MSc Program
Engineering Management

ELECTRIC VEHICLES IN INDIA AND THE NATIONAL ELECTRIC MOBILITY MISSION PLAN 2020

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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31 March 2016, Vienna

TABLE OF CONTENTS

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Affidavit

I, **ANGELO DAS MERCÊS JOÃO** , hereby declare

1. that I am the sole author of the present Master's Thesis, "ELECTRIC VEHICLES IN INDIA AND THE NATIONAL ELECTRIC MOBILITY MISSION PLAN 2020 ", 72 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 01.04.2017

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Signature

ACKNOWLEDGEMENT

The completion of this undertaking could not have been possible without the support and guidance of so many people whose names may not all be enumerated. Their contributions are sincerely appreciated and gratefully acknowledged. However, I would like to express my deep appreciation and indebtedness particularly to the following:

To my Mom, Dad and Sister for their endless inspiration, undying love, and support.

To Professor Peter Kopacek, Academic program Director, MSc Program Engineering Management and my thesis supervisor Dipl.-Ing. Dr. Bernd Kopacek for their unforgettable boundless support and guidance in the writing of this thesis.

Above all, to the Great Almighty, the source of all knowledge and wisdom, for his countless love.

ABSTRACT

In the new era of energy, environment and information, Electric Vehicles have become a paradigm shift in promoting global economic development, transport, and growth. Although a lot of clean technologies and fuels have been developed over the past years, Electric vehicles have shown the most promise. Electric vehicles have the edge over conventional gasoline vehicles in terms of cleaner technology, lower environmental emissions, higher energy efficiency, and reduced oil dependency. In spite of these advantages, there are a number of barriers to the rapid widespread adoption of electric cars, including the limitations of battery technology, purchase costs, and the lack of development of infrastructure. The automobile sector in India is in the phase of rapid growth and is becoming quite a significant competitor even on a global scale. However, this growth is coupled with several challenges from energy security, environmental degrading and dependency on oil imports. In order to overcome these challenges, there is a need to undertake a sustainable solution beyond existing measures and policies to mitigate the adverse effects of the growth in mobility.

The solution is Electric Mobility! Electric vehicles though existing since the 1800s have not been significant until now. With the technological and battery advancements in the recent years, they are becoming cheaper and more attractive to consumers causing a paradigm shift in the transport market.

Electric vehicles are environment-friendly, can save billions of dollars in oil imports increasing energy security and are a sustainable solution to a rapidly growing Indian economy. Furthermore, this new technology can lead to massive economic growth by creating new industries, a lot of jobs and develop related technology. It is vital to successfully introduce Electric Vehicle technology, develop the market and achieve mass penetration of electric vehicles in order to obtain these positive effects. Setting suitable targets along with developing appropriate strategies to achieve them, intensive consumer research on needs and behavior, and development initiatives must be promoted.

Having recognized this and the with the growing demand in the transport sector, the Indian government in collaboration with all stakeholders from Industry to consumers

is taking active steps to develop the domestic EV industry and emerge as a strong significant leader in global EV markets.

The National Electric Mobility Mission Plan 2020(NEMMP 2020) launched by the Prime Minister of India in January 2013 is the heart of Indian Dream to sustainable Electric mobility. It is the result of collaborative planning for the promotion of hybrid and electric mobility in India and achieving a total of 6-7 million electric/hybrid vehicles in India by the year 2020 through a combination of policies along with a certain level of indigenisation of technology ensuring India's global leadership in the automobile market. This report draws inspiration from this mission and attempts to understand the current EV landscape, market, technology and how the NEMMP 2020 will play a significant role in India.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

BEV	Battery Electric Vehicles
CO2	Carbon dioxide
CSS	Charging Station Selection Server
EM	Electric Motorcycles
ES	Electric Scooters
EV	Electric Vehicle
ECM	Electric Cycles and Mopeds
E2W	Electric two-wheelers
E3W	Electric three-wheelers
E4W	Electric four-wheelers
EVSE	Electric Vehicle Supply Equipment
FY	Financial Year
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
GDP	Gross Domestic Product
HEV	Hybrid electric vehicles
IC	Internal Combustion
IEA	International Energy Agency
Li-ion	Lithium Ion
NAB	National Automotive Board
NBEM	National Board of Electric Mobility
NCEM	National Council for Electric Mobility
NMEM	National Mission for Electric Mobility
NATIS	National Action Plan for Climate Change
NEMMP	National Electric Mobility Mission Plan

NiCad	Nickel Cadmium
NiMH	Nickel Metal Hydride
OEM	Original Equipment Manufacturers
OPEC	Organization of the Petroleum Exporting Countries
PHEV	Plug-in Hybrid Electric Vehicles
PESTEL	Political, Economic, Social, Technological, Legal and Environmental
R&D	Research & Development
SG	Sub Groups
SAE	Society of Automotive Engineers
SIAM	Society of Indian Automobile Manufacturers
SWOT	Strengths Weaknesses Opportunities Threats
VAT	Value Added Tax
WG	Working Groups

1 INTRODUCTION

1.1 Thesis Introduction:

The automobile sector is the backbone of the economy, as its contributes to the Gross domestic product, creates employment and meets the logistical and transportation needs of a country. As of today, India is the 6th largest global manufacturer in the automotive industry contributing a total of 7.1 percent to the national GDP. At the rate at which the automotive industry is growing and with the increasing demand, India is expected to be the 3rd largest market in the world by 2020. However, this growth poses numerous challenges like Energy security, Increasing costs of oil imports and environmental impacts of mobility. With the growing middle class and increase in buying power of the general population the vehicular populating will rise fast along the demand for fossil fuel and the need to mitigate the effects on the environment. As per the International Energy Agency(IEA), the transport sector contributes to 20% of the global greenhouse gasses also making it the 2nd largest contributor to C02 emissions worldwide. India ranks 4th in global greenhouse gas emissions with the transport sector contributing to 13% of its C02 emissions which are projected to increase with an increase in vehicular sales. India's dependency on foreign Oil imports to meet its energy need and growing fuel prices are recognized as a significant threat to its fuel security.

Having identified these various challenges, the government of India through its Department of Heavy Industry imitated the NMEM to fast-track the manufacture and introduction of a full range of electric vehicles in India. Due to its importance, the electromotive initiate was taken on a national mission board setting up the National Council for Electric Mobility(NCEM) and National Board of Electric Mobility(NBEM) creating a high-level apex structure. Based on the results of on-road realities, through in-depth studies, survey and consultations involving all stakeholders from the government, industry, consumers and research associations the NBEM set up the general principles, guidelines, and framework to establish the National Electric Mobility Mission Plan (NEMMP) 2020.

The NEMMP 2020 aims to achieve a paradigm shift in the automobile industry for the strong and sustainable growth of the automobile industry by laying the vision and providing the roadmap for achieving a significant amount of market penetration and manufacture of environmentally friendly electric vehicle technologies in India by 2020 through the involvement of all stakeholders. Through various schemes, interventions, policies, and projects the NEMMP mission focuses on getting 6-7 million of Electric vehicle sales and 2.2-2.5 million of tons in fuel saving.

1.2 Summary:

The thesis “Electric Vehicles in India and the National Electric Mobility Plan 2020 “is a comprehensive research study and gives a global outlook into the Electric Vehicle industry, the scenario in India and Indian road map to becoming a significant player in the global EV market through the NEMMP 2020 mission.

The thesis is composed of five chapters, each of them dealing with different aspects of Electric vehicles from technology to policies.

Chapter One is introductory and consists of 5 parts. Part One is the general introduction about Electric Vehicles and the National Electric Mobility Mission Plan 2020 which is the guiding policy for electric mobility by the Indian government. Part Two is the current chapter summarizes the entire content and gives a general idea of the thesis. Part Three highlights the objectives of the thesis. The objectives are subdivided into primary and secondary objectives based on their importance. Part Four shows the guiding methodology in used in the writing of the thesis by describing them in brief steps and the research methodology with the help of a flowchart. Chapter One ends with part Five which highlights the limitations of the thesis.

Chapter 2 gives an overview of the technology and EV industry on the whole. It consists of seven parts. Part One is a walk through the History of Electric Vehicles highlighting key moments from its birth to the present. Part Two classifies Electric vehicles into the different market segments and briefly analyzes each market segment. Battery technology is an integral part of electric vehicles and is explained in some detail in Part Three of this chapter. Part Four describes and helps understand the basic infrastructure required for Electric vehicles to function and strive efficiently. For a technology to gain attention and be adopted it should have a definite edge over existing technology already in use. Part Five Shows the advantages in adopting EVs. Even though this technology has numerous advantages it has not yet become the dominant transport technology due to a number of barriers to wide-scale adoption, which are explained in Part Six of this chapter. This chapter ends with Part Seven explaining the to the working principles of Electric Vehicles

Chapter 3 is more relevant to the Indian scenario. It is divided into five parts. It tries to show and explain how the technological shift to electrical vehicle technology is vital to the country by making use of research and some analytical models. Part One tries to show the situation of the Indian Automobile market, its classification, and magnitude. Part Two shows the current status of Electric Vehicles in India and highlights some of the key Electric Vehicles sold in the Indian Market. Part Four runs SWOT, PESTEL and Porters Five Forces model and explains the results derived from this analysis on the Indian EV market. In Part Six, India's key policies in its goal to achieve on-road electromobility are summarized. This chapter concludes with Part Seven showing the Taxation system that is relevant to EVs.

Chapter 4 concentrates in explaining all aspects of the NEMMP 2020 mission and is the heart of this thesis. It has six subsections. Part One is the Vision statement adopted for the NEMMP 2020. Part Two explains in detail the methodology used for its creation. Part Three,Four Five and Six show the roadmap, strategies that will be used for the successful implantation of EVs, implementation mechanism and potential benefits of this policy respectively.

In Chapter 5 after detailed evaluation and understanding of the NEMMP 2020, the author gives suggestions and recommendations which when adopted the author believes will lead to a stronger growth, technological development and widespread adoption of Electric vehicles in India.

The Thesis ends with Chapter Six after hoping to have met all the thesis objectives and with the final conclusion from the author.

1.3 Objectives of Thesis:

The primary objectives of this thesis are:

1- To understand the Indian Automobile Sector

- Current Automobile market
- Current EV market

2- To analyze the Indian EV market though Analytical models like SWOT. PESTEL and Porters analysis.

3- To understand and summarize the NEMMP 2020

- The vision of the Mission.
- Stakeholders involved in its creation and execution.
- Target and goals.
- Methodology of development of mission.
- Strategies of execution.
- Implementation.
- Benefits provided through the mission.

Secondary objectives include:

1- To provide an outlook on EV technology

- History
- Segmentation in Electric Vehicles
- Battery technology
- Infrastructure needed for an EV ecosystem
- Advantages of adopting technology
- Working principle of an electric vehicle

1.4 Methodology

The step by step methodology used in the writing of this thesis is explained in the following steps:

1. Informative session:

A kick-off orientation was conducted highlighting the important aspects of the Master thesis and guidelines to write it.

2. Topic identification and selection:

The subject of choice and the topic of interest was selected. A PowerPoint presentation was done to the Director of the Engineering Management program for approval of the topic.

3. Assignment of Thesis Supervisor

The best-qualified Thesis supervisor was suggested and assigned by the director to guide in the writing of the thesis.

4. Supervision Agreement

A supervision agreement with the Thesis topic and selected supervisor was submitted to the Program Management

5. Research proposal:

A research proposal was drafted and submitted to the thesis supervisor on the signing of the supervision agreement.

6. Research and writing:

Quantitative and qualitative research was done on the Thesis topic and written down in a structured format agreed on, by reading books, scientific papers, and resources on the internet

7. Presentation of Draft and Final thesis:

Drafts of the thesis were periodically submitted for correction before the submission of the final Thesis for grading.

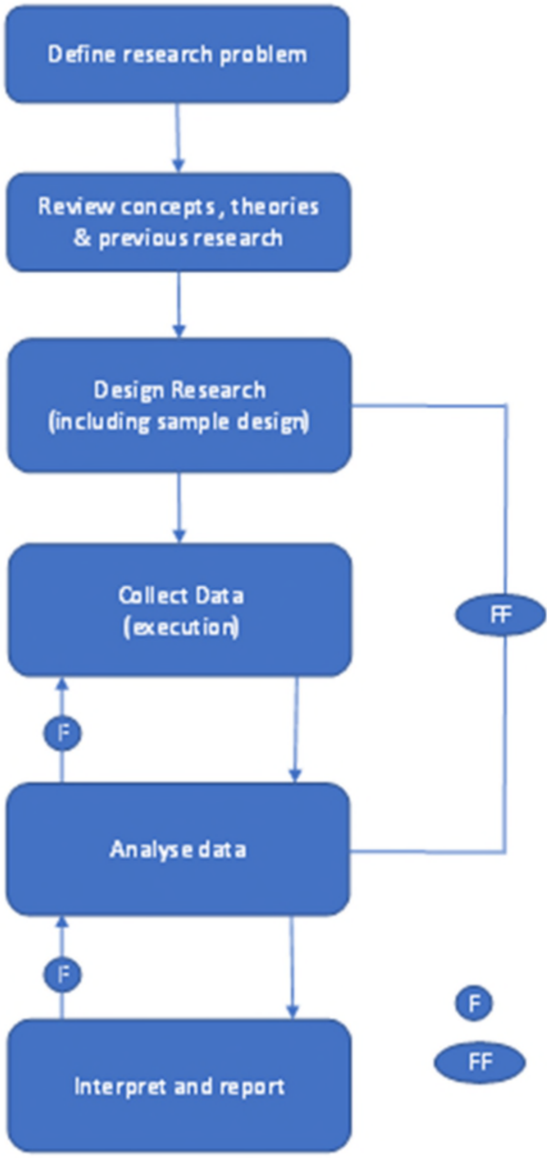


Figure 1: Research Flowchart

(Source: : Self-generated)

1.5 Limitations of Thesis:

It should be noted that this thesis has several limitations as mentioned below:

- Electromobility being a very vast topic, the electric vehicles are focus in this thesis are restricted to Road transport in this thesis

- All information used in the research is from Technical papers, books and other sources found on the internet.

- Only Battery Electric Vehicles(BEV) have been taken into consideration in the technology section of this thesis even though Electric vehicle technology includes Hybrid electric vehicles (HEV) and other types

- This thesis mainly focuses on the NEMMP 2020 as it is the official national policy guiding all national and other state-wide EV programs in India

- NEMMP 2020 (2013) is the official document guiding all Indian EV policies. Chapter Four is an interpretation of this document.

- Since EV technology in India is still in its nascent stages, information is limited and most of it based on projections in comparison to actual data in countries like the United States showing the need to conduct further research studies over time

2 ELECTRIC VEHICLES

2.1 History:

Mobility has evolved significantly over time. Earlier mobility was mainly concentrated to carriages drawn by domesticated animals such as horses. In 1801 Richard Trevithick built the steam-powered carriage starting an era of Horseless transportation. In 1828, after almost 30 years of the noisy and dirty steam engine a Hungarian, Anyos Jedlik, invented a small-scale model car powered by an electric motor that he designed. (C.C Chan, 2013) Many inventors started making significant progress soon after. In 1835, Professor Stratingh of Groningen and his assistant Christopher Becker designed and built a small-scale electric car: More practical and successful electric road vehicles were invented by both Thomas Davenport and Scotsmen Robert Davidson around 1842. Both inventors were the first to use the newly invented non-rechargeable electric cells or batteries. A significant boost to electrical cars was provided by efficient dc electrical motors, which were primarily introduced by Zenobe Gramm in France in 1873 and Plante's rechargeable lead- acid battery, which was perfected into a successful product in the same country in 1881 by Camille Alphonse Faure. (Massimo Guarnieri, 2011)

In the late 1800s, France and England were the first nations to support the widespread development of Electric Vehicles. It was not until 1895 after A.L. Ryker built an electric tricycle and William Morrison built a six-passenger wagon, that America paid attention to the electric vehicle. In 1902 Wood created the Electric Phaeton, which was more than an electrified horseless carriage and Surrey. "The Phaeton had a range of 18 miles, a top speed of 14 mph and cost $2,000". (Rony Argueta, 2010) In France between 1899 and 1906, Bouquet, Garcin, and Schivre manufactured various types of commercial EVs with in-house designed and manufactured batteries. The 1900 BGS EV held the record for the world's longest range - 290 km per charge. (C.C Chan, 2013) However, the first commercially successful electric car, able to carry six passengers at 16 km/h, was made in 1893 by Paul Pouchain.

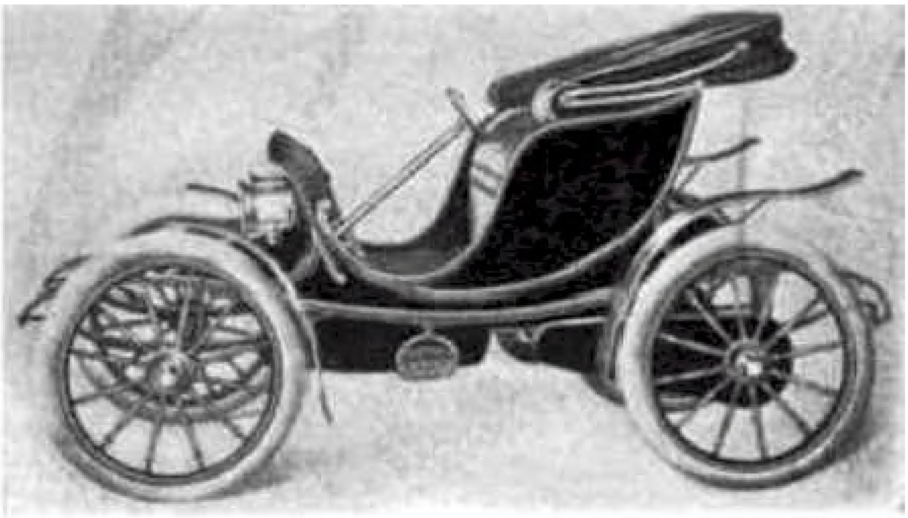


Figure 2: 1907 Bailey Electric Victoria Phaeton Automobile
(Source: The Rise & Fall of Electric Vehicles In 1828–1930:
Lessons Learned)

By 1912, electric infrastructure was well established creating a surge in the popularity of electric cars. They did not have the vibration, smell, and noise associated with gasoline cars. The gear shifting in gasoline cars turned up to be a problem to many while driving. While steam, driven cars had no gear shifting they suffered from long start-up times in winter. Moreover, the Electric vehicle was preferred by many because it did not require a manual hand crank to start the car.

But around the 1920s the popularity declined. The invention of the electric starter by Charles Kettering in 1912 (Boyd et al., 1957), need for long range vehicle due to improved road system between cities, the affordable availability of gasoline coupled with the mass production of gasoline vehicles by manufacturers Henry Ford like where the main contributors for the downfall.

In 1970, the Clean Air Act was established, which required states to take control of their air quality and meet certain standards by deadlines. The OPEC oil embargo of 1973, which skyrocketed gasoline prices, also sparked interest in alternatives to fuelled vehicles. (Cadie Thompson, 2015)

Ever since the early 1990 s, as concerns about global climate change and emissions started growing, alternate vehicles such as EVs regained the attention of manufacturers and policy makers. The Californian zero-emission vehicle mandates strict emission standards to deal with health problems encouraged large car manufacturers to show increasing commitment to the battery electric vehicle technology. Similarly, some demonstration projects in Europe were showing success. (P. R. Shukla et al., 2014) Since 2005, there has been a new impetus for electric mobility following concerns over climate change and energy security. Thus, the global stock of electric cars has crossed 500,000 in 2015 (IEA, 2016). There have been substantial improvements in battery capacity and technology, and significant decline in costs of EVs and related components. This renewed interest in EVs has also been referred to as the "third age" of EVs by the International Energy Agency (IEA, 2013).

2.2 Market Segments:

Electric road vehicles today come in a wide range. They diversify from electric two-wheelers(E2W), three-wheelers(E3W) and four-wheelers(E4W). Electric two-wheelers are used to refer to e-bikes and e-scooters. E-Rickshaws also known as Tuk-tuk's constitute Electric three-wheelers and the remaining E-cars and E-buses constitute electric four vehicles. There are also hybrid-electric vehicles like the Toyota Prius which are a Plug-in hybrid electric vehicles(PHEV) having both, an electric motor and gasoline engine. They differ from the normal Battery electric vehicles(BEV) which run purely on the electric propulsion of their electric motors using batteries as a storage medium.

Electric vehicles can be further classified based on their characteristics such as Price, Range, Speed and charging time. The most important from a customer point of view being Charging time and range. E2W's, E3W's and some E4W's having a small driving range sometimes as little as 15 Km/ charge are mainly favored means for "inter-city transport" and those with longer ranges (100-400 km/charge) mostly E4W's are used for intra-city transport. The latter though being used for both.

Data from the top 10 E4W vehicles has been collected to generate the chart in Figure 3. It can be noted that there is always a positive correlation between price, range and top speed. This is due to the utilization of better technology with the increase in prices.

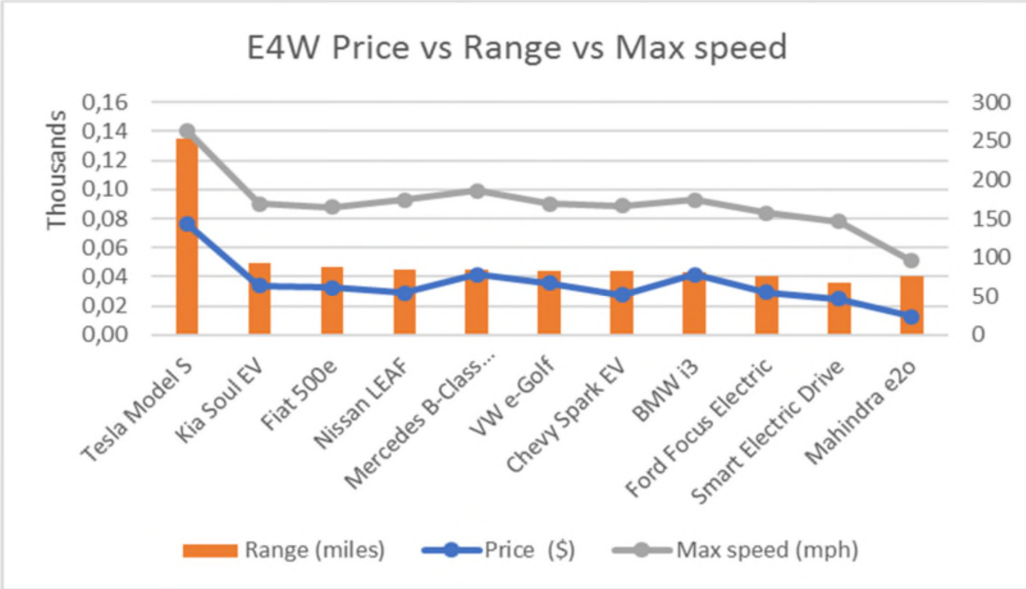


Figure 3: Electric 4-Wheeler Price vs Range vs Max Speed

(Source: Self-generated)

Charging mainly depends on the input power characteristics such as input voltage and current, battery type, and battery capacity. Based on the charging time Electric vehicles can be classified into Level 1 to Level 4. All EV's have Level 1 charging capability using 110V charging at 10–15 amps. Level 2 charging depending on the car and its capacity uses 220V or 240V power operating between 30–50 amps ranging from 3.3–10 kW. Level 3 also known as "Fast charging" is intended to quickly deliver at higher amperages and from 10–50 kW. Level 4 aka "Supercharging" is a proprietary high-speed charging option developed by Tesla, capable of pumping up to 400 of driving capacity miles per hour of driving capabilities. (Zach ,2015)

Model	Charging
Tesla Model S	Level4
Kia Soul EV	Level 3
Fiat 500e	Level 2
Nissan LEAF	Level 3
Mercedes B-Class Electric	Level 2
VW e-Golf	Level 3
Chevy Spark EV	Level 3
BMW i3	Level 3
Ford Focus Electric	Level 3
Smart Electric Drive	Level 2
Mahindra e2o	Level 2

Table 1: Charging Classification of Cars

(Source: Self-generated)

E2W's basically can be subdivided into Electric cycles and Mopeds (ECM), Electric Scooters (ES) and Electric Motorcycles(EM).Being short distance vehicles and at lower prices than E4W's they are starting to gain significance globally especially in Asian countries such as India and China.

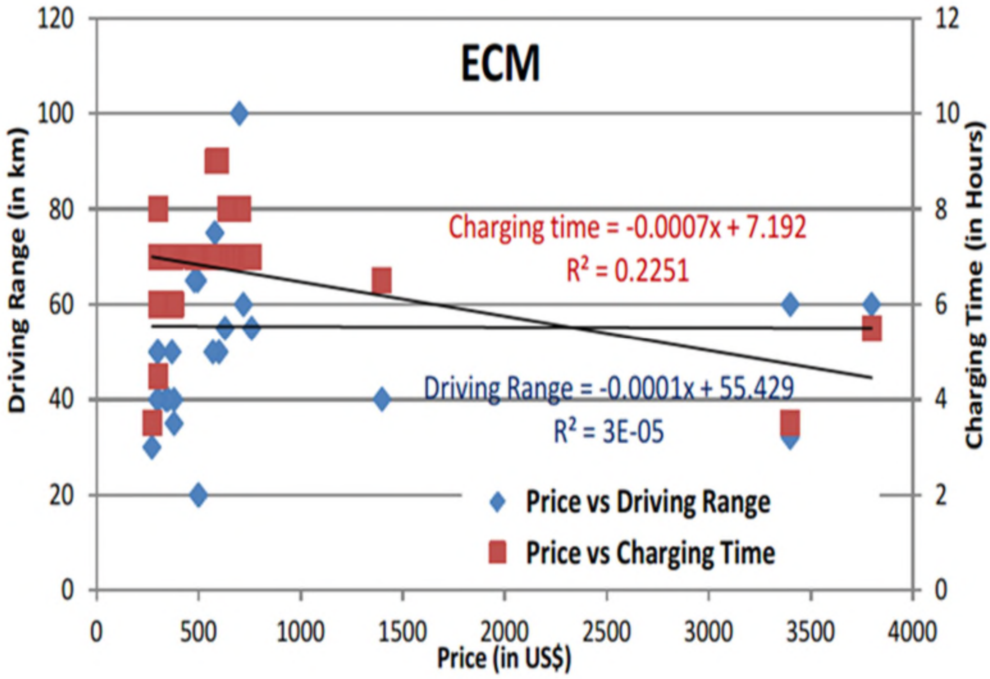


Figure 4: ECM Driving Range vs Price vs Charging Time

(Source: Promoting Low Carbon Transport in India)

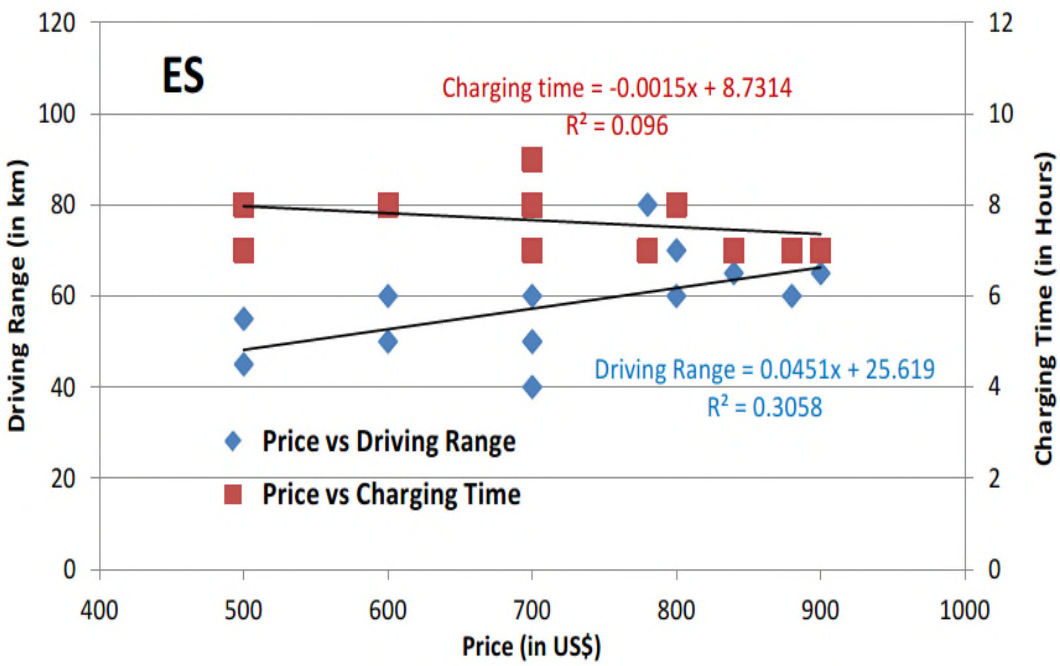


Figure 5: ES Driving Range vs Price vs Charging Time

(Source: Promoting Low Carbon Transport in India)

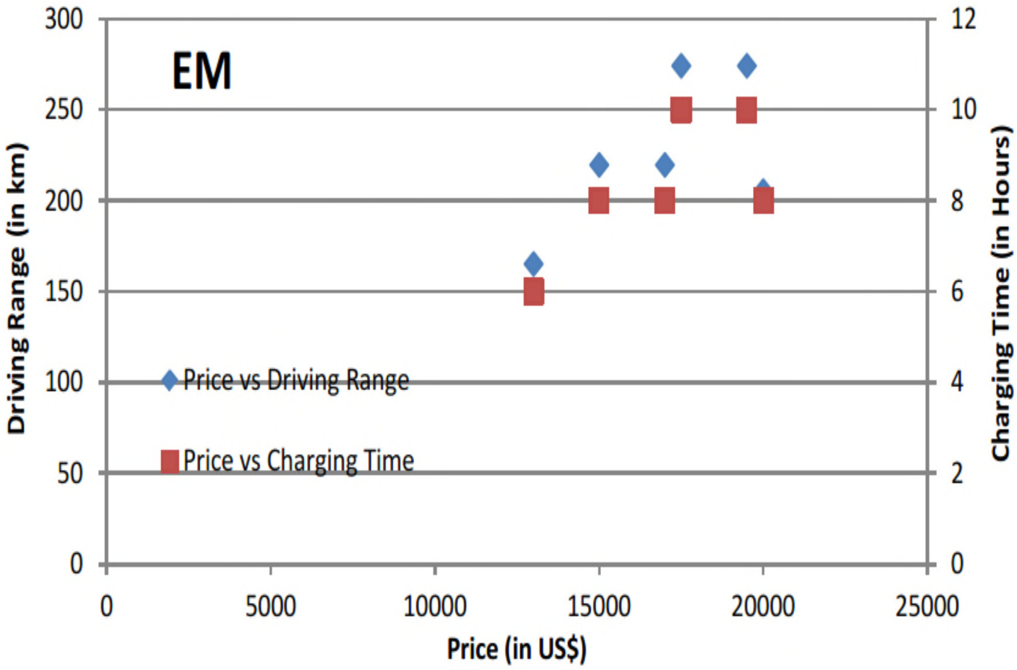


Figure 6: EM Driving Range vs Price vs Charging Time

(Source: Promoting Low Carbon Transport in India)

From the above graphs, it is clear that Electric motorcycles are preferred long distance options due to their higher driving range which increases with price along with the charging time . In the ECM and ES, the range is more or less the same and their charging times inconsistent.

With the advancement in technology, the range and charging times are resulting in interest from the general masses. Significant investments in infrastructure such as charging stations and production in many countries have led to a reduction of prices of EVs making them affordable and driving up EV sales hinting a bright future.

2.3 Battery Technology

A battery is a device that converts chemical energy into electrical energy powering the electric motor creating propulsion in an Electric Vehicle. It is the core component of an electric vehicle constituting more than half of the EV's weight and value.

The value chain of the battery consists of 7 steps from component production to recycling & reuse as can be seen in Figure 7.

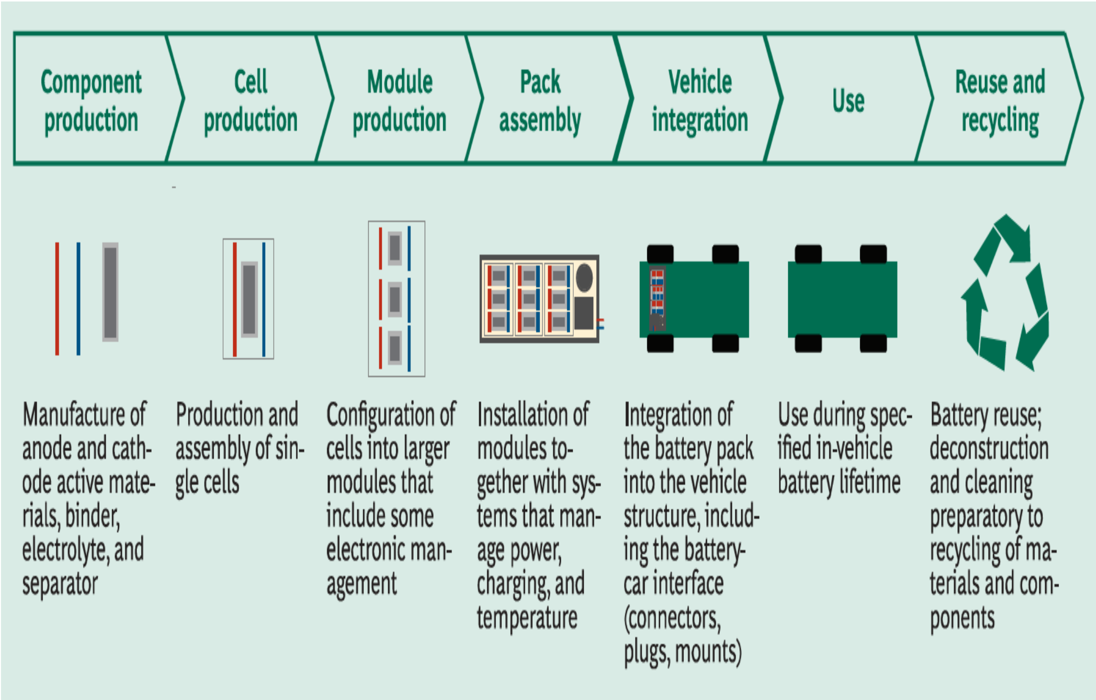


Figure 7: Battery Value Chain

(Source: http://www.bcg.at/documents/file36615.pdf)

EV batteries are quite different from batteries used in other electronic devices as they need to have high energy capacity and handle high power while having strict space and weight constraints, having to be at an affordable price.

EVs today mainly use lithium ion (Li-ion), Nickel metal hydride (NiMH), Lead Acid, and Nickel Cadmium (NiCad) batteries. Nickel metal hydride (NiMH) batteries are commonly used in HEVs due to their mature technology and due to their higher specific energy and energy density. For a given size Lithium batteries have the greatest future potential for PHEV's , BEV's and can significantly reduce costs.

Energy storage strategy	Specific energy [MJ/kg]	Energy density [MJ/L]	Storage mass[1] [kg]	Storage volume[1] [L]
Gasoline and tank	30	30	16	16
Ethanol and tank	19	20	25	24
CNG and tank[2]	11	11	44	44
Hydrogen storage strategies	2.0-6.0	2.0-3.5	40-120	70-120
Advanced battery module (hypothetical)	0.5-1.0	1.0-2.0	150-300	75-150
$LiCoO_2$ cathode Li-ion battery module	0.5	1.0	300	150
NiMH battery module	0.2	0.5	750	300
Pb-Acid battery module	0.1	0.3	1500	500

Table 2: Specific energy and energy density of various portable energy storage strategies

(Source: https://gcep.stanford.edu/pdfs/assessments/ev_battery_assessment.pdf)

The energy density of batteries is expected to double up to 300 Wh/kg by the year 2030. Lithium ion batteries have low cycle time and losses but are sensitive to overcharging. Other battery types like NiMH have low energy density so are of not much scope. Lithium based batteries such as Lithium-Air batteries are projected to develop densities up to 11680 Wh / kg (Paul et al. 2016:3)

With continued advancements in battery technology battery costs are bound to reduce in the future thereby reducing the overall EV costs and increasing demand for ´this technology.

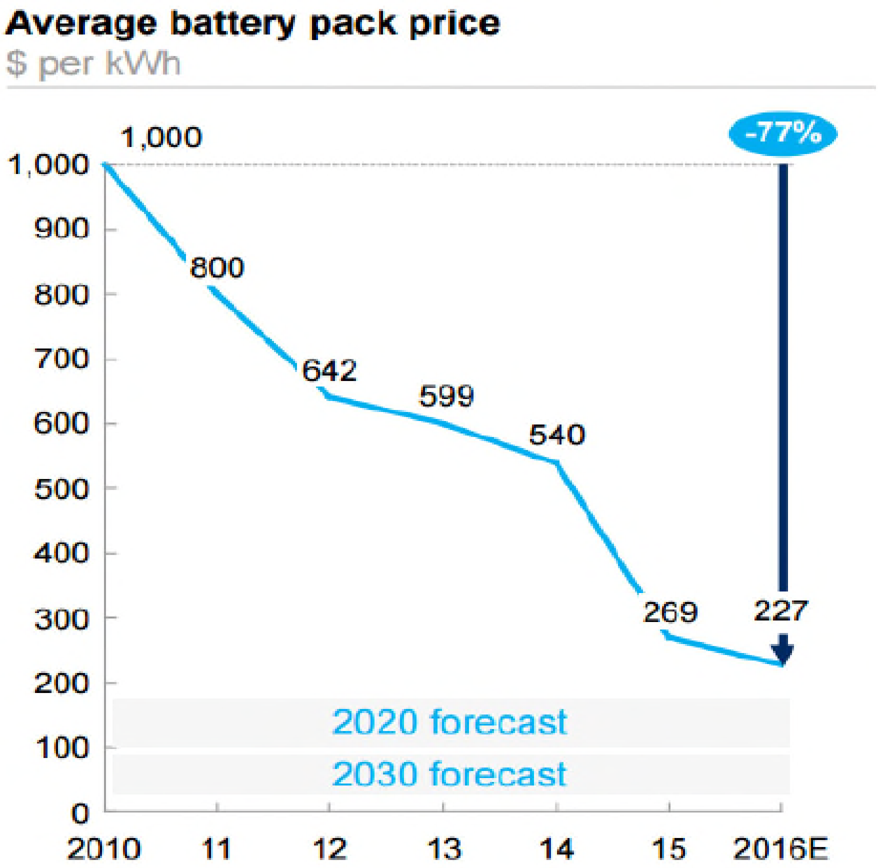


Figure 8: Battery pack Price vs Year

(Source: https://electrek.co/2017/01/30/electric-vehicle-battery-cost-dropped-80-6-years-227kwh-tesla-190kwh/)

Tesla is a trend leader. McKinsey has projected that battery pack prices will fall below $190/kWh by the end of the decade. According to leading Electric car manufacturer Tesla ,it is already at this target since early 2016(Fred Lambert,2017).

With the world and the focus of EV's being to develop green technology, the Recycling and reuse is an essential part of the value cycle of the batteries as indicated previously. Unsafe disposal can have adverse climatic and environmental impacts. Strict regulations are in place to enforce this, thereby encouraging manufacturers to develop not only efficient but also eco-friendly technology.

2.4 INFRASTRUCTURE:

For Electrical Vehicles to gain dominance in the market, there is dire need to develop the environment to support their existence and use with adequate charging infrastructure. Charging infrastructure may include a number of aspects from energy storage, charging equipment, Electric vehicle supply equipment(EVSE), smart grids, communication and information equipment.

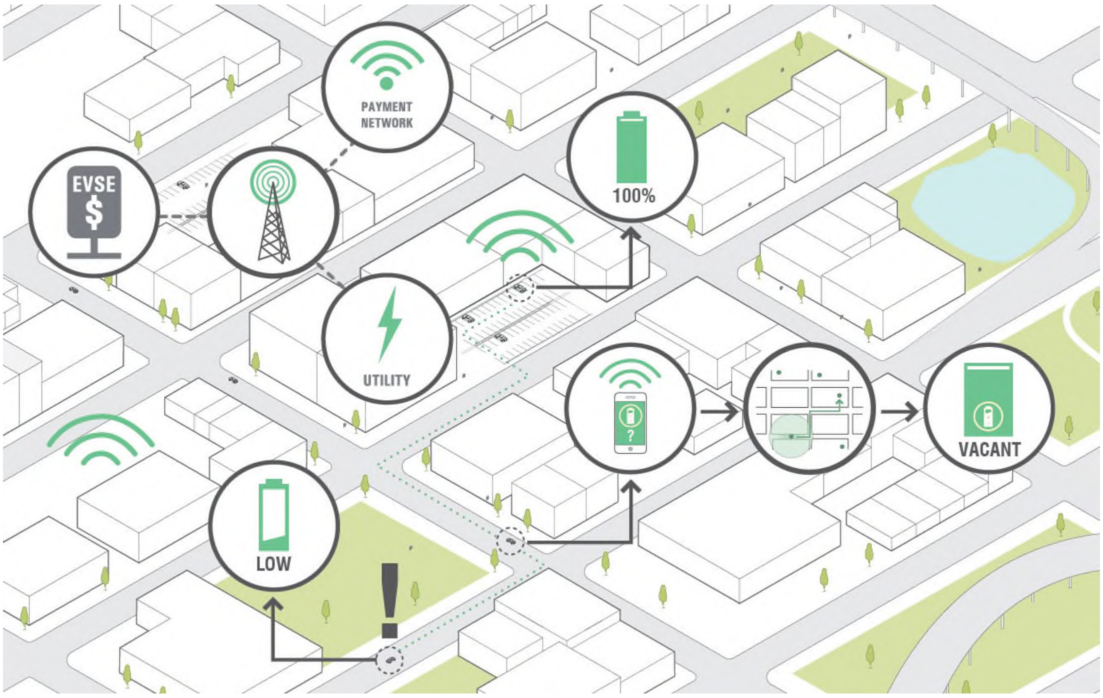


Figure 9: EV Infrastructure

(Source: www.wxystudio.com/projects/planning/nyserda_electric_vehicles_supply_equipment_evse)

The charging infrastructure makes sure that the energy is transferred from the grid to the vehicle. Energy is stored on board the vehicles through their batteries is the enabler for electrified transportation. The size energy storage may be dependent on its efficiency and availability of charging points. While smaller batteries may reduce the vehicle costs, the use of large batteries may also have additional value like providing grid facilities to and from the vehicle. The vehicle needs to be connected to the grid physically through connectors. Due to the high variant of vehicles, there may be a need to standardize the cables and connectors. In the US the SAE is trying to standardize a 5 pin configuration J1772 connector for Level1 and Level 2 charging.(Todd Marcuchhi, 2013). The EVSE (electric vehicle supply equipment) establishes protocols to create the Chargers to enhance safety by enabling two-way communication between the electric vehicle and the charging station. (Jonas Dalidd, 2010).

Figure 10: Standard J1772 plug and port

(Source: http://www.edn.com/electronics-blogs/automotive-currents/4421241/How-the-J1772-charging-standard-for-plug-in-vehicles-works)

Energy management is paramount to ensure efficiency and reduce costs. Smart grids enable this by allowing 2-way dialogue where information and electricity are exchanged between the utility and the customers making it more efficient, secure and green. Smart meters and smart chargers will help to prevent overloading the grid and enable customers to program their cars to delay charging until the midnight or when demand is low. (Kevin Bullis ,2010) This helps reducing costs as the rates are lower at off-peak hours.

For most EV consumers, the primary charging location is at home. Charging outside the home, managing multi-party use of infrastructure providing greatest cost-benefit to the owner and operator is a challenge. Developing charging centers in parking lots and office areas is vital and involves a lot of planning. Algorithms like Charging Station Selection Server (CSS) help in planning when to charge and where by checking the instantaneous location of the vehicle and range of the nearest charging spot taking into account charge remaining and approximate time. In the case of traffic also providing alternate routes and options.(Parveen and Kalyan, 2013)

China is taking significant leaps in developing its EV infrastructure. To make Beijing more EV-friendly, between 2016 and 2020 the city plans to install 435,000 charging stations. EV brands like Tesla offer free unlimited fast recharges at the company's 11 Beijing stations. (Zhang Chun,2016). A similar drive is seen the US and Europe as these countries push real hard to promote green transport.

2.5 Advantages of EVs:

- Energy security:

  Electric vehicles help countries develop energy security on a national level. Local and renewable energy sources can be used as a source of powers thereby reducing the dependence on foreign oil. Local generation of electricity enhanced by the use of electric vehicles also generates a lot of employment opportunities.

- Environment-friendly:

  Electric vehicles run on electrically powered eco-friendly engines and don't emit smoke or other toxic emissions. EVs have zero exhaust emissions. The use of renewable energy sources reduces greenhouse emissions even further. Most companies are also focusing on eco-friendly production and use of eco-friendly materials, thereby promoting a green and healthy environment.

- Cheaper maintenance:

  The number of moving parts in electric vehicles are drastically lower than conventional petrol/diesel vehicles. Many of the expensive parts like IC motor, exhaust systems, radiators, etc. are absent in EVs. Hence reducing the servicing frequency and costs by a considerable margin in comparison to gasoline vehicles.

- Safety:

  Electric vehicles have the same safety standards as typical gasoline cars but since they have fewer moving parts the tendency of component failure leading to breakdown is lesser. The risk of major fires or explosions in case of collisions is much lower too due to the absence of flammable substances like gasoline which run conventional IC engines.

- Lower running cost:

  Electric vehicles have much lower running costs compared to gasoline vehicles. The per kilometer cost of electricity for running an EV is almost one-third when compared to that of a similar variant of petrol powered vehicle.

- Cost effectiveness:

  EVs have become more cost effective due to the reduction in vehicle cost by tremendous technological advancements, lower maintenance costs, incentives by national governments and mass production of batteries.

- Noise Pollution reduction:

  Electric cars curb noise pollution as they are much quieter. Even at high speeds, the sound of the electric engine is non-existent when compared to conventional gasoline vehicles.

2.6 Barriers to Widespread Adoption

The widespread adoption of electric vehicles is hindered due to a number of factors which are summarized below:

- Lack of customer awareness:

  Most prospects for electric vehicles lack the familiarity with the vehicles, their operation, and maintenance. This lack of customer awareness is a substantial barrier for the widespread deployments of EVs.

- High Price Tag:

  Most Electric vehicles are high priced compared to their comparable conventional gasoline based vehicles. The high price coupled with the lack of customer awareness regarding future gains is a major hindrance.

- Short Driving Range:

  Gasoline vehicles have much higher driving range compared to their comparable EV models. Though most customers commute less than 40 miles per day which can be easily accommodated by almost all EVs, this serves as a technological and psychological barrier.

- Limited Variants:

  The number of EV models in the market are limited and may not meet all the needs of the customer.

- Undeveloped Charging Infrastructure:

  Charging infrastructure is not yet well established and matured in most countries. The cost of setting up residential charging infrastructure in old houses is high and not easy. Moreover, workplace and public charging infrastructure is limited and just in nascent stages in most places.

- Grid problems:

  The electric grid infrastructure is many places needs to be developed to handle the load of mass adoption of EVs. Though countries like the United States and some European countries have a well-developed grid, many Asian and other nations need to invest a lot in the development.

- Clean energy:

  The high cost or the lack of access to clean electricity could be a barrier to countries seeking to mitigate their environmental impacts

2.7 Working Components:

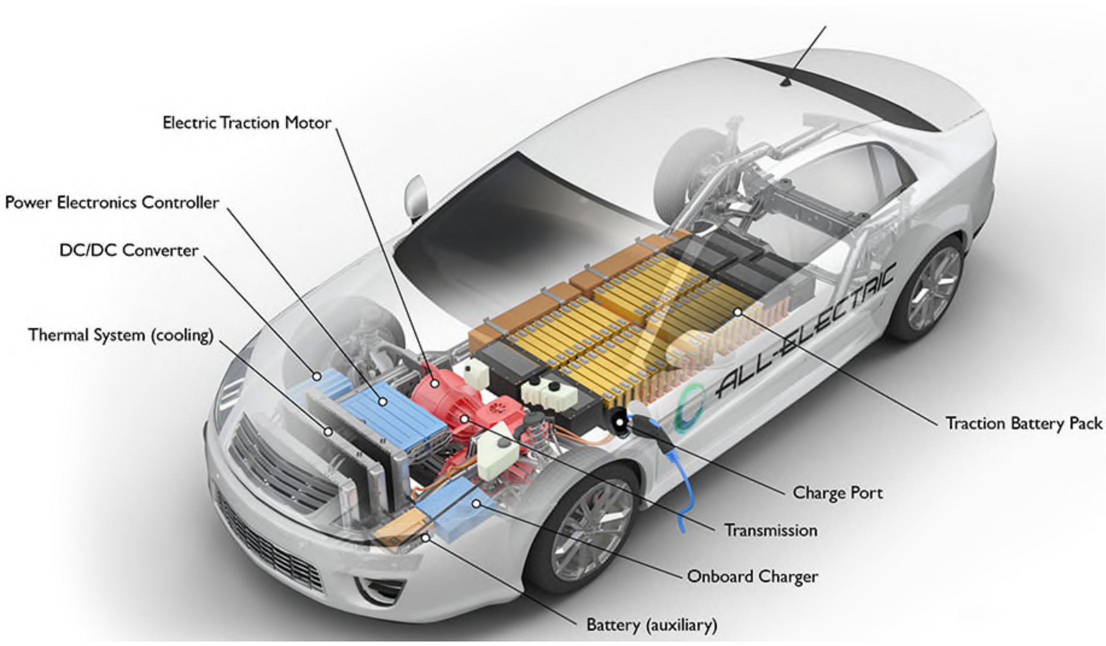


Figure 11: Components of an All-electric vehicle

(Source: http://www.afdc.energy.gov/vehicles/how-do-all-electric-cars-work)

The main components of an electric vehicle are the Battery, Electric Motor, and Controller.

For better understanding, the key components of an Electric car shown in Figure 11 are summarized below.

- Auxiliary Battery:

  In an electric vehicle, this battery provides the initial electricity to start the electric car and power vehicle accessories before the traction battery is engaged.

- Traction Battery:

  This battery stores the electricity which is fed continuously to the Electric motor (traction motor) and propels the vehicle.

- Electric traction motor:

  This motor uses the power from the traction batteries to drive the wheels of the vehicle or propel the vehicle. Sometimes both drive and regeneration functions are performed by motor generators in some electric vehicles.

- Controller:

  The speed of the electric traction motor and the torque produced by it is managed by the controller unit by controlling the flow of electricity from the traction batteries to the electric motor

- Transmission:

  The transmission system transfers the Mechanical energy generated in the traction motor to the wheels of the vehicle.

- DC-DC converter:

  The DC-DC converter converts the high voltage DC power from the traction batteries to lower voltage power needed to recharge the auxiliary start-up battery and run various vehicle accessories.

- Thermal Cooling System:

  The function of this system is to maintain and make sure that the engine, electric motor, and other power electronic components run in the proper range of operating temperatures.

- Charge Port:

  This port facilitates the vehicle to be connected to an external power supply in order to charge the traction batteries.

- Onboard charger:

  This charger converts the external AC power supplied to the vehicle through its charging port into DC power required to charge the traction batteries. Battery characteristics like current, voltage, etc. are also regulated by the onboard charger.

3 ELECTRIC VEHICLES IN INDIA

3.1 Indian Transport Market:

India is the second largest economy and one of the fastest developing countries in the word with a population of more than 1.3 billion. This makes India a vast and lucrative automobile market. The industry accounts for 7.1 percent of the country's Gross Domestic Product (GDP). Presently, India ranks 2nd in the two-wheeler, 4^{th}in the commercial vehicle and the 11th largest market in the passenger car segment worldwide.

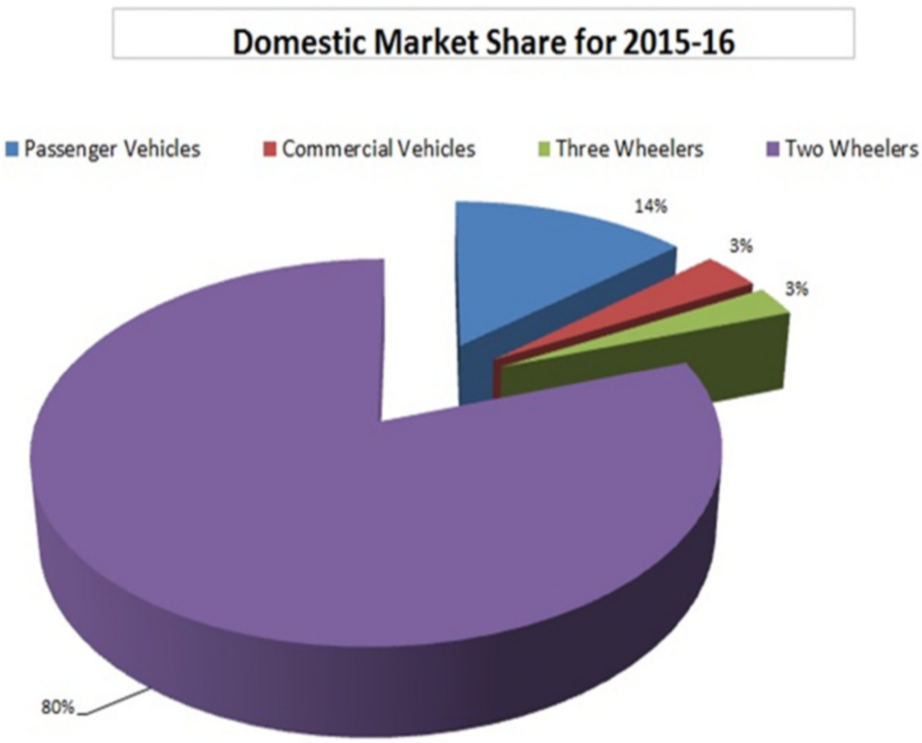


Figure 12: Indian Domestic Automobile Market Share 2015-16

(Source: http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=12)

As of the year 2016, as per the statistics of the Society of Indian Automobile Manufacturers, the two Wheelers segment is the largest having an 80% of the market share mainly due to the growing middle class and young population. Passenger

Vehicles comprise 14 percent market share. The remaining three-wheelers and commercial vehicles each taking 3% market share respectively.

The industry produced a total of 23,960,940 vehicles in April-March 2016 registering a marginal growth of 2.58 percent over the same period of 2015. (SIAM,2016)

Automobile Domestic Sales Trends						
Category	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Passenger Vehicles	25,01,542	26,29,839	26,65,015	25,03,509	26,01,236	27,89,678
Commercial Vehicles	6,84,905	8,09,499	7,93,211	6,32,851	6,14,948	6,85,704
Three Wheelers	5,26,024	5,13,281	5,38,290	4,80,085	5,32,626	5,38,092
Two Wheelers	1,17,68,910	1,34,09,150	1,37,97,185	1,48,06,778	1,59,75,561	1,64,55,911
Grand Total	**1,54,81,381**	**1,73,61,769**	**1,77,93,701**	**1,84,23,223**	**1,97,24,371**	**2,04,69,385**

Table 3: Domestic Automobile Sales Trends

(Source: http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=14)

This vehicular growth may have boosted the Indian economy but is the cause of bad air quality which has been lowered to troublesome qualities especially in the cities. Since almost all vehicles are gasoline based, they contribute to global warming, accounting for a significant and growing share of greenhouse gas emissions worldwide.

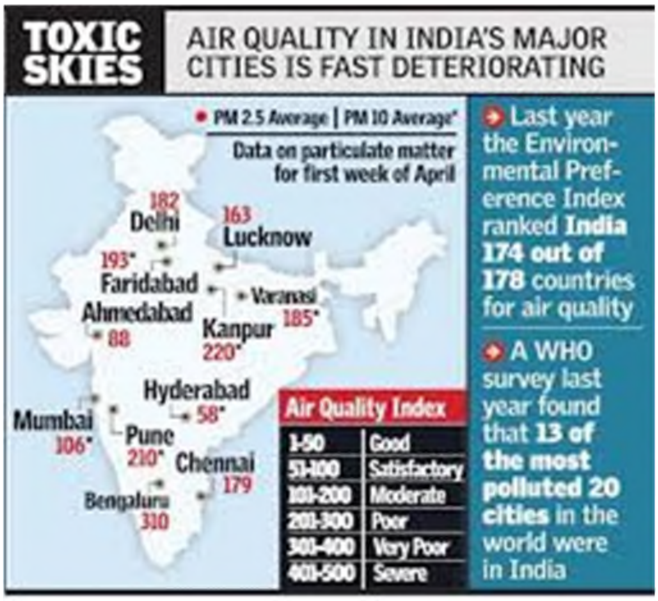


Figure 13: Air quality in Indian Major Cities

(Source:
https://encryptedtbn0.gstatic.com/images?q=tbn:ANd9GcQQK5JokMTNsCyfX2vVJsl0FBifzozJozAAeE9xGT8jR4a1ZsyUeg)

As seen in Figure 13 above, in most major cities the toxicity is reaching critical levels which have resulted in troublesome health implications Though many laws and guideline have been set to control these adverse effects there is a need to shift to greener transport technology now more than ever.

3.2 Current Indian EV Market:

The electric vehicles industry at a nascent stage in India. It comprises of less than 1% of the total vehicle sales, however, is expected to grow to more than 5% in few years.

In the year 2001 Chetan Maini as a joint venture between the Maini Group and Amerigon Electric Vehicles launched India's first electric car 'Reva.' In 2004, the Reva went on sale in Britain, branded as the G-Wiz. In the year 2010, Mahindra & Mahindra acquired a major stake in Reva Electric Car Company and rebranded itself as Mahindra Reva. Currently, the companies' E2O models are in the market and as per their specs ,running on Lithium ions batteries, with a range up to 140 km, top speed of 80-85 KM/hr and charging time of 6-9 hrs depending on the model. Another promising car by Mahindra is the Verio Electric with a range of 110 km, top speed of 86 km/hr and 8 hours charging time. A lot of companies such as TATA, Toyota, Maruthi have announced to launch their Electric cars soon.

Figure 14: Mahindra Reva E20

(Source: https://www.mahindrae2oplus.com/pages/buyers-guide/gallery)

Japanese electric vehicle maker Terra Motors Corporation plans to sell 30,000 e-rickshaws and 20000 sets of Terra batteries in the Indian market by the end of 2016. Other players in the 3wheerler segment include Lohia and Electrotherm.

Due to a steady rise in fuel prices and environmental issues, Electric motorcycles have started gaining popularity in India lately. Most electric two wheelers with a speed of just 20-40 km/hr are exempted from road tax and many other regulations. Moreover, do not require a driving license. Their relatively low prices around 300-500 Euros is a major selling point. Due to their short range are also mostly favorable within cities. Most of the e-bikes require a 6-8 hour of charge for a full battery. Some of the prominent companies in the two-wheeler segment include Hero Electric, BSA Motors, TVS Motors, BPG, Yo Bikes…

Figure 15: Hero Electric Photon
(Source: https://www.zigwheels.com/newbikes/Hero-Electric/Photon)

Main Barriers for electric vehicles in India include:

- Customer Awareness & acceptability
- Price-performance gap of EVs
- Low level of R&D
- Low Manufacturing investments limited to domestic manufacturing
- Non-existent supply chain
- Lack of Infrastructure

Having recognized these the government of India along with the help of the public sector hopes to overcome these barriers by planning and implementing various policies, schemes, and incentives which will be explained in the next section

.

3.3 SWOT, PESTAL & Porters Analysis:

3.3.1 SWOT Analysis

SWOT Analysis is a useful technique which can be applied to understand the Strengths and Weaknesses of the Indian EV industry, and for identifying both the Opportunities open and present threats for adoption and development.

Strengths:

- Very large automobile market
- Low running cost for maintenance and recharge
- Environmentally friendly
- No harmful exhaust emissions
- More energy efficient
- Reduced sound levels in especially in urban areas
- Reduces dependency on fossil fuel and imports and enhances national fuel security
- Availability of cheap skilled labor
- Can reduce utility prices -by charging at night
- Economic growth coupled with strong profit and revenues
- Governments rebates, more R&D can be done.
- Manufacturing facilities for conventional cars can be used

Weaknesses:

- Low customer awareness
- Dominance of private vehicle ownership
- High initial price compared conventional models.
- Limited range when compared to conventional cars.

- Recharging time which is greater compared to instantaneous fueling of conventional cars
- Limited models and variants in market
- Shortage of or availability spare parts and components
- Low sales-leading to lower revenues
- Lack of clean energy source
- Electric energy shortage

Threats:

- Lack of collaboration Between EV manufacturers
- Lack of infrastructure
- Lack of local manufacturing facilities
- Decrease in oil prices
- Improved public transportation
- Mass production of cheap gasoline vehicles

Opportunities:

- Development of Research and development
- Expansion of job market
- Development of related technologies
- To develop more efficient battery technology and increase EV range
- Government aid to develop automobile industry
- Small incentives to capture market
- Customized production to minimize losses
- Export opportunities
- Development of new ownership models like car-sharing

3.3.2 Porters Five Forces Analysis:

Porter's five forces model is an analysis tool that uses five industry forces to determine the intensity of competition in an industry and its profitability level.

It draws upon industrial organization (IO) economics to derive five forces that determine the competitive intensity and therefore attractiveness of an Industry.

Threat of new entrants:

- EV industry has very high entry barriers.
- Time and cost of entry-huge capital investments
- Specialist knowledge
- Lack of infrastructure, business models
- Traditional car manufacturers adopting electric technology
- High Taxes and duties on imports
- Incentives focused only on local manufacturers.

Threat of Substitutes:

- Large number of alternatives available
- CNG, LPG vehicles have already started making inroads in the market
- Faster market penetration of hybrid and plug-in vehicles since due to existing infrastructure
- Cheaper comparable gasoline vehicles
- Dominance of public transport

Buyer Power:

- Limited choices

- High bargaining power of customers
- High switching costs
- Too expensive to most of the consumer base
- Business to customer demand is low

Rivalry among competitors:

- Increased in number of competitors
- Traditional automobile industry competing head on with new players like Tesla
- Different business models
- Price-based competition
- Speeding technological growth

Supplier power:

- Specialized knowledge
- Limited suppliers for certain technology-Batteries
- Most components are prepared in-house to protect competitive edge

Threat of new entrants	- Medium
Threat of Substitutes	- High
Buyer Power	- Medium
Rivalry among competitors	- High
Supplier Power	- Low

3.3.3 PESTEL Analysis:

It is an analytical tool for strategic business planning.

PESTLE is a strategic framework for understanding external influences.

PESTLE is an abbreviation for "Political, Economic, Social, Technological, Legal and Environmental."

PESTEL analysis helps to understand the external environments affecting The Indian EV industry, can be used to maximize opportunities and minimize the threats

Political factors:

- Governmental incentives and schemes like NEMMP 2020 FAME to develop EV industry and market
- Expanding trade agreements between governments and between government and industry
- Unstable state governments-Threat
- Political stability of major markets
- Government plan to mitigate environmental pollution
- Reduction of tax rates

Economic factors:

- 2nd largest economy in the world
- Continues economic growth
- Stable economic policies
- Availability of Investment and Finance
- Increase in middle class of population
- Availability of incentives

- Decrease in battery costs
- Economic stability issues-Threat
- Cheap labour-low salaries-Threat

Social factors:

- EVs considered a status symbol
- Care for mother nature part of religious sentiment
- Continuously increasing customer awareness
- Increasing social initiatives to improve living standards
- Increasingly popularity of low-carbon lifestyles
- Increasing preference for renewable energy
- Increasing improvement in wealth distribution in developing markets

Technological factors:

- Large number of Engineer output from universities
- Local availability of abundant natural resources
- Presence of large number of International and Local OEMs
- Large in Automobile industry
- High rate of technological change
- Increasing automation in business
- Growing popularity of online mobile systems

Environmental factors:

- Alignment of Indian environmental standards with international standards
- Dedication to curb global warming

- Rising pollution levels in urban areas leading to consumers switching to healthier technology like EVS
- Expanding environmental programs
- Waste Disposal Threat & opportunity
- Initiatives by government to attain sustainable development
- Absence of clean or high cost of clean electric energy-Threat

Legal factors:

- Slow legal system-Threat
- The international expansion of patent protection
- Very high import duties
- Regulations for energy consumption
- Lower legal and safety standards n automobile industry
- Regulation for Dealership sales in India -opportunity & threat

3.4 Indian EV Policy and Initiatives:

National Electric Mobility Mission 2020 (NEMMP):

In 2013 the government of India launched the National Electric Mobility Mission Plan (NEMMP) 2020 to bring about a paradigm shift in transforming the automotive and transportation industry to achieve national fuel security at the same time ensuring India's global leadership in some vehicle segments through clean technology.

It aims to bring about 6-7 million electric/hybrid vehicles in India by the year 2020 gradually ensuring a vehicle population through various schemes, policies and monetary support. The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME India) scheme has been launched under the NEMMP 2020 for creating a market and ensuring early adoption of electric and hybrid vehicles in India The NEMMP uses various policy levers such as:

- Demand and Supply-side incentives to facilitate acquisition and promotion of hybrid/electric vehicles.
- R&D Promotion in technology ensuring industry participation in the same.
- Promotion of charging infrastructure.
- Encouragement to retro-fitment on-road vehicles with hybrid kit.

Faster Adoption and Manufacturing of Electric Vehicles (FAME):

The government of India launched the Faster Adoption and Manufacturing of Electric Vehicles (FAME) under NEMMP 2020 in the Union Budget for 2015-16 for implementation with effect from 1st April 2015. Its objective is to support hybrid/electric vehicles market development and Manufacturing eco-system. The scheme as per NEMMP 2020 guidelines focuses on the development of technology, the creation of demand, pilot projects and the creation of charging infrastructure. The phase-I of the scheme is being implemented for a period of 2 years i.e. FY 2015-16 and FY 2016-17 commencing from 1st April 2015. It aims to provide incentives for all electric and hybrid vehicle segments to develop their market. As shown in Figure 16

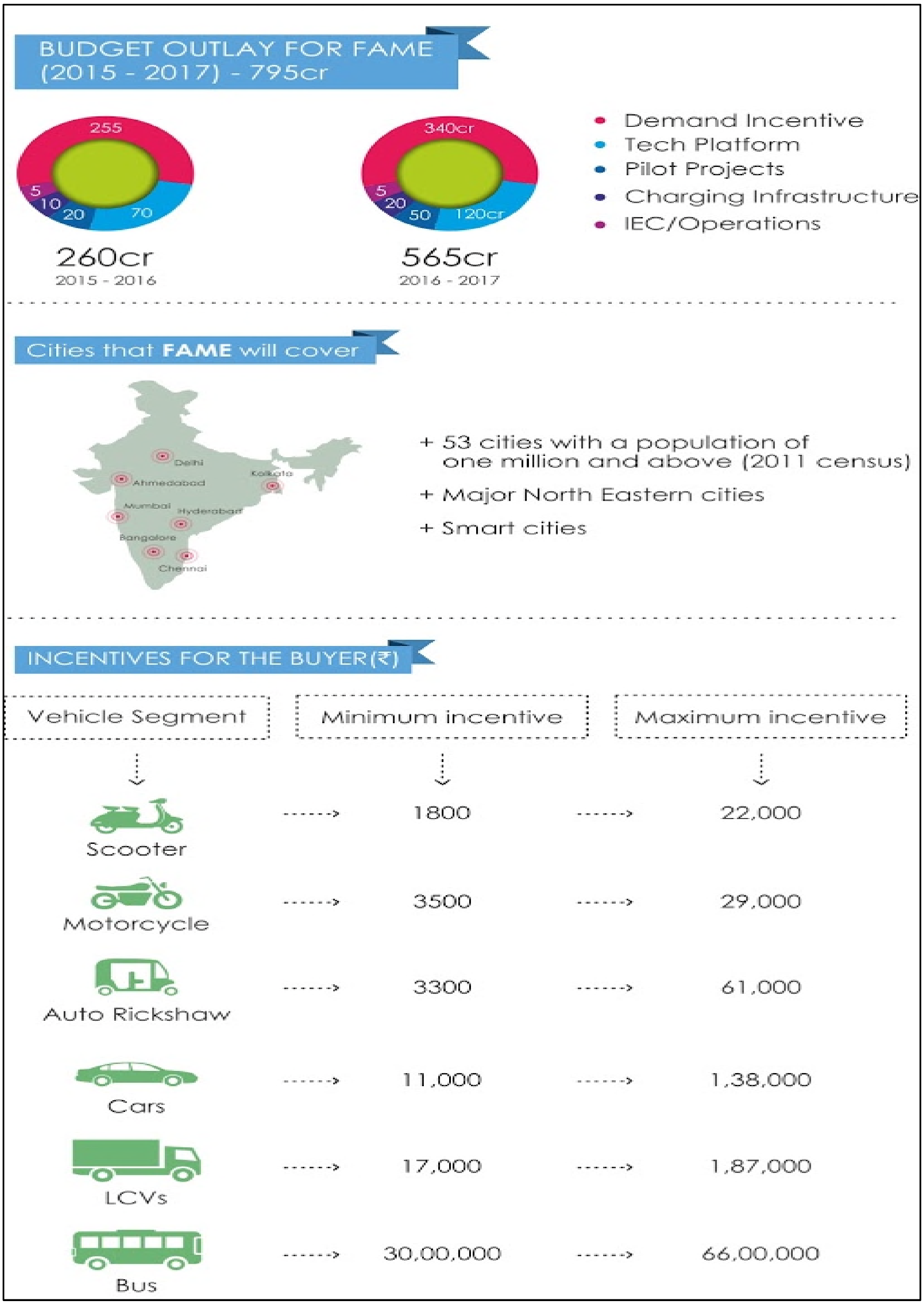


Figure 16: FAME India Scheme

(Source: https://www.atherenergy.com/blog/understanding-fame-india-scheme)

Under this scheme, about 99000 electric/hybrid vehicles have been incentivized since its launch and has also approved around 24 million dollars (nearly Rs. 155 Crores) for pilot projects, charging infrastructure projects and technological development projects.

3.5 Tax and Duty Structure:

Customs Duty on Import:

In order to promote The EV industry in India which is still in its nascent stages, the following EV components haven been exempted from normal import duty:

- Batteries
- Chargers
- Electric Motors
- Controllers & Convertors

On these components, only a total of 6% concessional duty + 2% Electric cess and 1% Hybrid electric cess is charged.

Excise Duty:

Basic Excise Duty is charged at 6% on Assessable Value and + 2% Electric cess and 1% Hybrid electric cess is charged.

Automobile Cess:

0.125% is currently levied on clearance of Electric Vehicles.

Value Added Tax(VAT)

This tax varies from state to state in India as shown in Table 4.

State	VAT	Entry Tax	Road Tax
Delhi	5.00%	0.00%	0.00%
Chandigarh	0.00%	0.00%	0.00%
Punjab	5.00%	0.00%	0.00%
Rajasthan	0.00%	0.00%	0.00%
Uttrakhand	0.00%	0.00%	0.00%
Uttar Pradesh	14.50%	0.00%	0.00%
Bihar	14.50%	0.00%	6.00%
Jharkhand	14.00%	0.00%	3.00%
Odisha	5.00%	2.00%	5.00%
West Bengal	5.00%	1.00%	9.00%
Gujarat	5.00%	0.00%	3.00%
Maharashtra	5.50%	3.50%	2.50%
Goa	12.50%	0.00%	Rs 1150
Madhya Pradesh	5.00%	1.00%	7.00%
Chhattisgarh	0.00%	1.00%	4.00%
Puducherry	8.00%	0.00%	0.00%
Tamil Nadu	5.00%	0.00%	4.00%
Kerala	5.00%	0.00%	6.00%
Karnataka	5.50%	0.00%	0.00%
Andhra Pradesh	5.00%	0.00%	5.00%
Haryana	5.00%	0.00%	6.00%

Table 4: VAT, Entry & Road Tax in Indian States

(Source: http://www.smev.in/industry-info/duty-and-tax-structure/)

4 NEMMP 2020

4.1 Vision Statement:

> ***"To encourage reliable, affordable and efficient xEVs that meet consumer performance and price expectations through Government - Industry collaboration for promotion and development of indigenous manufacturing capabilities, required infrastructure, consumer awareness and technology; thereby helping India to emerge as a leader in the xEV Two Wheeler and Four Wheeler market in the world by 2020, with total xEV sales of 6-7 million units thus enabling Indian automotive Industry to achieve global xEV manufacturing leadership and contributing towards National Fuel Security."***

Figure 17: NEMMP 2020 Vision Statement

(Source: NEMMP 2020)

4.2 Methodology Used:

4.2.1 Consumer Survey and Stakeholder Inputs:

Owing to the unique nature of the Indian ecosystem and its automotive market, in comparison to many countries, a unique tailor made solution was needed to suit all conditions and ground realities. Joint studies by the Indian Department of Heavy Industry and stakeholders like Industry and consumers gave a lot of vital information which would later be used to form the NEMMP 2020.

The studies were conducted based on the inputs obtained from extensive field level surveys and several focused group discussions with key stakeholders from all major cities and demographic profiles. The broad methodology of the study could be broken down into stages.

In the primary stage Understanding of the Global EV Market in terms of current stage of EV technological development, EV components (batteries, powertrains, electric motors...), global demand, Policy levers used by different countries and the very need to transit to this technology. These global inputs became the benchmark on which the Indian market would be compared and analyzed.

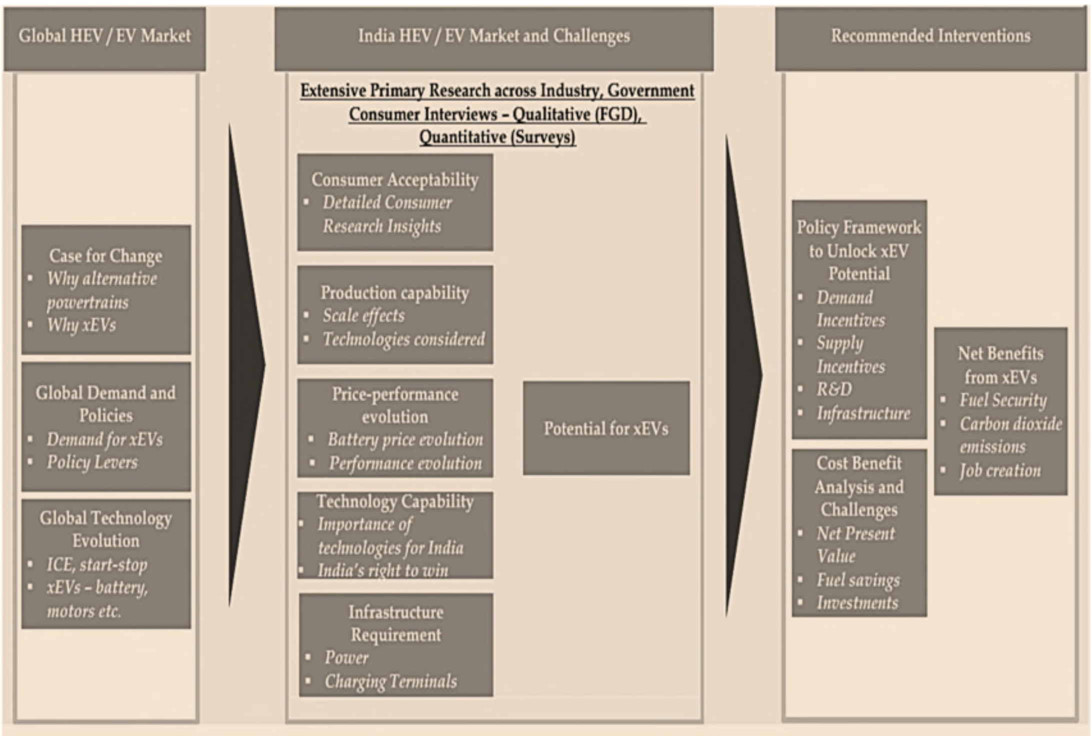


Figure 18: Broad Methodology followed in NEMMP study

(Source: NEMMP 2020)

In the next stage to understand the Indian EV scenario, detailed interactions were held with various key stakeholders like Government ministries, transport departments, power utilities, Industry consumers, Research institutions, etc. The surveys covered all vehicle segments involved 7000 consumer respondents from various Tier 1,2,3 &4 cities and 12 focus groups. In addition to the surveys, 200 specialized interviews and discussions were conducted with automotive industry stakeholders Including the government and the industry.

The interviews with the Industry stakeholders like OEMs and suppliers helped in understanding the existing capabilities in production, the potential for electric vehicles and local technological capabilities. The consumer surveys gave insights into aspects like consumer technological awareness and perceptions, preferences in terms of aspects like prices, range, etc..., significant barriers and drivers that could promote this technology.

4.2.2 Use of Analytical Models:

In order to determine and make projections in aspects like fuel savings, market penetration, CO2 emission savings, etc. a lot of analytical models have been used. Some of the key models that have been vital in the formulation of the NEMMP 2020 are shown below.

Fuel Savings Model:

This model takes into account the total fuel savings by switching to EV technology by calculating the total fuel consumption obtained from inputs of expected sales by 2020 in various vehicle segments, taking into consideration the expected range of the vehicles and total distance traveled annually. The is illustrated in Figure 19 below.

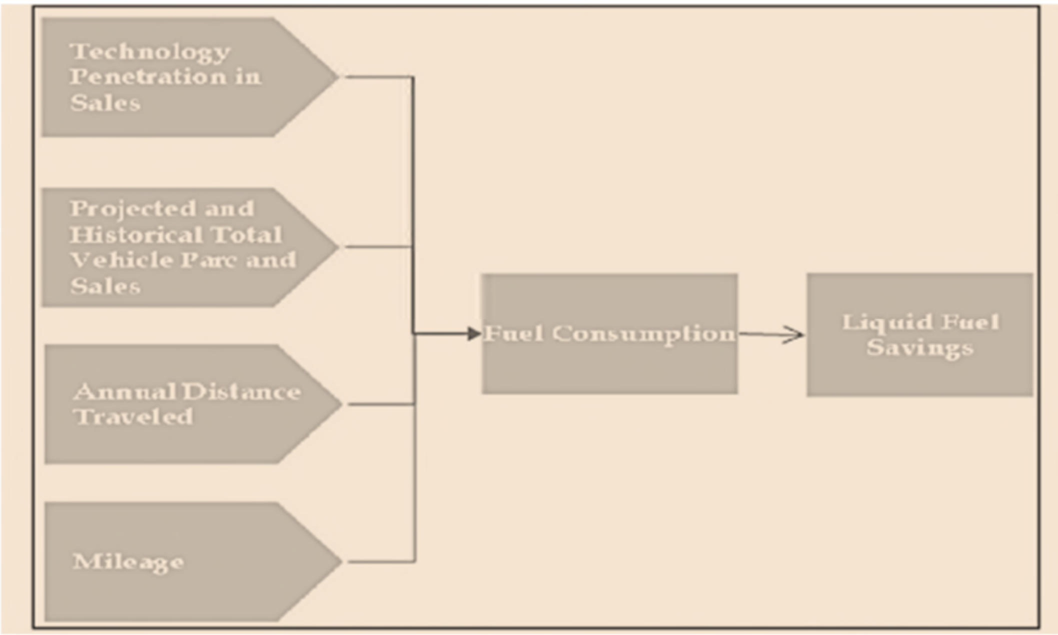
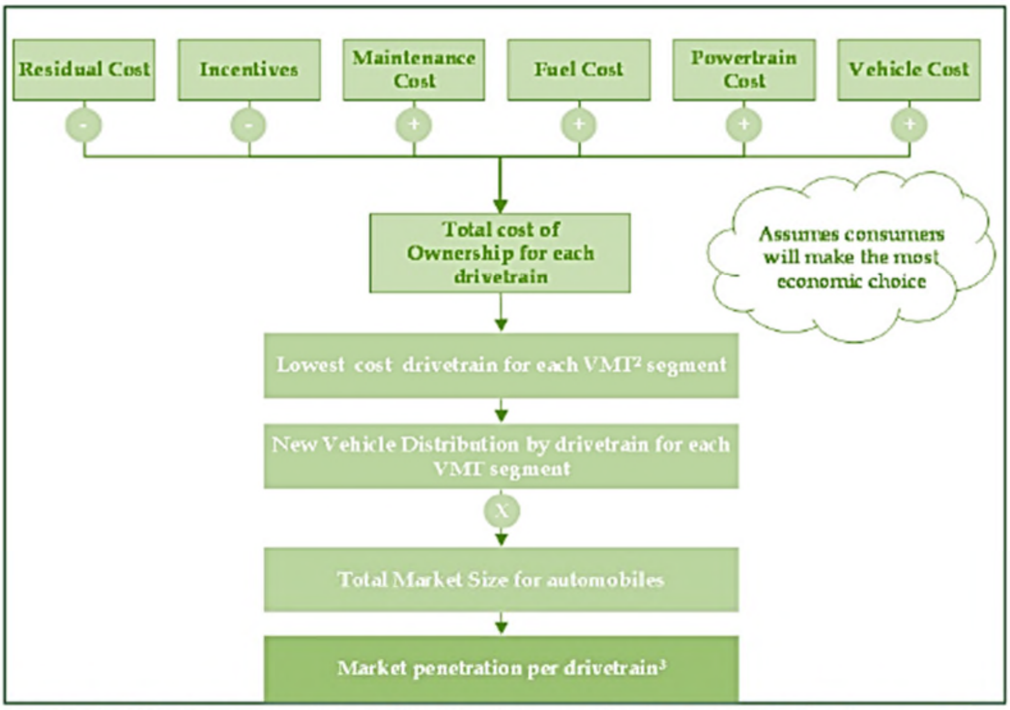


Figure 19: Fuel Saving Calculations

(Source: NEMMP 2020)

Total Cost of Ownership Model:

The model has been used to arrive at the total cost of ownership of specific drive train technology and of specific vehicle segments. By taking into account vehicle acquisition costs, powertrain costs, fuel cost maintenance, running costs, etc. the total cost is calculated. From this calculated cost, the lowest cost drivetrain for each vehicle segment is identified. By taking the assumed sales along with this lowest cost drive train in each segment, the market penetration of each drivetrain is projected as shown in Figure 20.



***Note:** Price in 2011 refers to expected price if OEMs bring the commercial product to the market based on current price and performance,*

2) VMT refers to the Total Vehicles Miles Travelled (annual distance travelled in km)

3) The Market penetration is adjusted with a market inertia factor to reflect consumer hesitance while shifting to new xEV technologies

Figure 20: Total Cost of Ownership Model

(Source: NEMMP 2020)

CO2 Emission Model:

This model was used to primarily estimated the Reduction of CO2 by the adoption of EV technology. The total emission per vehicle was calculated taking into consideration three components- Tank to wheel emission, tank emission, and material emission. The tank to wheel emission is dependent on the drivetrains fuel efficiency. Tank emission is a function of the size of the battery in addition to the efficiency of the fuel and the vehicle weight determines the material emissions. The total emissions per vehicle calculated along with total distance traveled by the vehicle annually give the total CO2 emissions a shown in Figure 21.

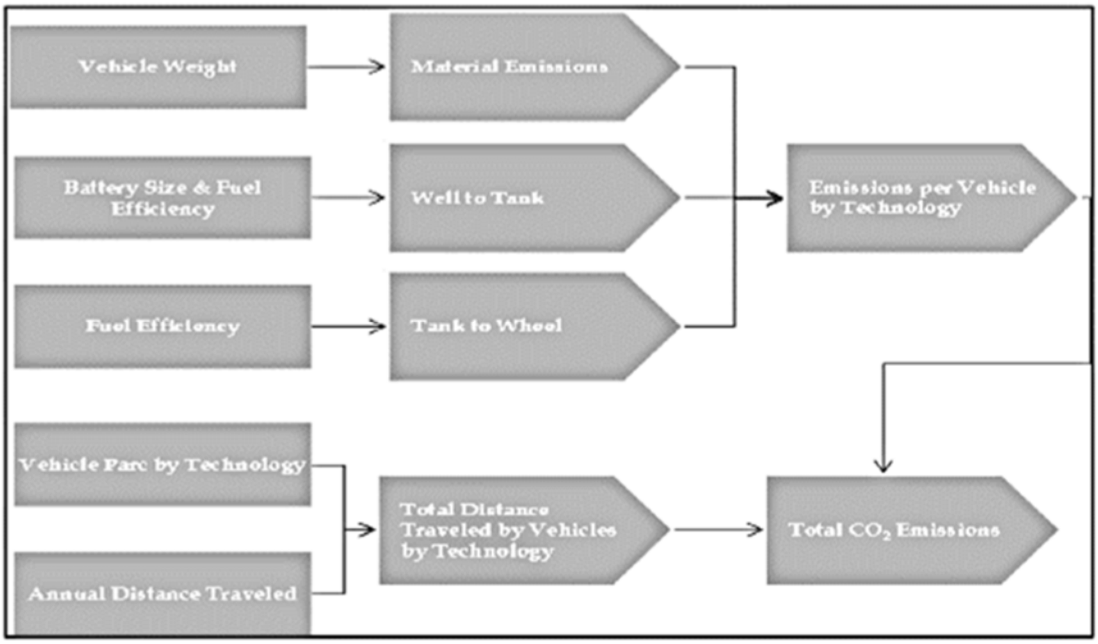


Figure 21: Carbon dioxide emission model

(Source: NEMMP 2020)

4.3 NEMMP 2020 Roadmap:

The transition or shift towards Electromobility will involve a significant amount of change for all the stakeholders in order to achieve the potential demand for EVs by 2020. It will require the government to work in unison and harmony with the industry to create consumer acceptability, attain technological development, set up manufacturing ecosystem and infrastructure for EVs. The NEMMP roadmap intends to provide a strong framework for rolling out numerous interventions, schemes, policies and projects to attain the 2020 targets. As shown in Figure 22.

The roadmap begins with the government generating consumer acceptability and creation of initial infrastructure. It will require the generation of necessary standards, guidelines, and procedures in this initial stage itself for developing the industry and generating a viable mechanism for incentivization. This is followed by development or acquisition of the necessary EV structure in order to encourage localization thereby developing the local market by creating price efficient options for customers. The industry, Government, and other stakeholders will work as a consortium. The government will provide encouragement through the creation of demand, initial framework, funding of R&D efforts and creation of infrastructure later which have to be taken over by the OEMS. Once the local Manufacturing capabilities are fully developed, the various incentivization or subsidies will be slowly withdrawn. At this point, the EV infrastructure is expected to be fully developed with sustaining EV production and shall be capable of exporting capabilities.

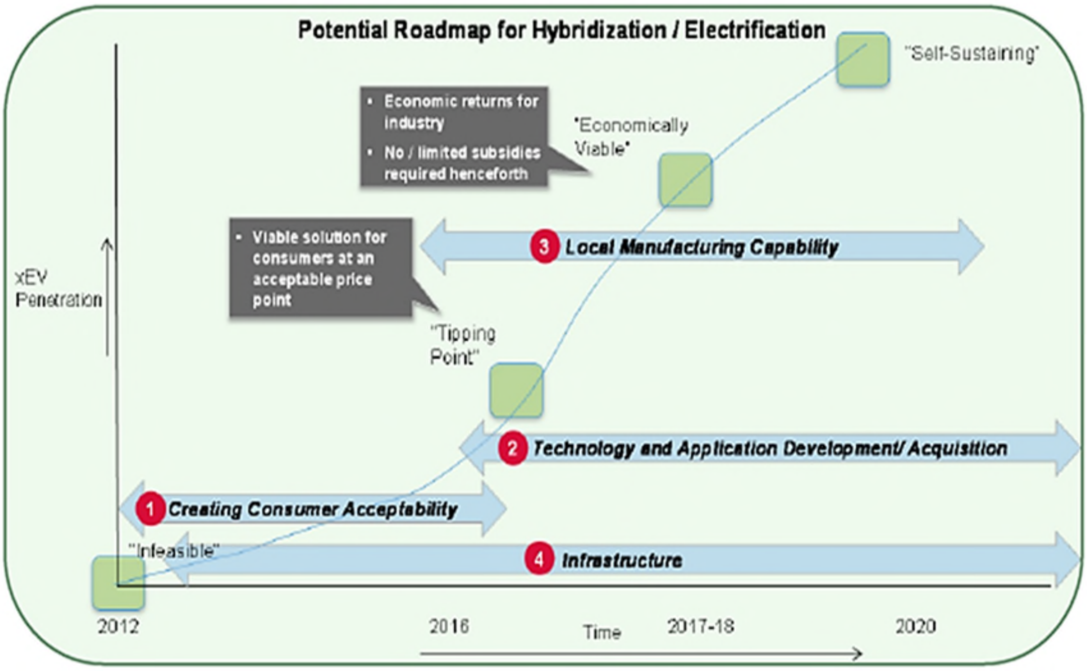


Figure 22: Potential Roadmap for Electrification/Hybridization

(Source: NEMMP 2020)

4.4 E-Mobility Strategy:

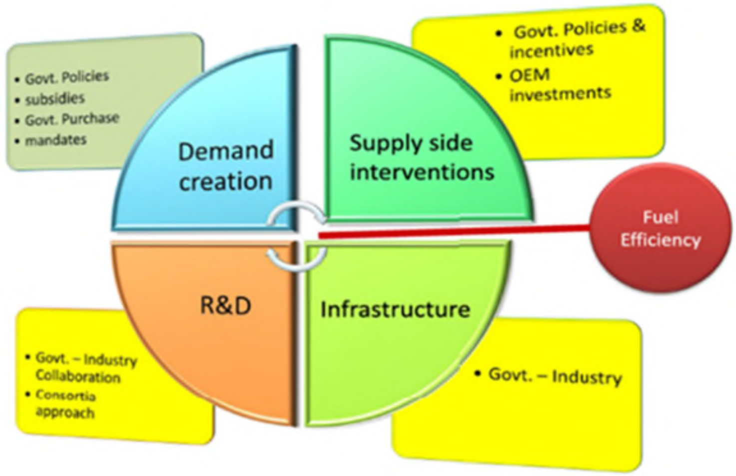


Figure 23: Levers supporting EV adoption

(Source: NEMMP 2020)

The Electromobility Strategy is divided into four parts – Demand Creation, Research & development, Manufacturing, and Infrastructure strategy as shown in Figure 23.

4.4.1 Demand Creation Strategy:

- Develop a demand incentive structure.
- Study of quantum of demand subsidy to be undertaken
- Set boundary parameters and create demand assurance measures
- Incentive Distribution criterion for different technology
- Localization of commitments
- Retro kits for Hybrid vehicles

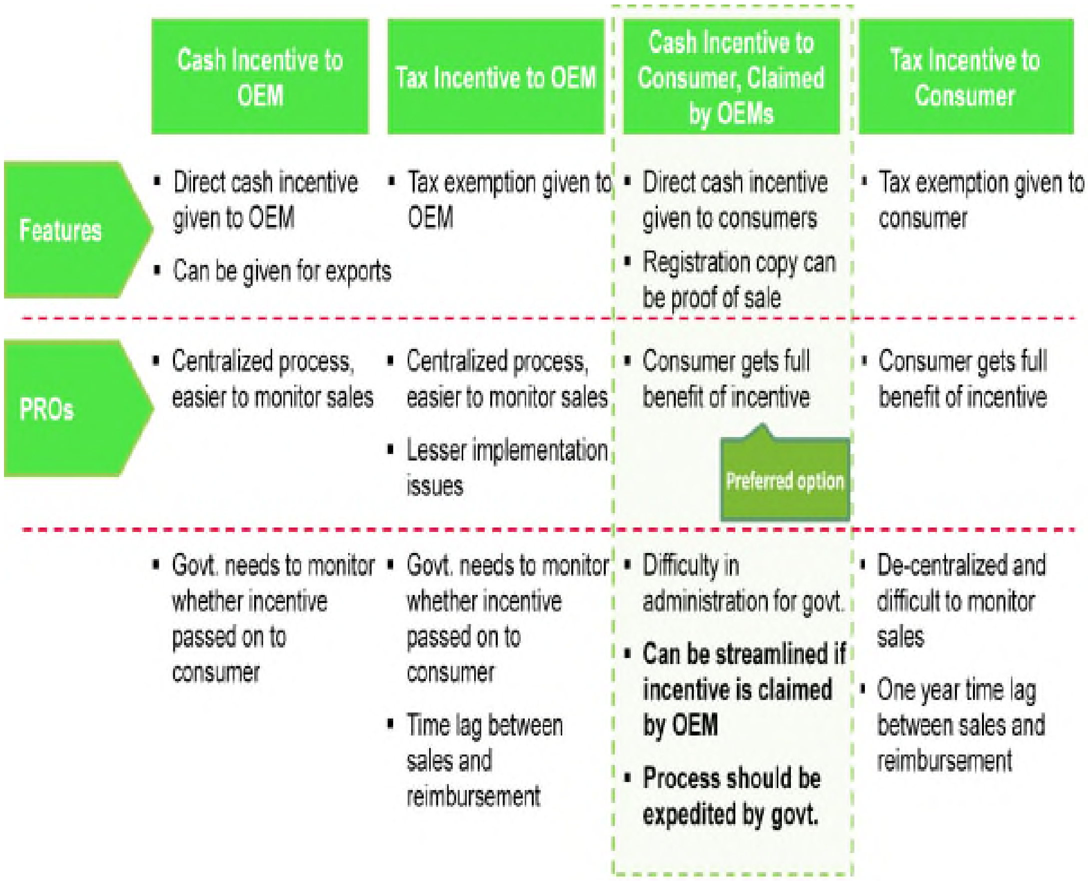


Figure 24: Options for channelizing Demand incentives

(Source: NEMMP 2020)

4.4.2 R&D Strategy:

- A collaborative effort between government, universities, Original Equipment Manufacturers and research centers.
- Consortium model of approach
- Identifying R&D projects to be undertaken, setting up necessary rules and guidelines and project detailing for effective rollout and implementation
- Development of Funding-investment model between Government and the private sector.

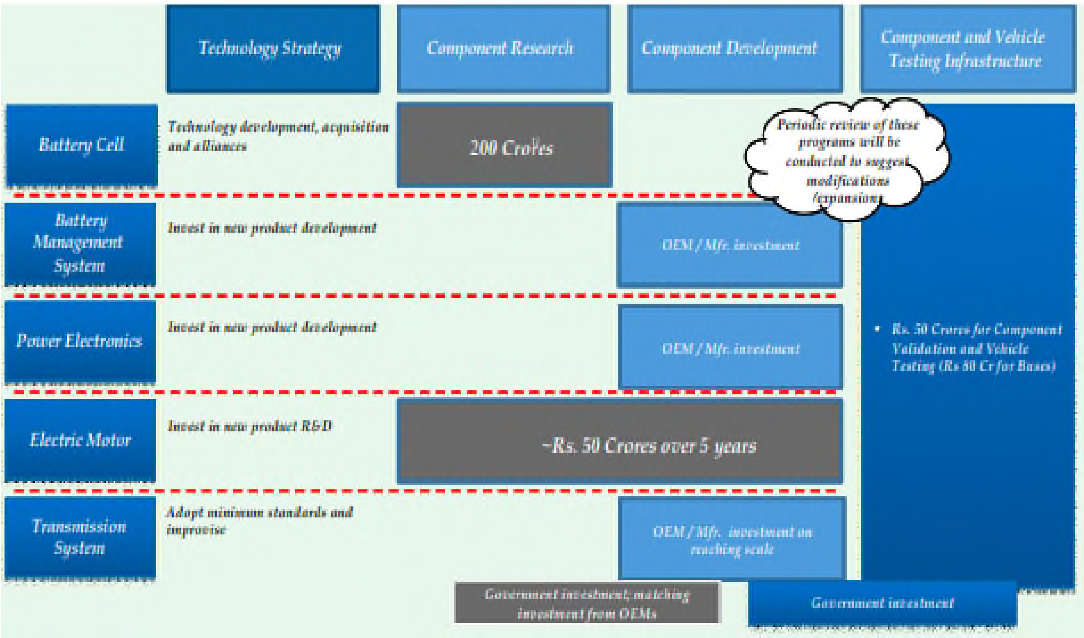


Figure 25: R&D Investment strategy

(Source: NEMMP 2020)

- Nascent technology like battery technology to be covered mostly by National labs, universities and some OEMs while Mature Technology funded largely by the government. Mature technologies Battery management systems, power electronics and electric motors to be covered component manufacturers & government

4.4.3 Manufacturing Strategy:

- Narrow price initially between IC and EV through demand Incentives.
- Localization criterion for getting a higher level of demand incentive.
- Phase approach:

The Demand strategy will be taken up in four phases

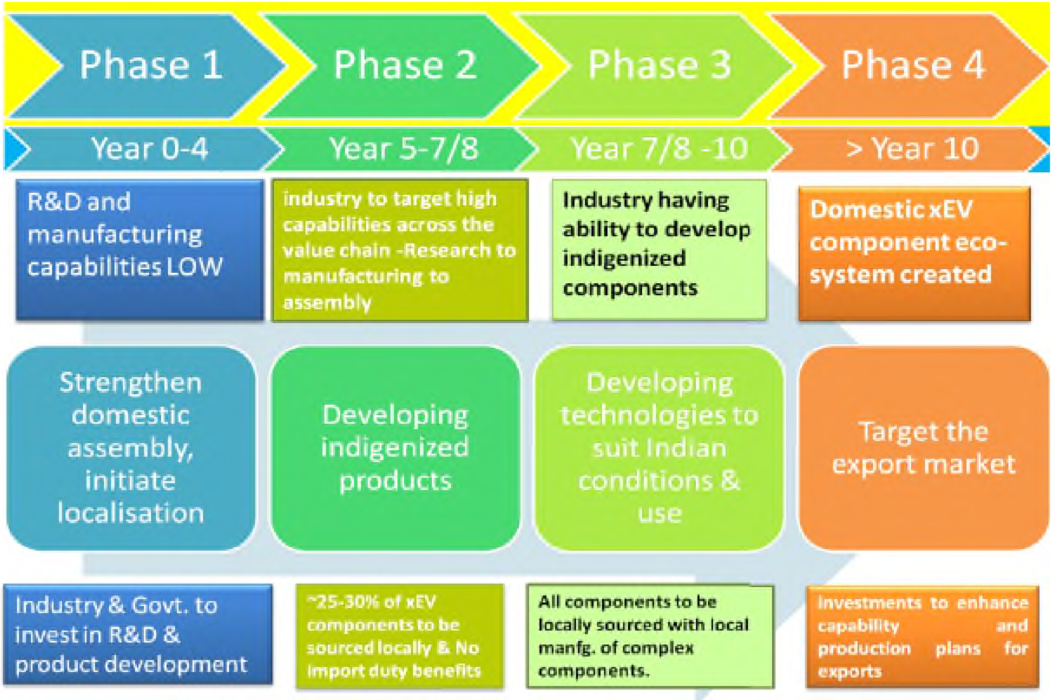


Figure 26: Four-Phase approach for developing EV manufacturing capability in India (Source: NEMMP 2020)

Phase 1: Domestic Assembly - Investments in R&D-Product development centers, increasing local sourcing and local assembly using local or imported components.

Phase 2: Developing Indigenized Products- Indigenized components, >25% local component sourcing and Local assembly using local components.

Phase 3: Locally developed Technology -100% local sourcing+battery manufacturing and 100% components indigenously developed for the Indian market.

Phase 4: Export capable facilities

4.4.4 Charging Infrastructure:

- Government and Private sector partnership.

- Initial investment framework by government and later by private sector

- Phase approach:

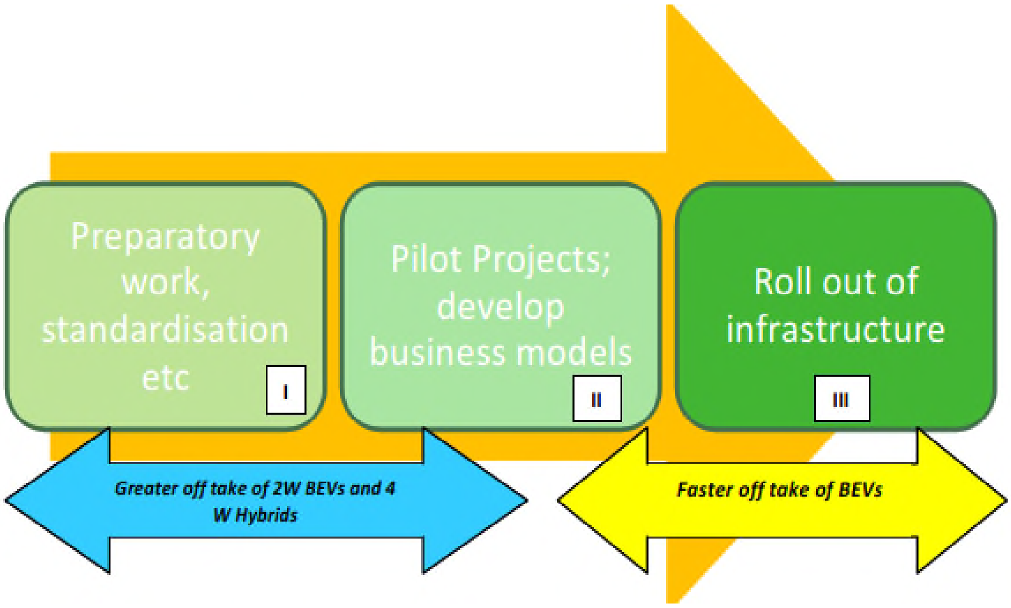


Figure 27: Strategy for EV infrastructure
(Source: NEMMP 2020)

Phase 1: Initial preparatory phase, option evaluation, framework setup, policies, infrastructure standards, laws and detailed studies

Phase 2: Impact assessment studies &programs, pilot projects, EV consortium infrastructure building activities and business models.

Phase 3: Medium and short term objectives that include ensuring reliable availability of electricity, adequate access to recharge facilities, development of EV charging as a viable business entity, the synergy between charging infrastructure and renewable energy generation and deployment of public recharging infrastructure.

4.5 Implementation Mechanism:

The implementation of the NEMMP 2020 through its policies, schemes, projects, etc. will be designed by involving all the stakeholders through the mechanism of Three working groups (WG) and various sub-groups set up by the NBEM where all stakeholders will be adequately represented. Figure 28 shows the implementation structure.

The NATIS/NAB will coordinate the WGS and SGs and examine all suggestions and all their formulations to make recommendations to the NBEM AND NCEM for approval. The Subgroups have to be created for critical areas to create guidelines framework, policies and schemes by accessing ground realities.

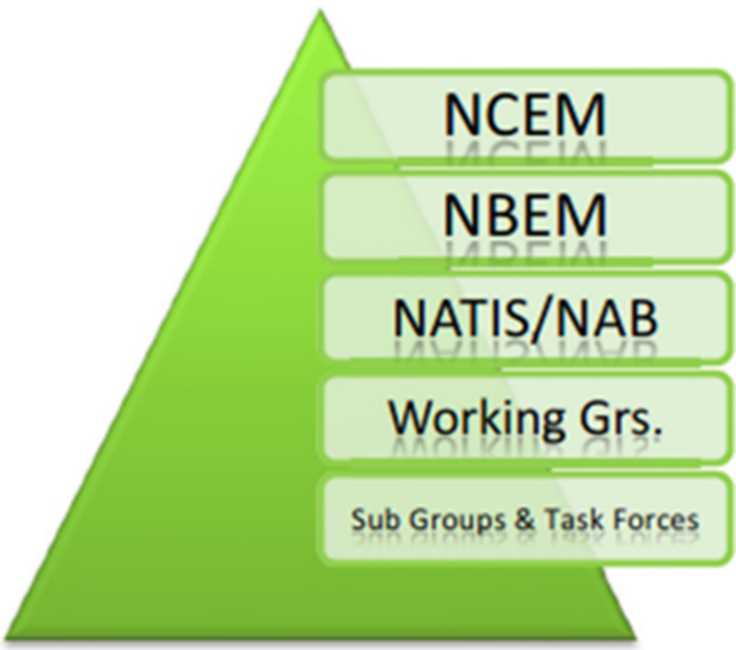


Figure 28: NEMMP implementation structure
(Source: NEMMP 2020)

The NATIS/NAB will act as the technical advisor to the NBEM and NCEM. The reports provided to The NBEM and NCEM will be for periodically assessment and to make necessary modifications to the various schemes, policies, and projects that are designed to evolve and improve continuously through a design-implementassignment feedback loop. The implementation of various interventions the concerned Ministries and assigned stakeholders by the government of India.

Table 35 – List of Sub Groups set up under the Working Groups

Sub-Groups under Working Group on R&D	
Sr. No	***Domain Area of Sub Group***
1	Sub Group on BMS & Battery
2	Sub Group on Power Electronics and Motors
3	Sub Group on testing infrastructure, human resources, energy efficiency technologies (light weighting etc.)
Sub-Group under Working Group on Infrastructure	
Sr. No.	***Doman Area of Sub Group***
1	Sub Group on technology and standards (SG-T&S)
2	Sub Group on infrastructure roll out (SG-IRO)
Sub-Group under Working Group on Demand & Supply Incentives	
Sr. No.	***Doman Area of Sub Group***
1	Core Group for finalizing the demand incentive scheme (CG-DI)
2	Sub Group on validation of level of demand incentives. (SG-VDI)
3	Sub Group on vehicle parameters & qualification criteria. (SG-VP&QC)
4	Sub Group on demand assurance policy. (SG-DAP)
5	Sub Group on incentive delivery and monitoring mechanism (SG-ID&MM)
6	Sub Group for promoting hybrid retro-fitment kits (SG-RFT)

Table 5: List of Sub-Groups set up under the Working Groups

(Source: NEMMP 2020)

4.6 Benefits of Initiative:

The NEMMP 2020 to aims to achieve the paradigm shift towards electromobility in India which will not only ensure the energy security of the country but also develop local EV manufacturing capabilities and mitigate the impacts of mobility on the environment.

The development of local EV ecosystem and manufacturing infrastructure will result in the significant increase in market penetration and generate additional value to the country by the growth of its automotive industry. As per projections EV manufacturing capabilities are expected to mature in 8-10 yrs, making India export capable and competitive in the global EV markets. All this growth through local manufacturing of EVS is expected to generate around 60,000-65,000 jobs by 2020 and 180,000-200,000 jobs from services. The development of battery, motor, and other technology will also have large impacts on other manufacturing segments in the supply chain and will help in the growth and development in energy efficiency in those segments.

One of the key objectives of the policy is to mitigate the effects of mobility on the environment. EVs are expected to have a much lower wheel to wheel emissions than gasoline vehicles and with the generation of cleaner electricity with an improved fuel mix is expected to lower emissions a lot. By estimation, if the projected demand for EVs is met in all vehicle segments, it will potentially reduce the CO2 emissions by 1.3-1.5%.

The estimated 6-7million sales of EVs by 2020 will result in huge volume of fuel savings of the order 2.2 2.5 MT with a bulk of these savings coming from the electric two-wheeler segment (>50%) and 20-25% from four wheelers as shown in Table 6

Segments	2W	4W	BUS	LCV	3W
xEV Vehicle Sales in 2020 ('000 units)					
HEV / PHEV	-	1275	2	120	-
BEV	4800	170-320	0.3-0.7	30-50	20-30
Fuel Savings due to xEVs in 2020 (Million Tonnes of Liquid Fuel)					
Fuel Savings	1.4	0.4-0.65	0.16-0.19	0.09-0.16	0.06-0.09

Table 6: Level of fuel saving in 2020

(Source: NEMMP 2020)

It is estimated that the net benefits due to the NEMMP 2020 would be 39,000 -43,000 Crore Indian Rupees.

The cost-benefit analysis showing the vehicle segment wise investments, fuel benefits, ease of implementation and Net Present Value(NPV) of benefits is shown in Table7.

Analysis		*Four Wheelers*	*Two Wheelers*	*Buses*	*Three Wheelers*	*LCVs*
Total Investments - next 8 years (Rs Crores)	HEV	7,200-7,300	10,000-10,500	1100-1200	500-600	1400-1500
	HEV/BEV	8,700-8,800		1200-1300	800-900	1700-1800
Fuel Benefits	*HG/HEV (fuel saving by 2020)*	*1.1 MT*	*4.9 MT by 2020*	*0.5 MT*	*0.2 MT*	*0.3 MT*
	HG/HEV/BEV (fuel saving by 2020)	*1.6 MT*		*0.6 MT*	*0.3 MT*	*0.5 MT*
Ease of Implementation	*CAPABILITIES*	*Low to Moderate*	*Moderate to High*	*Moderate*	*Moderate*	*Low*
	PRICE PERF. GAP	*Moderate to High*	*Low to Moderate*	*High*	*High*	*High*
	INVESTMENT	*Significant investments required by OEMs*	*High as volumes are high.*	*Moderate*	*Moderate*	*Moderate*
Total additional direct new jobs	*Numbers*	*26000-30000*	*22,000*	*1150-1200*	*1200*	*7200-8000*
NPV of benefits (Net Benefits)	**Rs Crores**	**4800-7100**	**28,000**	**3300 - 3700**	**1200-1700**	**1500-3000**

Table 7: Cost-benefit analysis

(Source: NEMMP 2020)

From the above table, it is apparent that the two-wheeler EV segment has the highest demand in the years to come with the highest net present value in benefits. The use of public transport in India being reasonably high and ease of implementation being reasonably moderate, investment in Buses and three-wheelers like e-rickshaws is good to be taken into consideration.

4 CONCLUSION

To the Indian scenario, Electric Vehicles are the solution and have the highest potential for achieving national energy security and mitigating the harmful effects of mobility on the local environment. Having recognized this Electromobility is one of the key focuses of the Indian national development policy in recent years.

Creation and implementation of NEMMP 2020 mission and sub-schemes under it like FAME are just part of the process of making India a vibrant EV market and manufacturing ecosystem. There still are numerous challenges to be overcome from creating general awareness among the public at large of the benefits of electric vehicles, developing manufacturing capabilities, infrastructure, etc.

The following are a few recommendations and suggestions:

- Develop more long-term Policies. The NEMMP is just the beginning of this road though it’s not is not yet entirely clear in many aspects. There is a need for more clear policies with long-term targets for electric vehicles and roadmaps on how to achieve them

- Increase Subsidies and Incentives. The EV market in India is still in its nascent stages and is a long way from maturity. There is a need to provide fiscal concessions like the removal of Value Added Tax(VAT), registration tax and other duties levied in addition to the concessions provide under FAME which is an NEMMP initiative.

- In addition to those of the NEMMP, more weight needs to put into policies accompanied by economic incentives for developing domestic manufacturing capabilities in India.

- Focus on an expedited Development of charging infrastructure in public and residential areas. In the meantime, provide facilities like Battery Swapping where customers can get fully charged battery pack services to bridge the gap at least until the charging infrastructure is fully developed.

- Develop and encourage new market models like Car sharing. This model provides access to a larger range of customers since it's on a rental basis and does not require personal investment into buying the vehicles. The other benefits of this include reduced road congestion along with greater vehicle utilization accompanied by the development of charging infrastructure at public parking stations.

- Provide prioritization for electric vehicles when it comes to Traffic and parking. Creation of dedicated tracks for an electric vehicle like low-speed electric two-wheelers, special lanes for electric cars and reserving special areas for EV parking will help increase interest in EVs. Dedicated parking areas with charging facilities will also contribute to tackling the range issues of electric vehicles.

- Changing public transport services into Electric. A significant amount of the general population India makes a high utilization of public transport mostly buses in urban areas. Rickshaws are also preferred means of transport for short distances and are abundant in number. Many of the pollution problems in cities can be tackled by the adoption of Electric buses and incentivization of electric rickshaws to encourage their road presence.

- Making stricter emission standards. This will help tackle pollution problems in cities especially by prohibiting the use of gasoline vehicles in certain areas and making them accessible only by electric vehicles providing a distinct advantage for their use.

- Setting common standards for the deployment of technology and infrastructure so that no monopoly or advantaged is retained or misused by certain stakeholders in the market.

- Develop Smart grids. There is a great need for government investment required to develop smart grids as they would help create more efficient pricing, better integration of intermittent renewables and make the electricity sector more sustainable.

- Creating a performance-oriented market. This will generate competition between electric vehicle manufacturers and creation of better solutions and products

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