Development of Roadmap for Electrification of Freight Vehicles: Review of Existing Policy Status

Authors
Gayathri R, Suby Charles, Vinoth Kumar L, Siddhartha MM, Rokom Perme, Surendra Reddy K, Gitakrishnan Ramadurai

Report I April 2020
Part 1

Centre of Excellence in Urban Transport
Indian Institute of Technology, Madras

Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the areas of clean power, energy efficiency, sustainable urban transport, climate change mitigation and clean energy finance.

IIT Madras is a residential institute with nearly 550 faculty, 8000 students and 1250 administrative & supporting staff and is a self-contained campus located in a beautiful, wooded land of about 250 hectares. The campus is located in the city of Chennai, previously known as Madras. The Institute has sixteen academic departments and a few advanced research centres in various disciplines of engineering and pure sciences, with nearly 100 laboratories.

Disclaimer

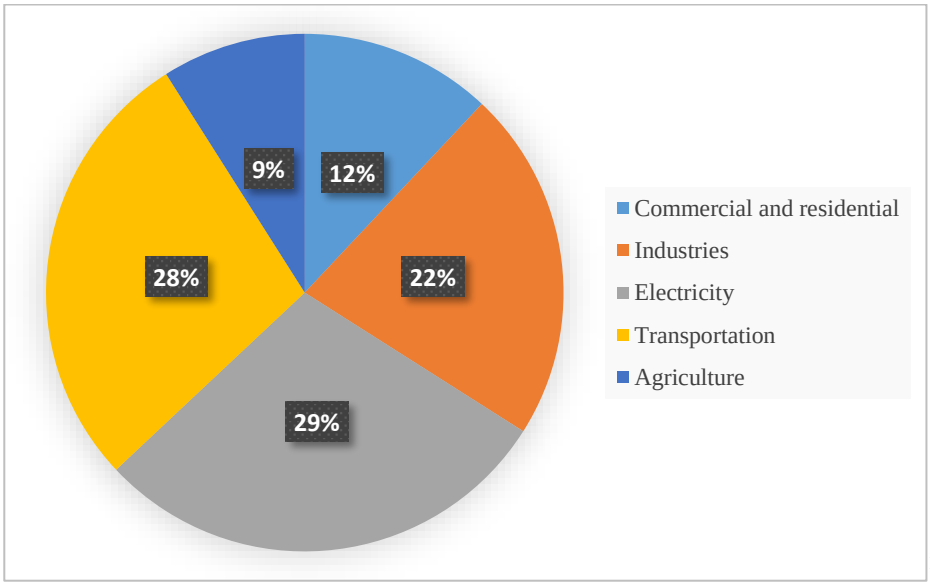
CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

While electric vehicles (EV) are not a new invention, the need for shifting to electric vehicles from conventional diesel-powered trucks has gained significant momentum in recent times. The world's first electric vehicle was built by Anyos Jedlik in 1828. But the first production electric vehicle was built in 1884 in London by Thomas Parker. However, the high cost of production, low top speed, and short-range of batteries compared with petrol- and diesel-powered internal combustion engine led to the decline of the electric vehicle. Except for vehicles that could hook onto an overhead electric cable such as trams and train locomotives, electric-powered vehicles saw limited applications in moving goods and people. Transportation alone is contributing about 29% of Green House Gases (GHG) emissions (figure 1). Increasing awareness of tailpipe emissions from diesel- and petrol-powered internal combustion engines and their consequent health and environmental impacts led to the comeback of electric vehicles. Improvements and technology innovations in charge storage and charging technology in batteries, as well as the electric motor, has contributed to the strong comeback of electric vehicles. Even the goods carriers are seeing the adoption of electric power trains.



[1]

Figure 1: Sectorwise contribution to GHGs

GHGs such as CO_2 and N_2O primarily come from burning of fossil fuels. Electric vehicles are one of the technologies that the Indian government is relying on to reduce India's vehicular emissions. In 2010, the transport sector accounted for 6.7Gt of emitted CO_2 or 23% of the

[1] United States Environmental Protection Agency

world's total[2]. Furthermore, global fuel demand for transportation is projected to grow by approximately 40% by 2035[2]. The Intergovernmental Panel on Climate Change (IPCC) has reported the need to reduce GHG emissions particularly in the energy and transport sector to avoid an increase of temperature by 2.4 - 6.4 degrees centigrade by 2020 relative to the temperature recorded in 1990. Electric vehicles are one of the innovative technologies that can help address environmental concerns.

Various public agencies and private sectors have come up with initiatives to help reduce GHG emissions from transportation sector. These can be broadly categorised into:

a. Emission regulations

b. Use of alternative source of energy.

Several countries have been following emission regulations that are enacted by federal agencies but are regulated and enforced by regional agencies. The United States Environmental Protection Agency (EPA) establishes and regulates the emission norms in the US. European Commission enacts the Euro Emission standards for the European Union (EU). In India, Bharat Stage Emission Standards (BSES) are instituted by the Government of India.

While emission regulation has helped in curbing emissions from a vehicle, it does not address the fact that the IC-based engines continue to grow in quantity especially in Asian countries. Also, vehicle emissions are distributed over time and space, making it difficult for enforcement agencies to monitor vehicles with emissions not conforming with the norms. On the other hand, electricity can be generated from renewable sources. Additionally, electricity generation at thermal power plants is a point source of pollution, making regulation of emissions more convenient and efficient. Thus, shifting to electricity-powered vehicles have the potential for cleaner and greener mobility of people and goods. EV sales and market share have grown significantly over the last decade, globally.

The report is organised as follows:

A review of the EV growth in the global market is discussed in section 2. Observations on the transition towards EV by various countries is discussed in section 3. Various policies and incentive schemes drafted / implemented by other countries to support EV manufacturing and procurement are described in section 4. EV policy and adoption plan in India is reviewed in section 5. Battery technology, charging infrastructure, EV market, and EVs available or

[2] IEA (2012) Improving the Fuel Economy of Road Vehicles: A policy package, Flagship report November 2012

expected to be launched in India, and the challenges and strategies for electric vehicle penetration are discussed in section 6.

2. EV MARKET GROWTH IN THE GLOBAL SCENARIO

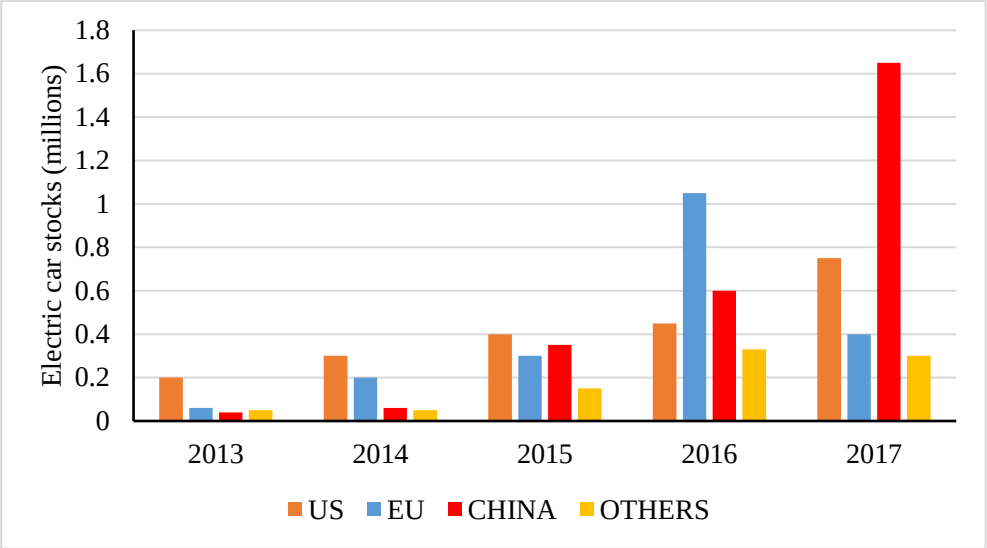


Figure 2: Electric vehicle growth in the global market

Though the sales of electric vehicles are gaining momentum globally, the distribution across countries is not uniform. China leads in EV sales. The EV market share in China was 4.7% in 2019[3]. Around 245,000 BEVs were sold in the US in the year 2019[4]. Electric cars sold in the Chinese market are more than double the units delivered in the United States, the second-largest electric car market globally as shown in (Figure 2).

[3] https://cleantechnica.com/2020/01/13/china-2019-electric-vehicle-market-share-grows-to-4-7-despite-tighter-incentives/

[4] https://www.statista.com/statistics/698414/sales-of-all-electric-vehicles-in-the-us-by-brand/

3. CHALLENGES IN SHIFTING TO ELECTRIC FREIGHT VEHICLES

Truck owners have their share of anxieties about EFV adoption. EFVs have a higher cost of production compared to its diesel engine counterparts. For example, Tata Ace, a Light Carrier Vehicle (LCV) of 1-ton cargo capacity cost [5]INR 3.99 lakhs (exclusive of taxes). While Croyance Electro 1T, an electric Light Carrier Vehicle (LCV) of 1-ton cargo capacity is expected to cost around [6]INR 7-7.5 lakhs (exclusive of taxes). The difference in cost is approximately 48%. However, the cost of operation is lower for the EFVs. The EFVs are more economical in terms of kilometres clocked per unit amount of money. [7] The energy consumption ratio for diesel-powered trucks and electric-powered vehicles is 5 for urban delivery trips. In other words, diesel-powered freight vehicles consume 5 times as much energy as an electric truck at a given average speed in urban areas. Also, [8]electric vehicles have fewer moving parts, and hence require lower maintenance costs. Due to the lower cost of operating EFVs, it is expected to compensate for the higher purchasing cost, leading to break-even in terms of Total Cost of Ownership (TCO) with the diesel-powered trucks over a longer period of time. On an average, the break-even period for TCO is expected to be 4-5 years in urban deliveries. The prices of the vehicles are expected to drop with the adoption of state-of-art technologies in battery charge storage and manufacturing technologies. Psychological factors such as technology anxiety among truck drivers acts as a barrier to the adoption of EFVs.[9] It is the fear and distrust in users about the usability of new technologies which is often caused by the mismatch between technology use and resource availability. The willingness of the truck owners and operators to shift to EFVs can be changed by bringing in EV friendly policies.

a. Case Study - Electric Vehicles in Urban Europe (FREVUE)

FREVUE is a European project started in 2017, to demonstrate and evaluate the electric freight vehicle in 8 European countries. This large scale 4.5-year initiative was strategised to

[5] https://ace.tatamotors.com/blog/what-is-the-price-of-tata-ace-models-in-the-key-markets/
[6]https://www.drivespark.com/four-wheelers/2019/electric-commercial-vehicles-india-croyance-electro-launch-027624.html
[7] Tanco, M., Cat, L., & Garat, S. (2019). A break-even analysis for battery electric trucks in Latin America. Journal of Cleaner Production, 228, 1354–1367. https://doi.org/10.1016/j.jclepro.2019.04.168
[8] Palmer, K., Tate, J. E., Wadud, Z., & Nellthorp, J. (2018). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. Applied Energy, 209(July 2017), 108–119. https://doi.org/10.1016/j.apenergy.2017.10.089
[9] Zhou, M., Kong, N., Zhao, L., Huang, F., Wang, S., & Campy, K. S. (2019). Understanding urban delivery drivers' intention to adopt electric trucks in China. Transportation Research Part D: Transport and Environment, 74(July), 65–81. https://doi.org/10.1016/j.trd.2019.07.024

test the electric vehicle in real-world urban logistics. A survey was conducted with the drivers before and after the deployment of EFV.

Few observations of the FREVUE project are as follows:

- Deployed in Amsterdam, Lisbon, London, Madrid, Milan, Oslo, Rotterdam, and Stockholm.
- Industrial deliveries including food, waste, pharmaceuticals, packages, and construction goods were part of the project.
- Analysis, collected from 105 vehicles with an average distance traveled 52 km per day, shows that their deployment alone led to NOx savings of up to 2,000 kg and PM10 savings of over 70 kg/day.
- CO_2 savings, using well-to-wheel analysis, are between 176 and 190 tonnes CO_2 per day.
- Analysis of the transport models shows that light goods vehicles (LGV) penetrate much more deeply into the local traffic network than heavy goods vehicles (HGV).
- About 72% of the respondents favoured the replacement of ICE vehicles with EV which was 12% more than the survey conducted before EV experience. Some of the reasons for considering the adoption of EV were reduced maintenance cost, understood range was not an issue, government incentive and tax exemptions, and savings in fuel cost, i.e. unit cost of charging.
- Range anxiety: 55% of the respondents were rarely concerned, and only 15% were always worried about the range. A drop of 30-40% of range performance was reported during cold winter days.
- Queues are likely at public charging points, which will cause additional delay and loss of income to both drivers and logistics companies. Pre-booked charging points can be utilised to reduce waiting time.
- Resale value: customers were concerned with significant uncertainty about the resale value of their EFVs.

4. EV FRIENDLY POLICIES IN OTHER COUNTRIES

The governments and automobile manufacturers can initiate programs that would help in faster market penetration of electric vehicles. Many such policies and initiatives are being formulated to prevent further growth of ICE vehicles and boosting EV growth and adoption. Government of countries currently active in the EV initiatives includes Canada, China, Finland, France, Germany, India, Japan, Mexico, Netherlands, Norway, Sweden, the United Kingdom, and the United States

According to a study done in the region of Latin America, the difference in the break-even period for EFV is as high as 12 years for Brazil and Uruguay for Light Duty Trucks (LDTs) for urban delivery (<100 km). The huge difference is owing to the differences in policies. [10]Brazil imposes 35% import duties on foreign trucks in addition to other taxes, such as PIS and COFINS at 1.65% and 7.6%, respectively. It illustrates how policies can change the outcome of adoption for truck operators. Adequate charging infrastructure is essential for successful market penetration of EFVs. Government public funding and relaxation on charging costs would boost the market penetration rate. Crowdfunding could also be adapted to significantly increase the installations of charging infrastructure and reduce the cost of charging[11]. Policies and initiatives taken by major economy countries are discussed further in the following section. The initiatives are in the front of the cost of manufacturing, cost of purchasing as well as Total Cost of Ownership (TCO), Electric Vehicle Supply Equipment (EVSE), and fleet procurement. The initiatives need to be carefully tailored after identifying the deterrents.

a. Cost of manufacturing

The very high cost of EV manufacturing translates to the high cost of selling EVs. High energy density batteries used to power EV contribute the most to the cost of EV manufacturing (57% in 2015) [12]. More Research and Development (R&D) will contribute to lower the cost of manufacturing. From 2010 to 2019, lithium-ion battery prices have fallen from $1,100 per kilowatt-hour to $156/kwh (87% reduction). There has been a 13% reduction in battery costs from 2018 to 2019 alone[13]. Research facilities and funds are required for R&D to improve technology and bring down the cost of production.

[10] Tanco, M., Cat, L., & Garat, S. (2019). A break-even analysis for battery electric trucks in Latin America. Journal of Cleaner Production, 228, 1354–1367. https://doi.org/10.1016/j.jclepro.2019.04.168

[11] Zhou, T., Roorda, M. J., MacLean, H. L., & Luk, J. (2017). Life cycle GHG emissions and lifetime costs of medium-duty diesel and battery electric trucks in Toronto, Canada. Transportation Research Part D: Transport and Environment, 55, 91–98. https://doi.org/10.1016/j.trd.2017.06.019

[12]https://easyelectriclife.groupe.renault.com/en/day-to-day/charging/what-is-the-price-of-an-electric-car-battery/

In the United States, the Public Transportation Innovation Program and the Low or No Emission Vehicle Program provide financial assistance to the government, private companies, non-profit organisations, and universities to research zero-emission public transportation. The Low-No Vehicle Program provided $55 million in funding for R&D to cities and public transportation providers in 2017. The Advanced Research Project Agency-Energy (ARPA-E), U.S., has funded many EV projects, including batteries, automotive controls, and efficient EV chargers. Stanford University was funded about $3 million for research on Multifunctional Battery Chassis Systems (MBCS) that will help to reduce the cost and weight of the batteries powering the EVs. With a $4 million grant from ARPA-E, a power electronics company from Arkansas is working on speeding up the EV charging process[13].

China established a small-scale R&D program aimed at developing new energy technologies in 2001. With this program, the Chinese government realised that new energy technologies are economically profitable as well as help mitigate environmental problems. In 2006, the government approved a $184 million fund to support R&D via the National High-Tech R&D Program administered by the Ministry of Science and Technology (MOST). As per the recent National Key Research and Development Program of China for the nation's 13th Five-Year Plan, $111 million will be invested for 20 EV research projects[13].

b. Cost of ownership

EVs have a very high cost of purchase compared to conventional ICE vehicles. The cost of ownership is therefore high for the users, which is a major deterrent to EV adoption. In 2016, EVs cost about $15,000 more than conventional vehicles on average. It is not expected to match the price of conventional vehicles until 2025.

US federal government has announced tax credit for EVs purchased after December 31, 2009. The tax credit ranges from $2,500 to $7,500 depending on the battery capacity and gross weight of a vehicle. It is available for a manufacturer until it sells 200,000 EVs. The credit becomes 50% for the six months after that. This becomes 50% of the 1st 50% amount for another 6 months and so on. Eventually, the credit disappears completely. States in the US offer additional or separate incentives to that of the federal government. California offers rebates to EVs were low salaried families are qualified for an extra $2,000. Tax reductions upto $2,500 and $3,000 per vehicle were given by Louisiana and Maryland respectively[13].

[13] https://www.eesi.org/articles/view/comparing-u.s.-and-chinese-electric-vehicle-policies

In China, EVs are exempt from purchase taxes since 2014. The central government has also started a consumer subsidy program which is renewed every two or three years. The subsidy is decreased, and the eligibility threshold raised with every renewal. In 2010, a subsidy of $9,530 was available for EV, which covered 40% to 60% of the cost of the EV. In 2013, the subsidies for EV ranged from $5,600 to $9,530 based on a vehicle range i.e. battery capacity. The subsidy has been reduced year on year and eventually phased out entirely by 2020. Local governments also have their EV initiatives. Beijing and Shenzhen started its program to provide similar subsidies to the central government. These local subsidies were limited to 50% of the amount subsidised by the central government in 2016 to stop people from misusing subsidies. Dual-credit policy which came in effect in April 2018 imposes compulsory targets for vehicle manufacturers starting from 2019. To obtain these new energy credits, manufacturers are mandated to produce a minimum number of EVs, and the amount of credits they receive is based on factors such as driving range and EV weight. Manufacturers failing to meet the requirements will be fined or must buy credits from other manufacturers.

c. Fleet Procurement

Fleet procurement is another major policy adopted by private as well as government entities of countries. EV adoption is more likely to be easier and faster for public and private agencies operating fleets of vehicles. The schedule and vehicle routing for their fleet's operations are pre-planned which will minimise the impact of charging durations as well as range anxiety.

EVs were procured using federal tax credits from companies such as Ford Motor and Nissan by U.S. Department of Navy and cities like New Bedford and Massachusetts. Cities namely Los Angeles, Seattle, San Francisco and Portland have plans to purchase around 24000 EVs. Amazon announced in September 2019 that it was buying 100,000 electric trucks from an EV start-up, [14]Rivian, as part of its efforts to eliminate the carbon footprint of the company by 2040. The order will be the largest purchase of light-duty EVs in history. It will be a turning point for the EV market which will now likely see fleets electrification faster than ever before.

In 2014, China mandated that the central government, as well as some cities and public organisations, should have at least 30 percent of their vehicle fleet compositions be EVs by 2016. This goal was increased to at least 50 percent EVs in 2016. In January 2020,

[14] https://qz.com/1712151/amazon-orders-100000-electric-delivery-trucks/

[15]Amazon made an announcement of purchasing and operating 10,000 EVs which includes four-wheelers and three-wheelers to its India delivery fleet by 2025. It is working with Original Equipment Manufacturers (OEMs) to build these vehicles.

d. Electric Vehicle Supply Equipment (EVSE) network expansion

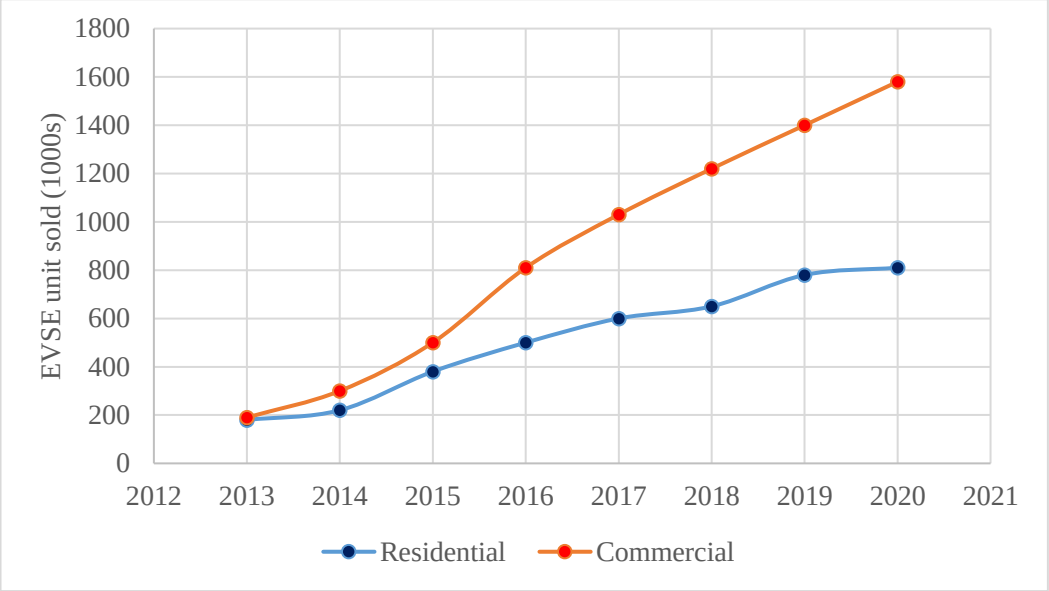
Another major deterrent for EV adoption by users is the range anxiety. Limited battery capacity and corresponding travel range necessitates additional charging stations and supporting infrastructure. The EVSEs are offered as domestic and commercial units depending on the location and the power connection types.

The European Automobile Manufacturers' Association (ACEA) came up with a 10-point plan to help the industry achieve targets set by Europe's Green Deal which included ramping-up EVSEs. The EU agreement of intervening to fill gaps on the network with areas of the low population did not satisfy the car manufacturers. The EV sector in the EU is in a state of mild decline. [16]The industry wants a guiding hand from the government to help manufacturers navigate the changes. Europe had 170,149 charging stations installed by the end of July 2019[17].

The US General Services Administration (GSA) has installed EV charging stations for federal employees and other authorised users. Discounts and tax credits are offered for installing charging stations. An attractive incentive of $4000 is provided to commercial customers with charging station by The Los Angeles Department of Water and Power. Residents of Arizona can receive a tax credit as high as $75 for installing a charging station in their own home[15]. As of March 2020, the United States has installed 78,500 charging outlets and 25,000 charging stations[18].

China had installed 213,903 charging outlets by 2017. The intention was to build an additional 120,000 charging stations and 4.8 million charging posts by 2020, which can accommodate 5 million EVs. $14 million will be provided to local governments to build charging stations provided they meet certain criteria such as reaching a set amount of EV purchases. Chinese provinces and cities have also announced to support installing charging stations with subsidies that could reach as high as 30% of the total investment[15]. Figure 3 shows the residential and commercial EVSE unit sales (2013-2020) in the world market.

[15] https://www.eesi.org/articles/view/comparing-u.s.-and-chinese-electric-vehicle-policies
[16] https://www.greentechmedia.com/articles/read/europes-car-makers-ask-for-help-to-realize-green-deal-goals
[17] https://www.statista.com/statistics/955443/number-of-electric-vehicle-charging-stations-in-europe/
[18] https://www.statista.com/statistics/416750/number-of-electric-vehicle-charging-stations-outlets-united-states/



[19]

Figure 3: Residential and Commercial EVSE Unit Sales, World Markets: 2013-2020

e. Preferential traffic treatment

Incentives in terms of preferential traffic treatment such as high occupancy vehicle (HOV) lane exemptions and expedited license plate acquisitions for EVs have also been offered. EVs have been allowed to use HOV lanes in more than 10 American states including California, Colorado, Florida, and New York. [20]In Hawaii, EVs are exempted from parking fees. EV drivers in New Jersey are offered a 10 percent discount on off-peak New Jersey Turnpike and toll road rates. Entry to bus lanes, free parking, fee reduction to obtain license plate and speedy processing are some of the advantages which makes EVs attractive in certain cities in China. Shanghai has waived the EV drivers' license plate fee which is about $15,900[20]. These incentives make EVs attractive to consumers in China where the process of obtaining a license is lengthy.

f. Comparison of EV incentives/ policy and market sales

Countries across the world have adopted numerous policy incentives designed to raise sales of electric vehicles, which act on automotive makers, private consumers, company consumers, and charging infrastructure facilitators. Incentives adopted in other countries including but not limited to direct subsidies, tax breaks, waivers on fees, electricity supply reductions, road priority, and access to restricted traffic zones.

[19] https://www.plugincars.com/simplicity-lower-prices-keys-evse-sales-growth-126787.html
[20] https://www.eesi.org/articles/view/comparing-u.s.-and-chinese-electric-vehicle-policies

Besides the vehicle characteristics and policy incentives, consumers' differences also have a great influence on electric vehicle acceptance and adoption. Table 1 shows the comparison of incentives for EVs across different countries.

Table 1: Comparison of incentives for EVs in different countries[21]

Country	Incentives for EVs
Norway	➢ Exempt from acquisition tax, representing around NOK 100 000 (USD 11 600) ➢ Exempt from the 25% value-added tax (VAT) on car purchases ➢ Waivers on fees such as road tolls and ferries
Iceland	➢ Exempt from all import duties on car purchases (0-65%), depending on CO2 emission level ➢ Exempt from 24% value-added tax (VAT)
China	➢ Exemptions from purchases and additional taxes ranged between CNY 35 000 and CNY 60 000 (USD 5 000 to USD 8 500) ➢ Local and regional authorities can complement these within the limit of 50% of the central subsidies
Japan	➢ Higher subsidies as the battery range increases, with the maximum subsidy set at JPY 850 000 (USD 7 700)
US	➢ Federal Internal Revenue Service (IRS) tax credit is for $2,500 to $7,500 per new EV purchased based on the size of the vehicle and battery capacity
UK	➢ 35% of the purchase price of an EV, or up to a maximum of £4,500, a grant of £500 is available to contribute towards the

[21] https://www.fleetcarma.com/countries-best-incentives-ev-purchases/

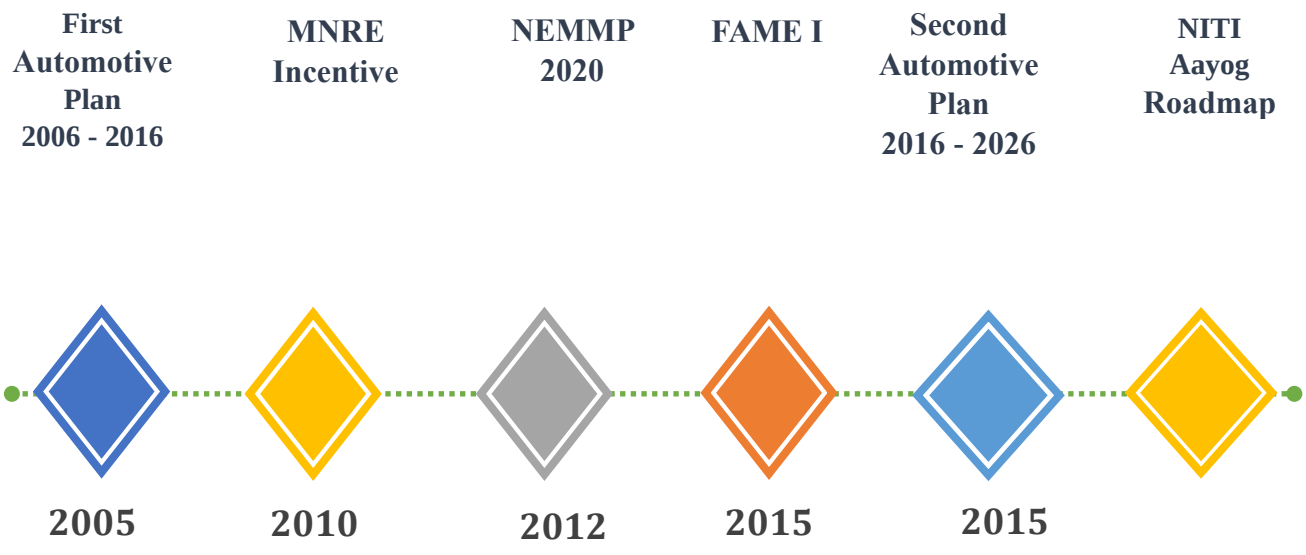
	cost of home charging installation
Canada	➢ The Ontario government offers a subsidy of up to $14,000 off the purchase price of an EV and up to $1,000 of the price of a home charging station and a green license plate. ➢ The Government of Quebec offers a rebate of up to $8,000 and 50% of the cost of a home charging station, or up to a maximum of $600. ➢ The Government of British Columbia offers a rebate of up to $5,000 of the price of an EV

5. ELECTRIFICATION OF VEHICLES – POLICY AND ADOPTION PLAN IN INDIA

The government of India has been working on electric vehicle policy and constantly revising them to increase the rate of EV adoption. Government EV policy is focused on developing a "shared, connected and electric" mobility option to reduce the dependence on crude oil and reduce carbon footprint in India. However, the policy-making is influenced by various economic and political conditions that affect the acceptance of public policy as well as its orientation towards supply or demand-side measures. Adoption of EVs depends on the system-wide changes in customer acceptance, public awareness of the technology, pricing of vehicle, set-up of public and private charging infrastructure, and government policy.

NITI Aayog is a policy think tank of the Government of India, established to achieve sustainable development goals. The organisation is the strategy arm of the government and has prepared the roadmap to steer, coordinate, and combine efforts of all the stakeholders. Three critical elements identified and discussed by NITI Aayog for causing a paradigm shift in the Indian mobility structure are system integration, shared infrastructure development, and scaled manufacturing. Different opportunity areas that include mobility as a service, big data, vehicle-grid interaction, and domestic manufacturing have been discussed. The proposed connected mobility strategy involves creating a fleet of electric vehicles that can transport people when needed and can support the grid at other times.

In India, 27 states have formulated or are in the process of formulating strategies and policies for transforming their mobility systems. This section discusses the steps taken by the government to support the early adoption of electric mobility solutions, and figure 4 shows the efforts with the timeline.



2017

Figure 4: Initiative by the Government of India towards EV

a. First Automotive mission plan (AMP) 2006-2016

It was launched in the year 2005 and the industry witnessed significant growth with a 10% excess in CAGR in the first half of the AMP. The slowdown in the global economy in the year 2008 saw a decline in sales across all vehicle segments except two-wheelers that experienced CAGR growth of 4.6%[22].

b. Ministry of New and Renewable Energy (MNRE) incentive plan

In 2010, the Ministry of New and Renewable Energy (MNRE) introduced a Rs. 95 cr subsidy scheme to provide incentives to electric vehicle buyers. The scheme provided subsidies of up to 20% on ex-factory prices of electric vehicles translating into a Rs. 4000 discount for low-speed and Rs. 5000 discount for high-speed electric two-wheelers; and close to Rs. 100000 for electric cars. The incentives increased the EV sales by 70% to about 80,000 units in 2011. The subsidy scheme expired in March 2012, which led to a steep drop in sales every month, leading to the shutdown of the industries. This clearly shows that the consumers and industries are dependent on subsidies and was the main reason for the scheme's failure as it was unable to create a sustainable market. New technology anxiety, lack of awareness, and unavailability of infrastructure support i.e. charging stations could be the major reasons for the low EV sales.

[22] "Automotive Mission Plan 2006 - 2016" by Ministry of Heavy Industries and Public Enterprises.

c. NEMMP 2020

National Electric Mobility Mission Plan (NEMMP) was a national mobility document prepared in 2012, providing the vision and the roadmap for the faster adoption of electric vehicles and their manufacturing in India. The highlights of the NEMMP 2020 are shown in table 2.

Table 2: Highlights of NEMMP 2020

Mission Highlight	Intended Effect/ Purpose
6-7 million electric vehicles on the road by 2020	• Reduction of GHG emission by 1.3% - 1.5% in 2020 compared to the status quo • Liquid fuel saving of 2-3 million tonnes
Government contribution of Rs. 12000-14000 cr and industry share Rs.8000 - 9000 cr i.e. a total of Rs.23000 cr is expected to be spent for the five year period	• Wider range of product in EV • Subsidies to boost EV sales • Good or adequate charging infrastructure • Extensive research

d. FAME I - 2015 to 2019

Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicle (FAME) scheme is an incentive scheme for the promotion of electric and hybrid vehicles in India. FAME was launched by the Ministry of Heavy Industries and Public Enterprises. FAME focuses on four areas, namely: technology development, demand creation, pilot projects, and charging infrastructure. FAME I started in 2015 and was completed on March 31st, 2019.

The main objective of this scheme was to promote electric mobility and plan financial incentives (subsidies to manufacturers and infrastructure providers) for enhancing the EV production and creation of transportation infrastructure.

Learnings from FAME 2015 are summarised below.

- Range of product: Customers were expecting a wider range of vehicle options to choose from. Delhi 2018 vehicle exhibition had 50 models of vehicles offering more choices for customers to adopt EV with the help of government incentives.

- Charging infrastructure: Adoption of EV faced challenges due to the availability of limited charging infrastructure. Focus on the development of charging infrastructure to meet the demand is addressed in FAME II
- Awareness programs: The general public was not aware of government efforts on EV adoption. Measures to promote awareness on EV adoption is essential in creating demand for EV adoption.
- Focus on shared transport: FAME I was focussed on options that would result in better outcomes in terms of more miles travelled, reducing traffic congestion and pollution.
- Incentives and subsidies: Subsidies and incentives can be offered to support Indian manufacturing units that manufacture EV components, batteries, and charging infrastructure. This will promote domestic manufacture that is suited for Indian conditions and reduce the cost of EV.

e. Second Automotive Mission Plan (AMP)

The second automotive mission was drafted for the years 2016 - 2026. This is a collective effort by the automotive industry and government of India to set the achievement target in the year 2026 on various segments of the automotive industry.

f. FAME II - 2019 - 2022

FAME II is the next phase of FAME I that is planned for a period of 3 years from 2019 till 2022. The total outlay of the scheme is Rs 10,000 crores which additionally focuses on charging infrastructure for electric vehicles. Incentives for freight vehicles have not been explicitly addressed in FAME II.

Highlights

The emphasis of this scheme is on the electrification of public transportation, including shared transport.

- For electric buses, demand incentives on operational expenditure to be delivered through state/city transport corporation (STUs).
- This scheme plans to support:
  - 10 lakh 2W (incentive of Rs. 20000/veh),
  - 5 lakh 3W (incentive of Rs. 50000/veh),
  - 55000 4W (incentive of Rs. 1.50 lakh/veh) and
  - 7000 buses (incentive of Rs 50 lakh/veh).
- 2Ws segment - focus on private vehicles.

- 3W and 4W segment - incentives apply mainly to vehicles used for public transport or those registered for commercial purposes.
- The incentive is offered by the government for electric buses.
- Incentives for plug-in hybrid vehicles with sizable lithium-ion batteries and electric motor are also included.
- The scheme proposes for the establishment of charging infrastructure, whereby about 2700 charging stations will be established in metros, other million-plus cities, smart cities and cities of hilly states across the country so that there will be the availability of at least one charging station in a grid of 3 km x 3 km.

Desired outcome

Penetration of EV: If FAME II and other measures are successful, India could realise EV sales penetration of 30% of private cars, 70% of commercial cars, 40% of buses, and 80% of two and three-wheelers by 2030[23].

Emission Savings: Assuming the above EV penetration until 2030 is successful, the vehicles supported under FAME II would cumulatively result in 5.4 M toe of oil demand savings and reduction of 7.4 MT of CO_2 emission over the deployed vehicle lifetime.

Vehicle kilometres travelled: EV buses deployed under FAME II by the year 2030 will cumulatively account for 3.8 billion vehicle kilometres travelled in the deployed lifetime. This is based on the assumption that buses operate for 365 days and runs 150 km/day for 10 years.

[23] "India's electric mobility transformation- Progress to date and future opportunities" by Niti Aayog and Rocky Mountain Institute.

6. EV – CURRENT SCENARIO IN INDIA

Electrification is an attractive solution to growing levels of vehicle pollution in metropolises and is of importance to India today. The automotive industry is already feeling the effects of electrification or e-mobility, both globally and in India. In [24]2030, the share of EVs is expected to range from 40% to 50% of new vehicle sales. Adoption rates could be higher in dense cities and metropolises with strict regulations and slow penetration in small towns.

E-mobility in India is happening now and is impacting auto component manufacturers. Auto manufacturers have started collaborating among themselves and OEMs to chart out a new path. A pan-India study to understand the adaptability of EV cars was conducted by Velocity MR, a market research and analysis company. In this research, data from a sample size of 2200 where only car owners were surveyed across Indian metro cities – Delhi, Mumbai, Bengaluru, Kolkata, Hyderabad, and Chennai. The results from their analysis showed that 90% of respondents showed a willingness to shift to EV cars provided that the right infrastructure is made available, along with optimum support systems for maintenance of their electric cars. 50% of the respondents suggested more government awareness programs to increase penetration of EV.

About 19 states and Union territories have charted and released guidelines and policies to ensure faster and seamless adoption of EVs. But these policy documents outline different approaches. Few states treat the EV shift as a manufacturing boon and, therefore, a job-creation opportunity, while other states are focused on building the public infrastructure of electric vehicles and charging stations. For instance, the EV policies of Uttar Pradesh and Maharashtra emphasise the promotion of EV manufacturing. States such as Delhi and Kerala, on the other hand, have policies that seek to reduce the number of ICE vehicles running and support the electrification of public and shared transport. Many more states are in the process of drafting their policies. Though different policies are likely to provide valuable experience and best practices, a common framework must be developed to encourage identifying and comparing the sustainability and longevity of EV policies drafted in all states.

a. Battery technology

As per NITI Aayog report, Indian government targets a minimum of 10 GWh (Gigawatt hours) of cells by 2022, which would need to be expanded to about 50 GWh by

[24] "India electric market overview report – 2018 to 2026". by India Energy Storage Alliance (IESA)

2025[25]. Lithium-ion battery technology stands at the centre of EV innovation, and a significant amount of progress has been made in this technology. Common battery technologies are discussed below:

- *NMC-Graphite battery cells:* These battery-cells use Nickel-Manganese-Cobalt (NMC) chemistry as cathode and graphite as the anode. At present these are the commonly used batteries that provide specific-energy of 200 Wh/kg or more, and the cell-costs are in between $150 to $200 per kWh. The major disadvantage is the safety issues due to the dissipation of heat. Thermal design incorporating heat-dissipation is, therefore, an important element of battery-pack design.

- *NMC-LTO:* These use Lithium-Titanium-Oxide (LTO) as anode instead of graphite. Their specific energy hovers around 80 Wh/kg to 100 Wh/kg and the current cost exceeds $450 per kWh. They can be used in specialised vehicles like buses that can be charged frequently when they stop at a bus stop.

- *LFP-Graphite:* Batteries with Lithium-Ferrous-Phosphate-Graphite (LFP-Graphite) have characteristics in between that of NMC-Graphite and NMC-LTO. Their specific energy is about 140 Wh/kg and has a theoretical limit of about 160 Wh/kg.

- *Lead-acid Battery:* These batteries employ lead oxide as positive active material; spongy lead as negative active element and sulphuric acid used as the electrolyte medium. The advantages of lead-acid batteries are that they are very commonly available and cost very less. The disadvantages are that they have a limited life cycle, low power density, and are very heavy.

Few future battery technologies include:

Solid - state batteries: These use solid electrolyte and solid electrodes instead of liquid or polymer gels. Automobile OEMs are taking a more proactive approach towards the R&D of solid-state batteries. Solid state batteries are expected to give a range of 800 km/charge and recharge 1000 times more than other types of batteries.

Carbon and its derivatives – Mumbai based start-up "Gegadyne energy" have tested batteries that use carbon and its derivative as active materials as battery technology. Carbon and its derivatives are available abundantly in India. It is expected that the batteries can be

25 'Zero Emission Vehicles: Towards A Policy Framework" submitted by Niti Aayog in Global mobility summit, September 2018

charged in less than 15 minutes from 0-100%. They are cheaper and lighter i.e. they are free from lithium and cobalt ion electrodes hence the cost to manufacture these batteries is 1.3X cheaper than lithium-ion batteries.

Metal-air battery: State-owned Indian Oil Corp (IOC) is looking to build-up India's capacity for developing indigenous batteries powered with new metals. IOC is working on metal-air battery technology that will produce energy by oxidising metals such as iron, zinc, and aluminium. These batteries cannot be recharged, but one can replace plates to power them up almost instantly, making it much more convenient for users, thereby eliminating the need for charging infrastructure. Since these indigenous metal powered batteries have high energy density, they promise to give a mileage of 500km.

b. Auto Manufacturing Industry

In India, the first wave focused on 2-wheelers, 3-wheelers, and passenger cars and several models have been launched in the past couple of years. Now the second wave focuses on buses and commercial vehicle segments.

2-wheelers: Already, several models of electric 2-wheelers such as Ather, Revolt, and Okinawa I Praise are in the market with the cost ranging from Rs.90,000 to Rs.1.15 lakh. Bike rental company Yulu and Bounce are using electric scooters that give a mileage of 60km per full charge.

Yulu @ Bengaluru | Ather | Revolt

Figure 5: Electric 2-wheelers in India

Passenger Cars: Few players who have launched EV passenger vehicles in India are Mahindra (Reva and Supro), Nissan Leaf, and Hyundai Kona. Electric SUV models have a mileage of 350 – 450 km/full charge and have a home charging facility. The cost range of the passenger SUV is Rs.18 lakh to 26 lakh based on the battery technology and car features. Sedans like Mahindra and Verito, Tata Tigor has 110 – 200 km mileage and price range of Rs.10 – 18 lakh.

Figure 6: Example of electric passenger cars

Light commercial trucks: Electric LCV is yet to hit the market and is given the least importance in the adoption plan. Only a few companies have plans for production and testing of electric LCV – 3 wheeler or 4 wheeler this year. Tata Ultra T7 launched recently has 62.5 kWh battery pack and a driving range of 100 km. It can be fully charged in an estimated time of two hours with a DC fast charger.

Amazon has planned 10,000 electric rickshaws by 2020 as part of the company's delivery vehicle fleet in India[26]. Amazon has been conducting pilot tests in various countries and based on the vision "Shipment Zero", Amazon has made a global commitment of 100,000 EV delivery fleet by 2030.

Figure 7: Tata Ultra V7

Bus: The Government of India (GoI) has launched the "Green Urban Transport Scheme", enabling a shift towards electric vehicles for public transport. The average cost of hybrid or electric buses is 3-4 times higher than diesel buses. The cost of a bus in India is in the range of Rs.1.75 - 2.5 Cr. However, GoI has sanctioned 5,095 electric buses to 64 cities for intercity, intra-city, and last-mile connectivity as an initiative to FAME II. These buses are

[26] The Economic times, December 2019, https://economictimes.indiatimes.com/

estimated to run 4 billion kilometres during the contract period, which will result in 1.2[27] billion litres of fuels saved cumulatively and avoid 2.6 million tonnes of CO_2 emission. Local manufactures such as Ashok Leyland, Deccan Auto limited and JBM have partnered with International manufacturers Optare of UK, Zhongtong Auto Co. of China, and Solaris Bus and Coach of Poland respectively to set up assembly units in India.

Tata Starbus

Volvo Electric

Figure 8: Examples of electric buses

c. Charging Infrastructure

As per FAME II the government has given sanction for setting up of 2636 charging stations in 62 cities across 24 states and union territories that includes 256 stations in Tamil Nadu. Out of 2636 stations, 1633 stations are planned to have fast charging and 1003 stations slow charging facility. Companies such as Tata Power and Indian Oil have plans to venture into charging infrastructure.

Swapping stations are considered as short-term infrastructure design and have an economic value for commercial users, as opposed to only a matter of convenience. While urban charging (fast) and personal or home chargers are mid-term infrastructures that are envisaged to reduce costs and have a high penetration of urban charging infrastructure, the long-term implementation will be towards highway charging and solar power panels. Developments in solar energy and decentralised renewable energy generation networks could account for a large share of mobility's energy requirements.

[27] "FAME II Report - 2019 – 2022" by Government of India and Ministry of Heavy Industries and Public Enterprises.

d. Market for EV

The shift to electric vehicles is of utmost significance, and in India EV market has gained significant momentum after the implementation of FAME. In 2018 the total EV sales were 365,920[28] units and is expected to grow at a CAGR of 36% till 2026. Linking FAME India and Make in India there is hope that there will be the faster adoption of EV in India.

Companies are designing and testing products suitable for the Indian market with a key focus on two-wheelers and three-wheelers. In 2019, the total EV sales reached a total of 759,600[29] units, which include electric two-wheelers (126,000), electric three-wheelers (630,000), and electric passenger vehicles (3,600).

Ola**,** an Indian Taxi Company has launched "Mission Electric" that plans to integrate 10,000 e-rickshaws and electric autos by 2020. They have also partnered with Kia and Hyundai for electric cars as an additional fleet to the existing vehicles.

Merger Trend: The emerging trend is that various auto manufacturers are going in for a merger with other companies to expand in the EV market. For example, Toyota, the No. 2 automaker in the world, and Suzuki, the third-largest in Japan on local sales, have entered into a partnership in shared procurement, green vehicles, IT, and safety technologies.[30]

e. Challenges in Penetration of EV

Incentives/subsidies play a major role in promoting EV sales however, few other factors/criteria are to be considered to improve or support the positive uptake.

- ***Charging infrastructure:*** From the operational perspective of EVs, the charging infrastructure is vital. Challenges to charging infrastructure arise out of its two components i.e. location (land resource) and electricity. Since land and electricity are handled by different departments in India in terms of policy making, governance, and operations, achieving close co-ordination among different departments is a key challenge in the absence of a single empowered group.
- ***Electric demand***: In India, at present only 33% of the electricity is [31]generated by renewable sources while the coal-based thermal power plants contribute a major portion of the non-renewable sources. Based on the estimated projection of growth in demand for EVs in the

[28]"India electric market overview report – 2018 to 2026". by India Energy Storage Alliance (IESA)
[29] "India's electric mobility transformation- Progress to date and future opportunities" by Niti Aayog and Rocky Mountain Institute.
[30] The Economic Times, November 18, 2019. https://economictimes.indiatimes.com/
[31] Ministry of New and Renewable Energy Annual report 2019" by MNRE

future "the overall electricity demand from electric vehicles in India is projected to be around 79.9 gigawatt hours by 2020 and is expected to reach 69.6 terawatt hours by 2030."[32]

- ***Sync of government policies:*** The central government has drafted policy and target to achieve 100% EV adoption in India by 2030 in terms of subsidies and incentives, and infrastructure plan. A major bottleneck is that the state government policies are not in sync with that of the centre. Only a few states such as Andhra Pradesh, Punjab, Delhi, and Tamil Nadu have initiated and drafted policy and regulation to align with the central government EV adoption plan.
- ***Emission*****:** The government strategy to adopt EV is to reduce the tailpipe emission of GHGs. While EVs are celebrated for their zero emissions from the tailpipe, one should consider the emissions from the source of generating electricity. Well-to-wheel provides a holistic view of the total pollution caused by driving the vehicle. In India, the main source of electricity is from coal-fired thermal power stations which cause air pollution. We need to consider if complete EV policy would be beneficial, particularly considering the long-term costs associated with healthcare and environmental degradation.
- ***Range Anxiety:*** The range anxiety of an EV is an outlook challenge that has resulted in the low uptake of EVs, further resulting in low investments from the private sector.
- **Product range:** Customers expect vehicle models with various capacities and features to choose from.
- **Ownership Cost –** About 70% of the respondents of the survey conducted by Velocity VR were willing to pay 17% more than their ICE vehicles of the same category. According to the survey conducted by Bloomberg NEF, a research organisation, 69% of the [33]Indian car buyers preferred vehicles priced below $10,000 and 26% responded that they would consider EV if the price is between $10,000 to $19,000.
- ***Policy, Tariff, and Design*****:** Changes in the policies and regulations, and appropriate electricity tariffs will accelerate the adoption of EVs. Government has to collect a nominal tariff for EV charging that will motivate people to adopt or switch to the electric vehicle.
- ***Charging Standards:*** Application and development of power and communication standards to future-proof electrification investment and open doors for low-cost innovation.

[32] Ministry of New and Renewable Energy Annual report 2019" by MNRE
[33] "Electric vehicle outlook 2019" a report by Bloomberg NEF

- ***Vehicle safety:*** Stringent quality measures and safety standards have to be implemented to ensure only good quality batteries are used in the cars. This will assure people to invest in EV.
- ***After-sale service:*** Customers are unsure of the after-sale service in terms of maintenance and change of parts coverage. Good after-sale service and planned infrastructure will attract consumers to purchase EV.
- ***Battery degradation:*** Li-ion heats up at a temperature of 32^oF – 45^oF and loses 2% of the shelf life every month. Life of battery life depletes if the battery is kept on the shelf for more than 2 years. Hence, customers have to make sure new batteries are purchased with the EV. Build up are formed in the electrodes due to the chemical reaction while charging that contributes to the sudden loss of capacity.

f. Strategies/ consideration to improve EV penetration

- Awareness Program: One of the main reasons for the difficulty faced in the penetration of EVs in India is the lack of awareness among the consumers. The government, together with the manufacturers, can conduct awareness programs to clear misconceptions about range, cost, and infrastructure. More emphasis on the benefits of EV, the environment and reduced fuel cost can be highlighted.
- Fossil fuel prices: In recent years, the cost of fossil fuel is steeply rising, and the hike in fuel prices will favour the penetration of EV in India. The government subsidies for EV will further motivate consumers to shift to EV.
- Focus on the 2-wheeler market: In India, two-wheelers are predominantly used. Focus on improving the penetration of EV two-wheelers will boost EV sales and market.
- Charging Infrastructure: Currently, in India, charging infrastructure is in a nascent phase with few stations implemented in some states while it is still in the planning phase in other states. Installing more stations that are easily accessible and at proximity to users will motivate the customers to purchase EV.