility, they do not seem to be adequate. This is evident in the report by Lancet Commission on Pollution and Health which states that India and Bangladesh have had maximum increase in deaths due to pollution. The results of a study published by the Government of India estimates that air pollution led to nearly 620,000 early deaths in 2010 and cost about three per cent of India's GDP in terms of impact on health.

Even the battery swapping model given by NITI Aayog suffers from limitations. Battery Swapping Model does not fall in the evolution path of battery technology. The rationale for battery swapping model are (a) low energy density of batteries leading to low range of batteries that require frequent charging in a day, (b) long time taken for charging and (c) high cost of battery ownership. However, all these rationales are expected to rapidly fade away in the next five years, as techno-economic development makes batteries cheaper, with significantly higher energy capacity for longer range and with ability to recharge in a very short period of time. Therefore, any investments into battery swapping infrastructure, is likely to become redundant within the next five years.

Commercial failures globally: 100 per cent EV sales and adoption amongst Indian consumers is only possible if a consumer experiences continuity and certainty. Prominent battery swapping companies, including Better Place – the pioneer of battery swapping model, have failed in the past to sustain operations.

Add to the costs: As per NITI Aayog, in 2030 alone over 4.5 crore battery packs will be required for motorcycles, scooters, autorickshaws, cars and jeeps. A battery swapping model will only increase the battery pack requirement and add a 'multiple' to the cost as raw material in the form of mineral reserves will continue to be imported. Costs of the additional battery, swapping of battery, storage, asset under-utilisation and profit by the commercial entity involved (and possibly higher electricity rate due to commercial operations and higher GST for batteries) will have to be absorbed by the vehicle owners using battery swapping models.

Absence of battery standardisation: While standardisation has been largely achieved for other applications of lithium-ion battery packs such as electronic devices, it is still to be achieved for EVs as the industry is at a nascent stage and still evolving. In the long run, standardisation has to be achieved since the battery packs would need to find secondary usage once it is no longer fit for EV usage. However, till there is reasonable homogeneity and consistency in operational procedures, it will be difficult to efficiently implement battery swapping models.

Practical and safety issues: There will always be concerns around safety as battery swapping will involve regular/daily interference with the original structure of the vehicle with a critical component getting changed every day.

4.4 Potential Policy and Regulatory Measures

Policy to encourage retrofit hybrids for rapid transition to cleaner vehicles: The Government of India is moving towards the direct transition from ICE-powered engines to EVs. However, the ultimate goal is to shift to fuel efficient transportation that has less impact on the environment and health and reduced dependency on oil. Also, there are many challenges involved in the direct transition to EVs from ICE. One of the main challenge is the lack of charging infrastructure. Since, hybrid vehicles are less dependent on charging infrastructure, the transition to hybrid could play a crucial role by bridging between ICE vehicles and EVs. Existing ICE-powered vehicles need to be incentivised to shift to hybrids using available technologies such as hybrid-retrofits, so that the journey to a cleaner future begins right now with the available, ready to use technology.

Tax benefits: As per the NITI Aayog report 'India Leaps Ahead', May 2017, it has suggested, reducing the interest rates, indirect taxes and registration taxes at state level. In order to increase the number of EVs or hybrid vehicles on road, tax benefits could play a significant role. There needs to be zero registration fees for both EVs and hybrids. Also, EV and hybrid vehicles should be exempted from GST, till the time the target of complete electric mobility is achieved.

Demand Push at the state level: Demand push from the state government could play a crucial role in rapid adoption of EV/hybrid vehicles. Many state governments such as Telangana, Maharashtra and Karnataka are moving towards the adoption of electric vehicles in their policy. Several incentives could be considered to create a demand for EVs such as: Preferred/Free Parking at Municipalities/Private Parking/Airports, etc., exemption or reduction of toll taxes and road taxes for commercial electric/hybrid vehicles. The vehicles should be certified by the government and should have a green number plate. Also, EV trucks should be exempted from the interstate time restrictions.

Incentives/subsidies for retrofit EV/Hybrids in the policy: FAME-2 is being implemented at present and subsidies are being provided by the government on purchase of EVs. Since the demand of EVs is also at a nascent stage, the Government of India can afford to provide subsidies to the end consumer. However, continuous support to end users in form of subsidies is untenable in the long run as demand picks up. NITI Aayog has suggested a fee – rebate model where efficient vehicles are rewarded with rebates through a surcharge on inefficient vehicles. The Government of India could develop a policy to provide a subsidy to vehicle owners as an incentive for the conversion of petrol/diesel vehicles with more fuel-efficient vehicles such as hybrids. Different incentives could be provided on the basis of the type of vehicle (cars, vans, buses, trucks, etc.). Japan's 'Vehicle Replacement Scheme' is a successful initiative by the Government of Japan to increase the number of hybrid cars on road, could be taken as a reference study.

Investing in Research and Development: As per the report by NITI Aayog 'India Energy Storage Mission' by investing in research and development of new and advanced battery technology, India can build a sustainable battery manufacturing supply chain. As per the report, cheap batteries, made in India, can not only support the government's goals for vehicle electrification, renewable energy integration and job growth, but also speed up the world's transition to a clean energy economy. Research and development would also lead to innovation and improvements. For example: Some companies have found a way to reduce the amount of key rare earth metal used in magnets for EV motors by around 20 per cent, which could help in lowering the EV production cost and reduce the risk of shortage of rare earth metals. Also, some companies are moving towards accumulating cobalt for battery manufacturing.

Global Collaborative Campaign in India: This global collaborative campaign in India is likely to bring together all the major stakeholders in electric and hybrid vehicles related industry which could be automobile, technology, energy, etc. and consumers to promote the use of both electric and hybrid vehicles. It could help the vehicle owners/buyers to understand the benefits of hybrid vehicles and their contribution to healthy environment and health. One of the successful examples of mass collaborative campaign is the 'Go Ultra Low' campaign in the U.K.

Public Procurement of electric and hybrid vehicles: The Government of India could mandate the public procurement of hybrid vehicles in all the states in India for government staff to promote the benefits and visibility of electric and hybrid cars on the road.

Temporary ban on petrol/diesel vehicles during air pollution crises: During emergency situations, where air pollution reaches alarming levels such as: alarming air pollution levels in Delhi during November 2016, 2017 and 2019, the state government could impose the temporary ban on petrol/ diesel vehicles with 24 hours prior notice. Eco-friendly vehicles such as electric/hybrid/CNG vehicles could be exempted from the temporary ban. Consumers could then realise the benefits of hybrid/electric vehicles to both health and environment. One of the successful examples is the temporary diesel cars ban in London and Oxford (U.K.), which was launched to mitigate the rising air pollution levels in the city.

CSR activity for corporate organisations for influencing or incentivising employees for buying EV/Hybrid vehicles as a 'Go Green' initiative: As per the Company Act 2013, companies having net worth of INR500 crore or more, or turnover of INR1000 crore or more, or a net profit of INR5 crore or more during any financial year shall contribute at least two per cent of the average net profits of the company made during the immediately preceding financial year to Corporate Social Responsibility (CSR). As per CSR activities defined in Schedule 7 of the Companies Act 2013 'Ensuring environmental sustainability, ecological balance, protection of flora and fauna, animal welfare, agroforestry, conservation of natural resources and maintaining quality of soil, air and water including contribution to the Clean Ganga Fund setup by the Central Government for rejuvenation of river Ganga', companies could contribute to the transition to EV/Hybrid vehicles and help in ensuring environment sustainability.

Chapter 5: Interpretation of Result: Electric Vehicles as Sustainable Mobility

5.1 Introduction

The transport sector is the main responsible of the air pollution in India, as it produces almost a quarter of all the greenhouse gas (GHG) emissions. Road transport, in particular, was considered responsible for more than 70% of GHG emissions from the transport sector in 2014. In December 2015, 195 countries including Canada acceded to the Paris Agreement, an additional international measure to more increase efforts to address climate change through a reduction of global GHG emissions, and restriction of the global average temperatures to below 2°C. According to the Intergovernmental Panel on Climate Change, this is based on understanding that 2°C is the maximum allowable emissions threshold, after which irreversible climate harm would have occurred. All efforts must consequently be on deck to resolutely instigate to lower GHG emissions in order to avoid unsustainable climate conditions from occurring. Considering that nations have different sectors contributing to their respective GHG emission profiles, each is anticipated to accomplish its obligation by engaging diverse procedures.

The measures to be taken to accomplish air purification will include:

- Leveraging digital technologies, implementing affordable pricing and promoting the move to decrease emissions from transportation, in order to enhance the efficiency of the transport system.
- Encouraging and accelerating a revolutionary shift to internal combustion engines, and alternative sources of energy for transportation having lower emission levels and which use alternative fuels such as hydrogen, innovative biofuels and renewable synthetic fuels, and electricity.
- Accelerating the conversion in the direction of low- and zero-emission vehicles.

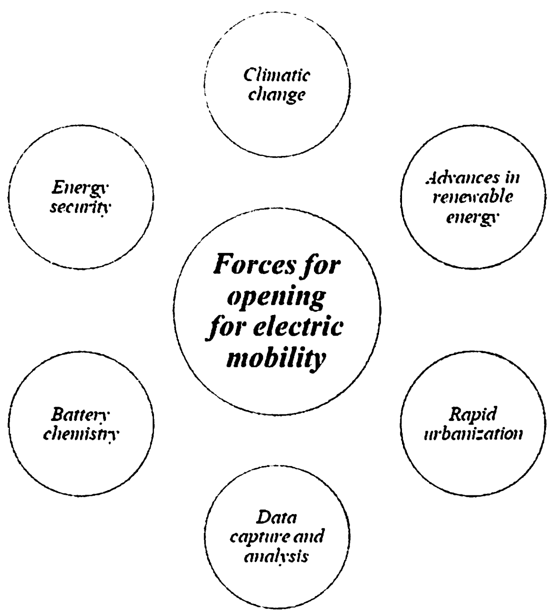

Figure 14: India towards sustainable mobility

A critical determinant of the success of these strategies is the consistent support of local authorities. These authorities may offer incentives to people to use vehicles with low- emission based on their employing alternative energy sources. They may also encourage the use of other methods of conveyance, including biking and walking, public transport and car- sharing/ pooling arrangements, which effectually decrease polluting emissions.

Recently, EVs have become in some way widespread, principally because of their negligible flue gas emissions and lesser reliance on oil. It is estimated that by 2022, EVs will be over 35 million in the World. However, a critical problem associated with EVs is that their high penetration raises branch and transformer congestion and heavy electricity demand to the power grid. One efficient approach to relieve the effect is to integrate local power generation such as Renewable Energy Sources (RESs) into the EV charging infrastructure. There is a lack of systematic studies considering the interaction and integration of EVs with renewable energy sources, the power grid, the charging infrastructure and the strategies to decrease air pollution, all together. This chapter seeks to investigate the integration of EVs with RESs for sustainable mobility in greatly reducing GHG emissions.

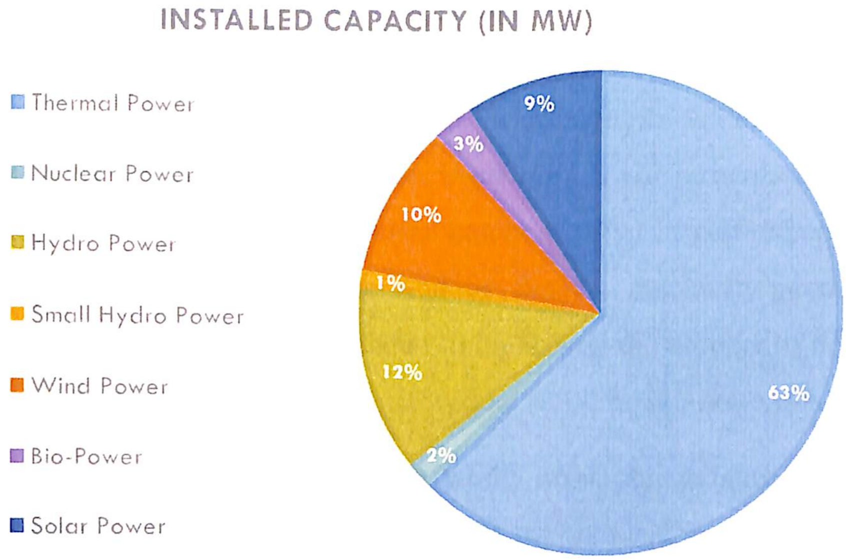

Figure 15: Total installed capacity (in MW) of power stations in India (as on 31.01.2020)

5.2 Road transportation and the menace of harmful emissions

Electric Vehicles have a three times higher efficiency than internal combustion engine vehicles. Moreover, they emit no tailpipe CO_2 and other pollutants like nitrogen oxides (NOx), non-methane hydrocarbons (NMHC) and particulate matter (PM). Furthermore, they are really silent and do not produce any vibration. The future optimisation of EVs is focused on technological optimization and market development. On the technology side, the main efforts are on the reliability and durability of batteries and supercapacitors, on the reduction of battery weight and volume, on improving their safety and on reducing their cost. Other technological challenges regard improving hybrid electric powertrains, charging infrastructure and plug-in solutions.

The potential of Renewable Energy Sources to power EVs can help reduce pollution, with a considerable decarbonisation effect and improve resource efficiency. Surely, it varies a lot by country, based on the level of the infrastructures and on the demand for additional electricity. Currently, it is quite impossible to tell, how much electricity is required and what type of production can be sufficient to cover the current electricity demand. However, once certainty has been attained, the increasing demand for electricity generation is likely to have an enormous impact on the overall power system in India. In general, the increased number of EVs will automatically need an additional generation of electricity. Importantly, the core principles of management strategies depend on the nation's types of renewable energy as well as conventional power generation systems. For instance, states characterised by high solar energy production capacity for which the preferred charging peak will be during the day will have to adopt different power management strategies from countries which only depend on wind, combined solar or wind electricity production. In addition, it will be necessary for regions with weak network infrastructure to add grid reinforcement or rather implement specific smart charging approaches to ensure efficiency as well as flexible electricity production and distribution infrastructure. The main benefit related to increasing the number of EVs is that it significantly minimises direct emissions of CO_2 as well as air pollutants from road transport.

Nonetheless, these positive impacts could be partially offset due to additional emissions caused by increased amount of electricity needed as well as continued use of fossil fuel in the power industry. That is to say, lower emissions of CO_2 and air pollutants determined by a substantial increase of EVs could cause higher emissions by the electricity generation when it is based on fossil fuel combustion and when the reduction in electricity demand is not made in other sectors.

Overall, the avoided CO_2 emissions in the road transport sector should outweigh the higher emissions from electricity generation. In countries with high shares of fossil fuel power plants, electric vehicle demand could, however, lead to higher CO_2 emissions. Ecologically, Electric Vehicles Integrated with Renewable Energy Sources for Sustainable Mobility the significance of electrically driven automobiles in cases of EV aggregator may not wholly be accomplished.

In the process of incorporating extra electricity need, it is worth considering that road and energy sectors should be firmly joined. Besides, the decisions regarding policies as well as investments across these two sectors should be integrated. The replacement of the conventional cars with electricity-driven ones is a significant means of reducing emissions, but this relies on which source of electricity to rejuvenate the vehicles. Causes may include; renewable sources, fossil fuels and also nuclear. Therefore, blindly substituting the conventional cars is not a perfect solution to the transport-related issues, for instance, rapid congestions as well as demand for road transportation. It is evident that proper systems of the transport are urgently required, and this may encompass additional expansion of renewable energy like biofuels. In a nutshell, a deviation in the public means of transportation as well as the underlying structures.

5.3 Electric vehicle integration with renewable energy sources (RESs)

The growing wind power and solar photovoltaic (PV) installed capacity has initiated high requirements on power balance control and power quality in India. The transmission system operator (TSO) plays a significant role in ensuring the balance between consumption and production at all times including at intra hour time scale. Importantly, the research has majorly focused on the potential contribution of EVs to facilitate the integration of RESs in the power system. The research topic has been developed within the paradigm of the smart grid, and it is centred on the EVs potential of establishing mutual benefits to both the electric power system with RES and future EV users. The term "smart grid" refers to the operation of the power system using communication, control technology, power electronics technologies as well as storage technologies to balance production and consumption at all levels. Regarding this vision, an EV is in a position to act as a controllable load or as storage, charging or discharging part of its battery capacity back to the grid, conferring to the vehicle to grid (V2G) notion.

If the charging of EVs is uncoordinated, their impact on the grid is equivalent to a large electric load resulting in higher power systems peak-load and to distribution grid congestion issues. To avoid such scenarios, the study has researched on what impacts EV coordinated charging can have in correlation with renewable energy sources production. To be precise, the research has focused on the solutions using EVs for the provision of ancillary services for wind integration as well as energy storage for PV integration.

Electric vehicle integration with wind energy: Using EVs in power systems together with wind power has been reported to be ideally suited for the provision of ancillary services. EVs should be coordinated for high-value services including ancillary services that often reduces the operating cost to EV owner in the short-term period. The EV owners are likely to experience lower price despite a higher initial value compared to the ICE cars.

The main concern is at the disposition of secondary reserves, load frequency control (LFC), which is assessed through simulation models. Regarding the simulation, it is observable that vehicles batteries are subject to extensive energy excursion, which tends to pass from empty to full state of charge. It was discovered that the penetration level of wind power could be increased even more by using a coordinated EV load. In a different study, EVs and power systems are believed to be perfect as controllable loads in simulation environment; however, the research failed to address the possible hindrances like EV control requirements as well as EV elements response during moments of coordination.

Electric vehicle integration with solar energy: The research on the usage of solar power through EVs is significantly diversified as compared to various studies focusing on wind power and EVs. Substantially, it is possible to generate electricity PV at both medium and low voltage levels within the power systems. Besides, this alternative additionally motivates the concept of incorporating the PV generation with EVs. Utilising EVs in the process of distributing grids using PV is considered an alternative to storing energy instead of controllable loads vis-à-vis the suggestions made by various scholars. Additionally, research reveals that during the daytime when the solar radiation is at the peak, solar power can be easily stored in the car batteries for future usage. In this field, several contributions, for instance, the idea of "green" charge has enabled people to understand the significance of maximising the cost of EVs throughout the irradiation period. The scholars introduced a concept in which EVs can be charged during the day at the parking areas situated, for instance, within the workplaces. In addition, EVs can be re-energised entirely during the working periods to realise the solar-to vehicle (S2V) approach. Furthermore, the research also illustrates that energy generated in each parking area is essential in the extra generation of adequate electricity for transportation requirements for the EVs operator. Although grids may have high penetration capacity of PV, they may too have lower voltages. In such situations, the primary constraint is linked to variations of voltage magnitudes along the feeders. Moreover, such discrepancies can be noticed particularly within the periods of high production as well as the conditions of low load. Unsurprisingly, these events are likely to occur regularly, but on areas majorly the places of residence that have highly concentrated roof-top PVs. Conversely, many studies have examined various alternatives in the mitigation of voltage capacity, for instance, the grid reinforcement, approaches to reactive power control, harmonised active power curtailment, as well as permanent storage of energy.

The electrical network integration with the management of distribution grid: The need for a transition to a more sustainable energy system leads to a deep change in the energy, building and transports sector. Power installation from renewable energy sources is becoming more and more relevant, new mobility schemes, namely car sharing, are growing more popular and particular attention is paid to energy efficiency in buildings. Moreover, each of these aspects is related to another important concept that is energy storage. The greatest change in the energy sector has occurred due to the development of distributed (or diffused) generation (DG). According to DG consists of the totality of power plants having a nominal power lower than 10 MW and connected to the distribution network. DG plants exploit primary energy sources—in the majority of cases renewable—which are distributed on the territory (thus the name distributed generation) and that could not otherwise be exploited in a traditional centralised plant; they supply local loads and they can be operated in a co-generative mode.

In an urban district, examples of DG are PV panels and solar collectors mounted on top of buildings. One of the drawbacks of DG is the high specific investment cost mainly due to the fact that, being medium or small plants, scale economy cannot be applied. Nevertheless, this can be faced thanks to a suitable incentive strategy. The real problem is the difficulty in predicting and controlling the power produced and put on the distribution network. So, the distributed generation, together with other distributed energy resources such as EVs and energy storage, is the main driver for the shift to a new paradigm in the management of the grid: the passage to a smart grid.

Smart grid is defined as a modern electric power grid infrastructure that guarantees the reliability of the system and the security of supply, allowing to face problems related to the distributed power generation from renewable energy sources and to control the load, promoting energy efficiency and involving the passive final users. In order to do so, integration of the electrical grid with information and communication technology (ICT) is needed. The availability of electricity is of crucial importance for all human activities. Therefore, continuity and security of the supply service are necessary. Since nowadays electrical energy cannot be stored at low-cost and in large quantities, electrical systems must guarantee a constant equilibrium between production and consumption. This means that the power generated has to correspond exactly to the one requested at any time interval. The electrical network is ruled in a way to ensure that this balance is respected despite any possible disturbance, from load.

As more clients embrace EVs, vehicle-to-grid administrations ought to be considered to help level out power supply as well as demand. This alternative might be particularly helpful in urban communities that have embraced electric transports for public transportation. These electric transports could give power to the grid when not being used, diminishing expenses for the city as well as clients. Some alert ought to be taken as more EVs are associated with the grid. Huge spikes popular for power could cause anxiety that could influence soundness, productivity, and working expenses of the grid. Subsequently, the effect of charging an electric vehicle is subject to where it is situated on the grid and the season of day it is charged.

Utilities plan to utilise disseminated assets, for example, sustainable power source generation, storage and demand reaction, to incompletely control charging effects of EVs. Keen grid innovations, for example, progressed metering foundation could demonstrate accommodating in dealing with the charging of EVs. Such gadgets permit charging stations to be incorporated with time-based rates that support off-peak charging. They likewise enable utilities to examine charging station utilisation and charging practices to illuminate speculation choices. Moreover, calculations that successfully plan the charging and releasing of EVs are vital for the grid to work proficiently. Be that as it may, growing such calculations is troublesome because of the irregularity and vulnerability of future occasions. More electric vehicle charging stations in advantageous areas are important to adjust request on the grid and increment accommodation. On the off chance that an electric vehicle needs to charge amid a lengthy, difficult experience trip, it would need to stop at the closest charging station. The nearest charging zone may not be along the driver's way, conceivably expanding power utilisation and diminishing convenience. Microgrids could likewise support unwavering quality while charging EVs in an area or work zone. Small community areas with disseminated assets, for example, solar-power oriented, wind as well as storage would decrease the strain on our power grid. Maybe circling capacity into nearby microgrids would additionally improve power versatility. As clients receive EVs, it is vital to consider all the potential advantages these autos could give to the grid. The grid could turn out to be more adaptable amid peak times for less cost and costly foundation updates could be kept away from with vehicle-to grid administrations.

EVs represent one of the best promising technologies for green and sustainable transportation systems. The high penetration of EVs will have positive effects and benefits such as lesser fossil fuel reliance, significant reduction of GHG and toxic pollutant emissions, as well as the capability to contribute in the integration of renewable energy into existing electric grids. Thus, the interaction and integration of EVs with renewable energy sources such as wind energy, solar photovoltaics and EV coordination for sustainable mobility in significantly reducing air pollution.

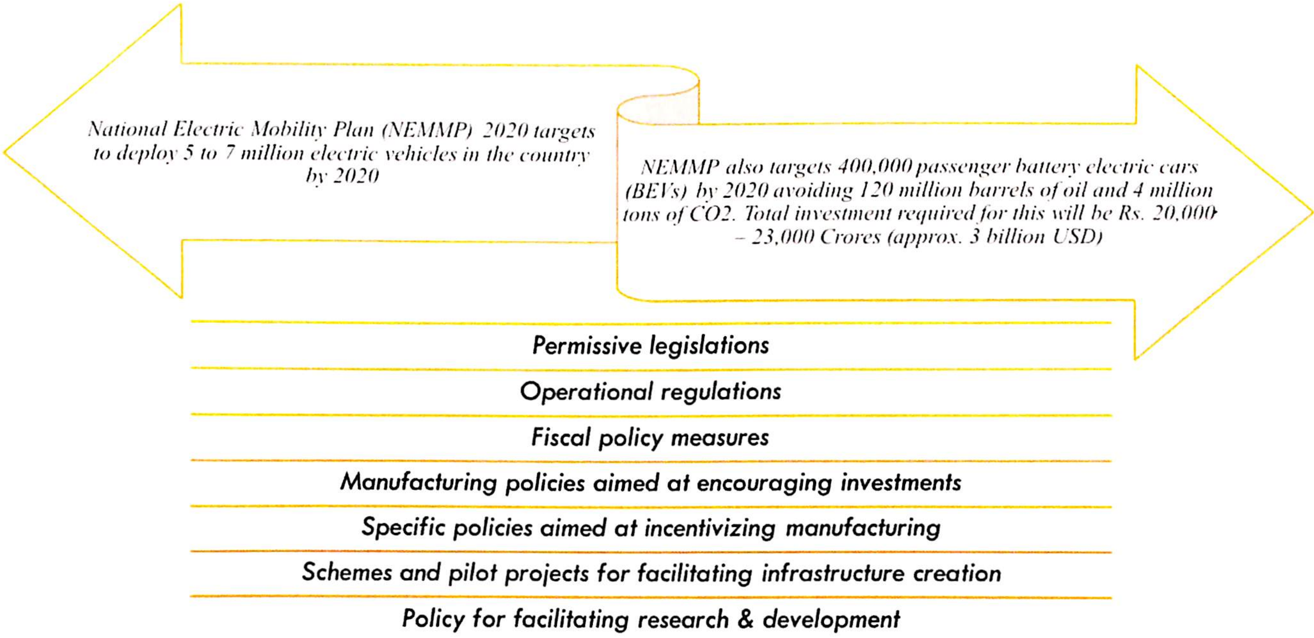

Figure 16: National Electric Mobility Mission Plan

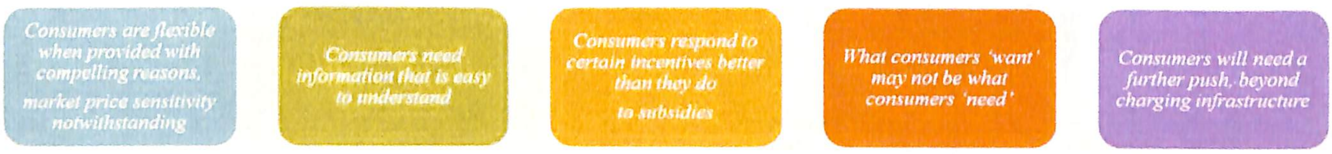

Figure 17: EV from consumer's perspective

Chapter 6: Conclusions and Scope for Future Work

6.1 Scope for Future Work & Recommendations for Faster EV Rollouts & Adoption

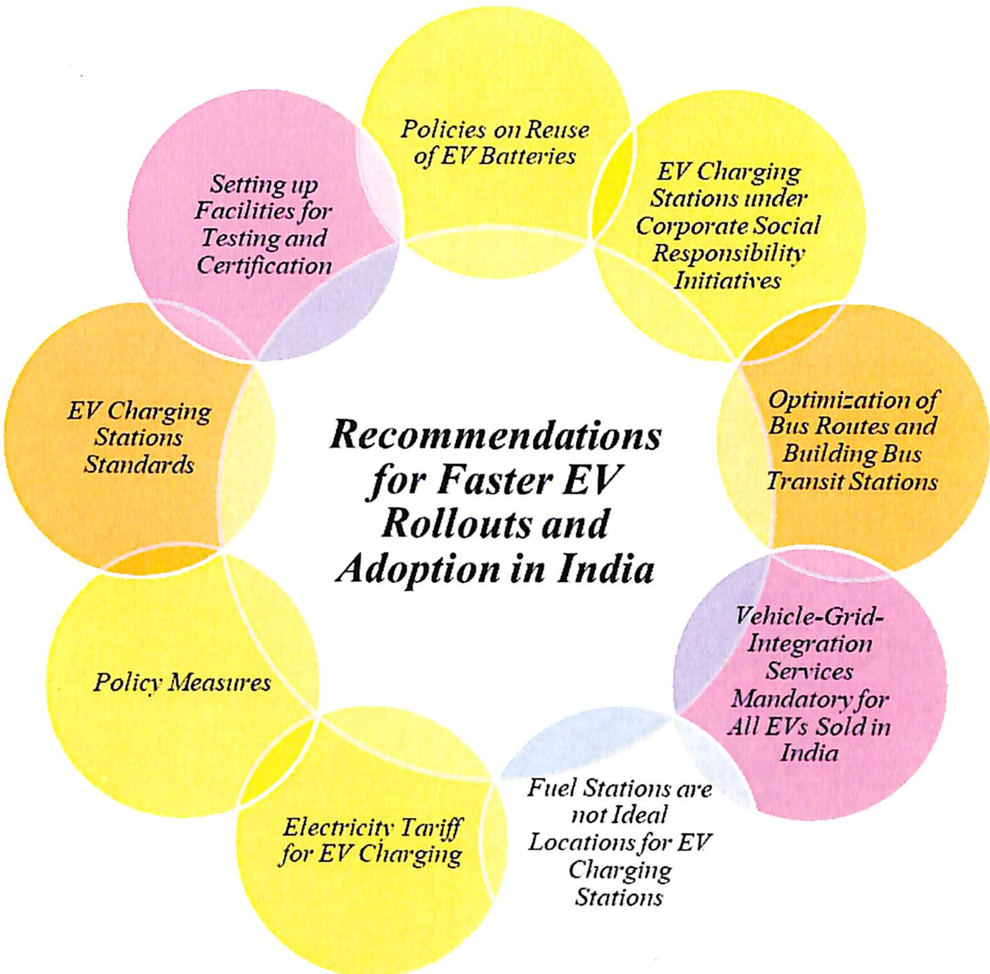

Figure 18: Recommendations for Faster EV Rollouts & Adoption in India

As per Indian Electricity Act 2003, sale of electricity requires a licence. So strictly going by the Act, sale of electricity from an EV charging station to an EV require license. Since amendments to the Act is a laborious exercise requiring approval of the parliament, MoP issued an order in April 2018 clarifying that charging of an EV battery from the electric grid is a delicensed activity. "Bundle EVSE as mandatory in new buildings through Building Codes for all categories of buildings exceeding certain built area - in this case the impact of Electric Vehicle Supply Equipment (EVSE) infrastructure cost in the per square meter cost of the buildings will be negligible". In February 2019, Town and Country Planning Organization (TCPO) under the Ministry of Housing and Urban Affairs issued amendments to the building byelaws mandating 20% parking spaces to be built with EV charging stations.

Separate tariff for EV charging in order to promote E-Mobility in the country. In 2017, Delhi Electricity Regulatory Commission (DERC) for the first time introduced a separate tariff category for EV charging which they further fine-tuned in 2018. As of July 2019, 12 states and one union territory issued separate tariffs for EV charging.

EV and EV Charging Basics

- Batteries cost 40% to 60% of the cost of an EV depending on the battery size and the driving range offered by the EV.
- Popular Lithium-ion Battery (LiB) chemistries deployed on EVs are:
    - Lithium-ion Iron Phosphate (LFP)
    - Lithium-ion Nickel Cobalt Aluminum (NCA)
    - Lithium-ion Nickel Cobalt Manganese (NMC)
    - Lithium-ion Titanium Oxide (LTO)
- Each of the above battery types have their own advantages and dis-advantages with respect to energy and power densities, number of cycles, charging speed (C-Rate), temperature tolerance etc.
- A battery that can be fully charged in 1 hour has 1C-Rate; a battery that can be charged in 30 minutes has 2C-Rate and a battery that takes 2 hours to charge has 0.5C-Rate
- While LFP, NCA and NMC can be have maximum 2C-Rate (full charge in 30 minutes), LTO can go up to 10C –Rate which means full charge in 6 minutes. Most of the popular EVs come with LFP, NCA or NMC batteries that charge at 0.33C-Rate (3 hours for full charge) or 0.5C-Rate (2 hours for full charge) or 1C-Rate (1 hour for full charge) depending on different battery chemistries. LFP can function up to 40°C temperature, NCA and NMC are best below 35°C; but LTO can operate efficiently up to 60°C. LTO has relatively higher weight per kWh compared to other battery chemistries which is a disadvantage for mobility applications. LFP, NCA and NMC batteries are available at price range between US$ 200- 250/kWh (2019 prices). LTO prices are still around US$ 800-900/kWh. Life of LFP, NCA and NMC are between 3000 and 10,000 cycles; for LTO it is 15,000 to 20,000 cycles. So, the total cost of ownership (TCO) of LTO batteries is lower than other types of batteries for most applications.

EV Charging Stations – Standards and Pubic Charging Stations: Bureau of Indian Standards (BIS) issued IS:17017 Part-I in August 2018 which is the basic standards for EV chargers. The associated standards for communication protocols and connectors are in advanced stages of finalization by the BIS technical committee ETD-51. IS:17017 recommends both CHAdeMO and CCS-2 (besides AC Type-2 chargers) as the EVSE standards for India. It also allows Bharat Charger Standards issued by Department of Heavy Industries in 2017 which are based on Chinese GB/T standards to be in use. About 7000 electric cars running in India presently are made with systems imported from China and they follow GB/T standards. All these vehicles have batteries that require almost 3 hours to fully charge. Hence high capacity chargers (50 kW) are of no use for these vehicles.

Electric bus manufacturers supply (or recommend) proprietary chargers that may be installed in the bus depots and bus terminuses. It is not recommended to charge electric buses (which have large batteries) at any public charging stations and hence inter-operability and availability of public charging stations are not a constraint for roll out of electric buses. 3-Wheelers are ideal candidates for battery swapping. 3-wheelers will be sold without batteries; and Battery Leasing Agencies (BLA) will own the batteries; and they will rent charged batteries to 3- Wheelers. BLAs will setup and operate charging stations for mass charging of 3-Wheeler batteries. These charging stations may or may not follow IS standards. 2-Wheelers may be allowed to charge from any single-phase electricity connection or public charging stations as permitted by the vehicle manufacturer. So public charging stations are required primarily for cars only; and the volume of which are not expected to be large enough to justify investment in public charging stations as envisaged/planned presently.

Fuel Stations are not Ideal Locations for EV Charging Stations: Several agencies are in discussions with oil marketing companies for setting up of EV chargers in existing fuel stations. This is not the ideal solution for a host of reasons explained here. First of all, present generation of EVs need 30 minutes to 3 hours for charging; blocking charging stations for such long durations will result in long line of vehicles on the road creating traffic jams. The typical revenue from charging an EV for over two hours is maximum INR 150 to 225. Compare this with fuelling a typical car in 3-5 minutes for revenues of INR 2000 to 3500 – that is average INR 50,000 per hour from petrol/diesel versus less than INR 100 per hour from EVs! Which fuel station owners would consider that as a viable business model? Maruti Suzuki is expected to launch an electric car in 2020 with LTO battery (Suzuki is building a LTO battery manufacturing plant in Gujarat in partnership with Toshiba and Denso) that can be fast charged. If that Suzuki EV will have a 15kWh LTO battery, it requires a 150kW charger to fast charge at 10C-Rate in 5 minutes. 150kW charger operates at 500 Volts (300 Amperes) or above which is a safety risk in fuel stations – maximum 415 Volts only allowed in fuel stations presently. All the fast chargers of 250 to 500kW capacity operates at 500 to 800 Volts. The 900kW charger that China and Japan are co-developing will need 600 Ampere at 1500 Volts to deliver 900kW capacity. Existing fuel stations are certainly not the ideal places for these range of fast chargers expected to be popular in the immediate future.

Vehicle-Grid-Integration Services Mandatory for All EVs Sold in India: Vehicle-Grid-Integration (VGI) technologies have been successfully tested in several research labs and universities and are commercially deployed in few places. But most EV manufacturers are apprehensive of the effect of specific VGI methodologies on battery life and battery warrantees. The life of a battery is based on the number of charge-discharge cycles and in certain VGI methods such as vehicle-to-grid (V2G) operations, where battery is discharged to feed electricity to the grid, it can cause issue with battery warranties and degradation in lifetime. So theoretically for V2G services, the life of the battery can reduce in terms of years of service. Many V2G trials have shown that if the DOD is kept above 50% of the battery capacity, the effect of V2G operations on battery life will be minimal.

However, other alternatives such as V1G, where battery is managed smartly to charge based on the grid conditions or real-time prices has no adverse impacts on the batteries and can immediately considered for EVs and charging infrastructure. A 2017 report by University of Warwick "On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smart-grid system" describes the "massaging effect" on the EV batteries through partial charge-discharge cycles that could extend the life of lithium- ion batteries. From the future proofing context, it is recommended that by regulation VGI services should be enabled in all EVs sold in the country. This will be a great support for the grid with increasing share of renewable energy, though location specific constraints may be considered. The EV charging stations can also offer grid balancing and ancillary services to electric utilities which can be compensated to the charging stations owners/operators. EV charging stations may opt on subscription basis to facilitate: (a) Load Balancing; (b) Ancillary Services; (c) Demand Response; and (d) Other Load Time Shifting Requirements that the utilities would prefer.

Policies on Reuse of EV Batteries: When the capacity of an EV battery drops below 70% (typically after 3-4 years of use in cars and autorickshaws), it is replaced with a new battery. The retired battery from an EV can be reused for several years for stationery applications such as storage for solar PV systems, solar PV based street lighting, UPS, energy storage for microgrids, ancillary services and other grid support applications. Third party agencies may be encouraged to setup facilities for providing grid support services to both distribution and transmission grid operators. Such third parties can underwrite the cost of used EV batteries to be given to them after retirement from EVs at mutually agreed terms. This could significantly reduce the entry cost for an EV owner and will drive faster EV adoption. Deploying millions of EV batteries retired every year for grid applications would be the most cost-effective route to build GW scale energy storage systems for grid support services in India. Appropriate norms may also be prescribed in the policy for final disposal of the batteries at end of life.

EV Charging Stations under Corporate Social Responsibility Initiatives: Large companies may be advised to set up charging stations at strategic locations on fast track under their Corporate Social Responsibility (CSR) budget so that the e-mobility plan can be kick started immediately. Visibility of EV charging stations in parking lots, malls, railway stations, office complexes, hospitals, metro stations, government offices, highways etc., gives people comfort to buy EVs.

Optimization of Bus Routes and Building Bus Transit Stations: With introduction of electric buses, route optimization may be undertaken in cities so that route length is adjusted to the battery capacity of the buses which the bus operators may choose. This can be achieved through creation of interchange points or transit stations very much like the metro rail stations where passengers change from one line to another. Such interchange bus stations can be made either on the roadside itself or underground or over ground depending on the space availability in cities. These stations should have EV charging stations, toilets, cafes, and other convenience stores as well as charging facilities for electric buses.

Setting up Facilities for Testing and Certification: New EVs, batteries and charging stations need to be tested and certified which requires creation of facilities to be created in the country on fast track.

Electricity Tariff for EV Charging: Twelve states and one union territory have issued separate tariff for EV charging. While few states have waived off capacity charges, others have imposed capacity charges from INR 40/connection/month to 190/kVA/month. The energy charges vary from INR 4/kWh to INR 7.7/kWh. Major suggestion is that there should not be any capacity (fixed monthly) charges based on connection capacity (kVA or kW) in the initial 3 to 5 years as volumes will be very low and the capacity will be barely utilized. The energy charges may be made to follow the principle of time of day charges to discourage charging during peak hours; and incentivise charging during off-peak hours.

Other Policy Measures: For busy districts in the city, a congestion fee may be levied on non-electric vehicles (could have implementation challenges) during peak hours from 2022. Electric utilities may be mandated to setup charging station network in strategic locations in their service area under capex for grid upgrades (regulated asset). City Governments/Municipalities and Highway Authorities may be mandated to allot space for charging station networks on long lease at concessional (or free) rates through transparent selection route avoiding creation of monopolies. EV manufacturers to contribute a certain percentage of the vehicle cost towards Charging Station Fund which will be utilized to build charging station network in respective cities/states. Charging station may be clubbed with Highway construction cost – again it will have negligible impact on per kilometre cost of highways. In commercial centres, tourist places, religious places etc the shop owners may be encouraged to invest in charging stations and entry of petrol and diesel vehicles may be banned. Allot land and licences to setup large charging stations at strategic locations which will also have following facilities:

- Cafe/ATMs
- Convenient Store/ Grocery/Vegetables Shops
- Health Club (Gym)
- Gaming Stations/Barbershops/Beauty Parlours/Massage Centres
- Air and Tyre changing services
- EV manufacturers consortiums may promote charging station networks and collect monthly subscription from EV owners and pay to the charging station owners and operators (Japanese model)
- Fleet operators and car rental companies may be mandated to setup EVSE networks
- Other incentives for charging stations could include:
- Tax concessions
- Free or concessional land on long term lease
- Transparent allocation of land preventing formation of monopolies

6.2 Conclusions

Transformation of an entire nation towards electric mobility is going to be a huge effort. It will be important that polices are framed in a collaborative manner with a long-term vision in mind. Implementation of policy measures will require close coordination at several levels and amongst various departments & ministries of the central / state government and other public & private stakeholders. While taking firm and ambitious steps in going towards hundred percent pure electric regime, we must not lose sight of the fact that the actual production in India, of the inputs for the EVs must be ramped up in a calibrated manner, while not allowing the infrastructure for ICE vehicles to be neglected during this long transition phase. If electrification is attempted to be done too fast, it will likely have an adverse impact on local content due to increased imports, and will result in exporting jobs. Localization has to accompany or even precede the fast ramp up. Simply reducing import duty on completely built up (CBUs) or on semi knocked down (SKDs) may impose a high economic price on the country, if the local development and full manufacturing of electric vehicles does not happen in India, in a planned and assured manner.

It will be necessary to establish a collaborative platform for policy making and a nodal agency to coordinate and monitor activities at a pan India level. This shall ensure that the current momentum does not lose steam and the efforts can be sustained, thus enabling the country to achieve its e-mobility vision collectively.

Towards the common goal of sustainable mobility and building the nation responsibly, Society of Indian Automobile Manufacturers (SIAM) will look forward to proactively contribute in various aspects of this roadmap such as standards formulation, implementing various measures to be led by industry like CSR activities, spreading the public awareness, and not the least bring the industry together for taking up challenges as and when required.

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