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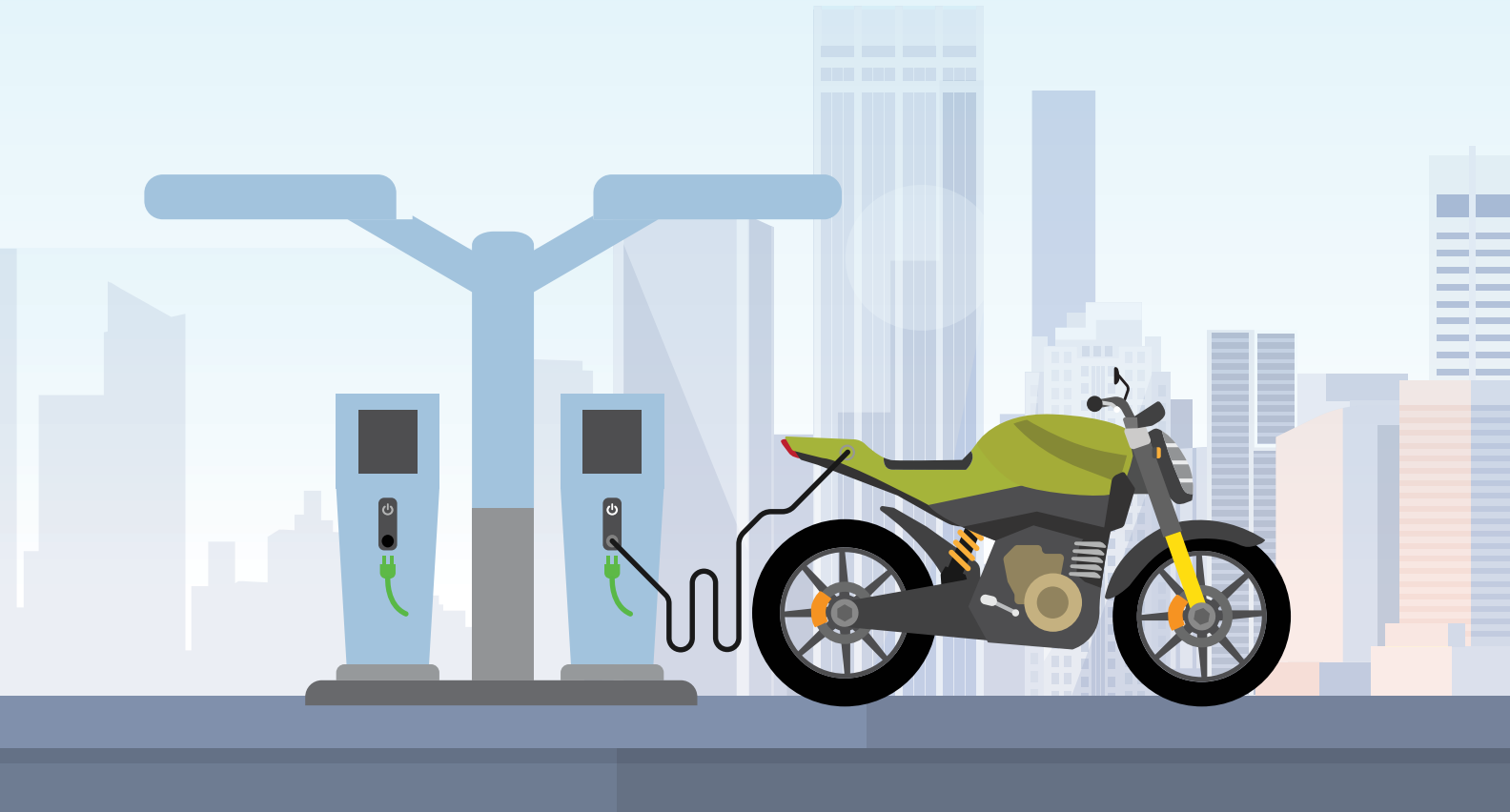
FASTER ADOPTION OF ELECTRIC VEHICLES IN INDIA: PERSPECTIVE OF CONSUMERS AND INDUSTRY



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Faster adoption of electric vehicles in India: Perspective of consumers and industry

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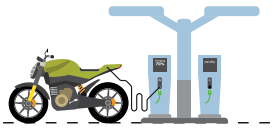

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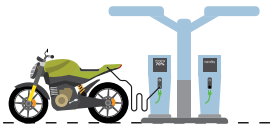

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EXECUTIVE SUMMARY

India endeavours to be on a path of energy transition in the road transport sector. The National Electric Mobility Mission Plan (NEMMP) 2020 was launched in 2013.The genesis of the endeavour is the vision to reduce urban pollution, meet the GHG emission targets as promised in UN climate change pact and to become an energy independent nation.

The objective of this report is therefore to do a comprehensive analysis on significance of electric vehicles (EV) as a solution, steps taken by government to promote the same, challenges to its adoption and evaluate solutions to promote faster adoption of EVs.

Mobility Scenario in India

In order to evaluate electric mobility as a promising solution, an in depth analysis of current and expected future mobility usage is required. According to 2011 census, approximately 31% of India's population resided in cities. This number is expected to increase to 40% in 2030 and 50% in 2050.

Analysis of travel pattern in Indian cities shows that two-wheelers are very popular. Two-wheelers provide a lifeline to majority of citizens in absence of an affordable and reliable public transport infrastructure. Two-wheeler ownership is at 45–50% of households in Tier II and Tier III cities and close to 30% for households in Tier I cities. Census data also shows that two-wheelers remain the most popular motorized mode to travel to work, even ahead of buses. According to the same data, 17% of people in urban areas and 8% in rural areas depend on two-wheelers for commuting to work. As most rural citizens do not have fixed places of work and have mixed transport needs, their dependence on two wheelers therefore have not been fully captured in Census numbers.

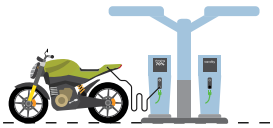
Analysis of trip lengths shows that 85% two-wheeler owners in rural and 75% two-wheeler owners in urban use their vehicles for <20km distance.

This report therefore focuses on analysing electrification of two wheelers, the most popular mode of motorized transport in India

Role of Electric Vehicles in India's Mobility Scenario

In 2017, with total vehicular production over a 25 million in numbers, India's auto industry was the fourth largest producer of cars and largest producer of two wheelers. Though penetration levels of the private vehicles is still among the lowest in the world, the sheer number of vehicles on roads presents some challenges. Emissions from vehicles are source of local pollution and is one of the challenges towards achieving India's climate change targets. Switching to alternate powertrains can help in reducing the emissions. As per the analysis in this report among all the alternate powertrain options- biofuel, hydrogen fuel, and CNG- electric powertrain promises to be more close to mass deployment.

Electric powertrains will not only help in reducing urban air pollution but also mitigating GHG emissions, and enhancing energy security. This report further validates



the narrative by calculating the actual impact of electric vehicles on emissions, and energy consumption in possible EV adoption scenarios.

Emission and Energy Impact of Electrification of Two- Wheelers in India

According to TERI analysis, Two-wheelers which composed of more than 80% of the vehicle sales in India were responsible for about only 13% of the emissions from all on-road vehicles in 2018-19.

To estimate the emission and energy savings from phased adoption of electric two- wheelers, the analysis followed a bottom-up approach. Growth scenarios in two- wheelers by 2025 and 2030 across different segments were projected based on GDP and population growth. This was followed by estimation of EV penetration under three scenarios. In the business as usual (BAU) scenario, a growth trend similar to what has been observed till now for this segment is assumed. The other two future scenarios are based on technology improvement and high ambitious policy pursued by the government with a very high degree of policy push along with technological improvements. Further savings in energy consumption and CO2 emission were calculated under these EV penetration scenarios.

The analysis reveals that the impact on emissions and energy savings is only significant in high ambitious scenario and is further limited in scope of consideration. The calculations consider only tank to wheel scope i.e. the emissions are estimated only for the use phase of the vehicles. If the scope is expanded to include well to wheel, the impact of transition may be lesser with projected mix of sources of generation of electricity in India. To achieve the energy independence and emission targets, phased adoption of EVs will have to be complimented with change to greener energy mix and thrust on expanding the reach of public transport systems.

The market penetration of electric two-wheelers in new sales under the three scenarios is assumed to range between 2-5% in 2025 and 10-30% in 2030. Corresponding range of expected emission and energy savings in 2030 are 2.7- 6% and 3-7% respectively. The High Ambition scenario is assumed with several unlikely factors playing in favour like policy support continuing at central and state level and falling battery prices in order to ensure parity between ICE and EV in two-wheelers.

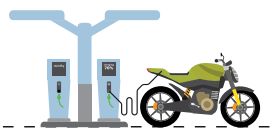
Perspective of Consumers in Electrification of Two-Wheelers

In order to achieve a higher EV penetration, an in depth understanding of consumer perspective towards EV is critical. An online stated preference survey was conducted on 212 individuals across the country towards this objective. The preferences of three categories of individuals were evaluated:

- Existing electric two-wheeler owners
- Potential electric two-wheeler owners and
- Potential petrol two-wheeler owners

The survey results as summarized below best describes EV as a secondary vehicle with limited applicability and associated with range anxiety. Higher price for ICE comparable EV, lack of adequate charging facilities and uncertainty around battery replacement came out as major barriers to adoption. Analysis of the survey data revealed the following:

1. Most electric two-wheeler owners also owned another ICE two-wheeler. None of them used the electric two-wheelers for work trips.
2. The potential and existing electric two-wheeler owners did not consider electric vehicles being economically better or having better utility than the comparable ICE vehicles. Environment friendliness comes out as the justification for choosing electric vehicles over ICE.
3. The range between charging and lack of charging facilities were the major sources of anxiety for existing and potential electric two-wheeler owners. However, the degree of anxiety amongst the potential owners was much higher than the existing owners.
4. The respondents who were planning on buying a petrol two-wheeler in the near future stated lack of charging facilities and concerns about battery



replacement as the main reasons for not choosing to buy an electric two-wheeler.

5. About one third of the potential petrol two wheeler owners were willing to pay up to Rs. 20,000 extra for an electric vehicle which offered similar performance as their preferred ICE vehicle.

Business Feasibility and Overall Expected Charging Infrastructure Requirement

To address the range anxiety among potential EV customers, adequate charging infrastructure is required. An in-depth analysis of various possibilities of EV charging and associated business models has also been carried out in this report.

Almost all electric two-wheeler owners charged their vehicles at home. Home charging is a complex problem in India as most urban citizens live in MURB (Multi Unit Residential Blocks) and many lack parking facilities within their buildings. Private charging facility at home is a primary consideration for boosting the initial uptake of electric vehicles.

As adequate public charging infrastructure is essential for increasing the adoption of electric vehicles. This report assessed the business feasibility of public charging stations (PCS). Through analysis it was found that break even occurs at tariffs significantly higher than home charging rates. On the other hand, it was found that existing or potential electric two-wheeler owners require public charging tariff to be competitive with the home charging rates, for regular charging and not charging only in the case of emergency. The main driver of longer breakeven are the real-estate rental costs in cities for PCS.

To make charging infrastructure viable for initial low demand scenario, measures such as enabling real estate procurement at key locations at lower costs, capital subsidy, or interest subvention on capital expenditure should be considered. The minimum charging station requirements to be eligible for incentives as per ministry of power guidelines should also be brought down. Support from state authorities and local DISCOMs for single window approvals and providing power infrastructure to bear additional electricity load is also needed. Finalization of charging standards for all vehicle categories will be helpful in reducing demand uncertainty for type of charging equipment and yielding higher utilization of charging infra.

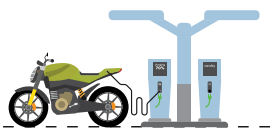
Business analysis of battery swapping stations was also undertaken. The analysis shows that BSS would even be more expensive than PCS and home charging, and presenting host of other customer satisfaction, operational and technical challenges.

This report also attempted to understand how much energy be required to be set up to cater to the electric two-wheeler demand projected in the technology upgradation scenario and what will be the costs for the same. To make a successful adoption of electric vehicles there has to be planned coordination in research, policy, and implementation of both energy and transport sectors.

Industry's Perspective in Electrification of Two-Wheelers

With the phased adoption of electric vehicles, the entire supply chain of the automobile industry is expected to be affected. All the major value drivers such as battery, motor, controller, chargers, and other electronics are currently being imported from other countries. India also does not have reserves of key raw materials for all the major components such as lithium, cobalt, permanent magnets etc. According to conversation with industry executives, Indian companies are already investing in EV research and manufacturing. But there is general concern against hasty push to EV. Therefore, policy measure is equally required for supply chain to retain the value addition in India. Initiatives at country level to procure strategic raw material reserves, bring investments for cell and other electronic component manufacturing, and reskilling of the workforce should be of paramount importance. Phased manufacturing of EV and its components linked with financial incentives such as laid out in FAME II is therefore a much appreciated a step in that direction.

More than 50% of the workforce directly employed in automobile sector is involved in engine manufacturing.



The sector also indirectly employs a large population in the after-sales service industry for ICE vehicle and the ancillary industry. This workforce will be at risk of unemployment and therefore is an area of concern for industry. Industry and government will have to work towards a reskilling plan and explore investments in charging infrastructure and energy management to create new employment opportunities.

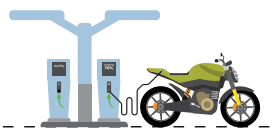
Business and Financing Models

Study projects phased adoption to electric two-wheelers as an important necessity, however, it comes with significant demand and supply side challenges. Bridging of wide cost gap of electric two-wheelers with ICE vehicle, setting up of widespread charging facilities to overcome the range anxiety issues among initial prospective customers are the key demand drivers. On the supply side, building a robust value chain for manufacturing electric two-wheelers will be necessary.

The electric vehicle adoption also presents the classical chicken and egg problem. Sustained policy support to bridge large cost gap and improve consideration for initial customers. Followed by achieving the critical mass demand and supporting EV research, supply chain localization and value retainment. Finally, leading to higher scale of domestic production has the potential sustainably reduce the vehicle cost for customers.

Direct financial incentives such as laid out in FAME II is the right step towards achieving this critical mass. Specific use cases highlighted in the report can further be focused upon. Use cases such as commercial application of electric two-wheelers for food & goods delivery, shared rental services can specifically be targeted. For the personal use case, cost effective leasing and other financial products need to be explored. Measures such as lower taxes, lower tolls, and special parking provisions can further aid the EV selling.

Battery amounts to almost 40~50% of the EV cost. Localization of cell manufacturing will therefore help in reducing EV costs, and achieving self-sufficiency to ensure a sustainable EV growth. A national level strategy to secure critical raw material sources for cell manufacturing, and to incentivize local cell manufacturing through capital subsidy, favourable trade & FDI policies, and investment models such as PPP are need of the hour.



1 BACKGROUND OF THE STUDY

India endeavours to be on a path of energy transition in the road transport sector. The National Electric Mobility Mission Plan (NEMMP) 2020, launched in 2013, aimed at paving the way for a shift from fossil fuel-based mobility to an electric powered one. The mission set an ambitious target of 6–7 million electric vehicles in the country by 2020. The impact of subsequent schemes and initiatives by the Government of India, mostly channelled through the FAME schemes, has been limited in achieving the targets of NEMMP. As of June, 2019, just about 2.7 lakh electric vehicles have been sold under the FAME scheme since its implementation in April, 2015 including about 1.7 lakh electric two-wheelers. The government has announced that the country would shift to an entirely electric public transport along with 30% electric private vehicles by 2030, lending a further push towards the goal of electrification (Sasi, 2019).

Recent data collated by SMEV[1] indicates that 54,800 electric two-wheelers and 1200 electric four-wheelers were sold in 2017–18. In terms of the total cars and two-wheeler sales, these figures translate into a miniscule proportion. Electric two-wheelers constituted an insignificant, 0.002%, in the entire two-wheeler sales in 2017–18. Similarly, electric cars formed a mere 0.0003% of the total car sales in India for the same financial year (FY). Considering the total market sales in FY 2016–17 were only 39,000 (electric two-wheelers and four-wheelers), India has certainly shown a progress towards electric vehicle adoption, but a slow one (SMEV, 2017). The sluggish growth as compared to the visioned numbers clearly indicates the presence of unforeseen challenges impeding the targeted electrification.

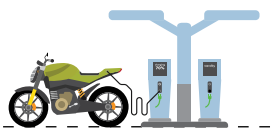
There is a need to acknowledge that a quick transition, howsoever well-desired, might be challenging to achieve in the absence of a clear policy, limited understanding about technological challenges, infrastructural deficiencies, and lack of consumer acceptance and awareness in the Indian market. Quick technological transitions may also have negative externalities on the job markets. To enable faster adoption of electric vehicles, it is imperative to develop an understanding of these challenges. Against this background, TERI in association with the Society for Development Studies (SDS) proposes to undertake a research study and aims to bridge the vital gap between the expectations of the consumers and the industry actors vis-à-vis government policies, initiatives, and actions.

Objectives of the Study

The proposed study aims to develop an understanding of the challenges that are limiting the adoption of electric vehicles in the country and suggest measures to address them. The study will focus on bringing forth the perspective of the consumers in terms of their preference and willingness to pay, perspective of the industry focusing on challenges faced in terms of their manufacturing capabilities, and resource availability.

TERI defines 'front runners' in the electric vehicle context as the segments that have potential to scale up with relatively lower investment, basic infrastructure

[1] Society of Manufacturers of Electric Vehicles, India



requirements, and minimal effort. TERI, in its earlier work, identified the front runners based on demonstration of early adoption success, dependence on public charging infrastructure, choice of products available to the consumers, local manufacturing capabilities, ease of implementation, and availability of government support. From the analysis TERI identified two-wheelers as a potential front runner in the personal vehicle segment contingent on certain factors.

The adoption of electric two-wheelers in India is larger and faster than other personal vehicle segments. Other than contributing to reduction in air pollution, switching to electric two-wheelers will also generate considerable savings for the users with negligible dependence on public charging. Even then, the growth of adoption of electric two-wheelers is just at a fraction of the rate required for achieving the national target. For the same reason, the electric two-wheelers are the primary focus of this study.

The broad objectives of the study are as follows:

1. To understand the mobility scenario in India

In this section, the study will investigate the current mobility pattern in India. The aim will be to understand the share of different modes in passenger transport and their preferences and roles. This section will also assess the negative externalities of rising travel demand in terms of energy consumption, carbon emissions, and local air pollution. This component of the study will also include a brief review of alternative fuel technologies for the transportation sector. This objective is covered in Chapter 2 of the report. The sub-objectives of the chapter are as follows:

a. Understand the mobility patterns: The preferences, shares, and roles of various modes in urban and rural India
b. Understand the transport-related externalities: Local air pollution, national energy security, and GHG emissions
c. Understand the alternative fuel technologies

2. **To understand the role of electric vehicles in India's mobility scenario**

Under this component, the study will investigate the role of electric vehicles as a potential solution for sustainable mobility in India. The section will aim to understand the Indian automobile industry regarding the segment-wise production and sales of vehicle. This section aims to understand the current state of electric mobility in India in terms of technology, sales, usage, and policy intervention at the local, state, and national levels. This objective is covered in Chapter 3 of the report. The sub-objectives of the chapter are as follows:

a. Understand the composition Indian automobile industry: vehicle production and sales
b. Understand the policy framework supporting electric mobility in India: national- and state-level policies
c. Understand the front runner vehicle segments in the electric adoption

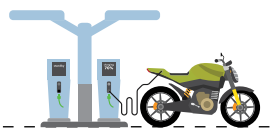
3. To estimate emission and energy impact of electrification of two-wheelers in India

Under this section, the study will estimate the potential emission, energy, and cost impact of different scales electric vehicle adoption developed as scenarios. Using bottom-up approach, this section projects the growth in two-wheelers by 2025 and 2030 across different segments. Based on alternative growth projections, the emissions and energy savings are estimated. This objective is covered in Chapter 4 of the report.

4. To understand perspective of consumers in electrification of two-wheelers

Under this component, the study will investigate current consumer preference, focusing specifically on the two-wheelers segment. The aim will be to gain insight on their product, technology, infrastructure, financial, and policy preference. Based on the literature and secondary data, consumer's willingness to pay will also be estimated.

The analysis will focus on assimilating preferences and willingness to pay for different consumer categories. A literature and industry review of Indian and similar global markets will be undertaken to understand the larger orientation and direction of the automotive market. The aim of this exercise will be to understand who will be the likely users of electric vehicles and what their likely needs and demands be. To understand the needs of the possible electric vehicle users, the study will also look into the current mobility pattern of the public and personal transport users. This section will help



in understanding the opportunities and obstacles in adoption of electric vehicles, as perceived by the users. This objective is covered in Chapter 5 of the report. The sub-objectives of the chapter are as follows:

a. To understand the current electric two-wheeler market
b. To understand the preferences for electric Two-wheelers amongst Indian consumers

5. To assess business feasibility and overall expected charging infrastructure requirement

This section will focus on understanding the ecosystem required for faster adoption of electric vehicles. The section will estimate the charging requirements for the predicted increase in electric two-wheelers in India. By developing scenarios based on capital costs, operational costs, battery prices, etc. this section will also assess the business feasibility of a PCS and the overall costs per electric two-wheeler for the charging ecosystem. The aim will be to identify the major components/costs impeding faster adoption of electric two-wheelers. The study will assess the scenarios for public charging, home/residential/private charging, and battery swapping. This objective is covered in Chapter 6 of the report. The sub-objectives of the chapter are as follows:

a. Understand the private charging scenario for supporting electric two-wheelers
b. Understand the business feasibility of a PCS
c. Understand the overall costs for an ecosystem of PCSs for electric two-wheelers
d. Understand the overall costs and feasibility of a battery swapping ecosystem for electric two-wheelers

6. To understand industry's perspective in electrification of two-wheelers

This section will focus on understanding the perspective of the automobile Industry and its ancillary industries regarding the paradigm shift into electric. The objective of this section is to understand the change in the supply and value chain of automobiles in India on phased adoption into electric. The section aims to briefly scope the effect on employment and domestic value added from the EV transition. The section will understand the perspective also through interviews with vehicle and component manufacturers, mobility service providers, and industry lobby bodies. This objective is covered in Chapter 7 of the report. The sub-objectives of the chapter are as follows:

a. Broadly understand the effect on employment from electric transition
b. Broadly understand the effect on GDP from the electric transition
c. Understand the industry's perspective, issues, and requirements for electric transition through primary interviews with the stakeholders

7. To identify suitable business and financing models for different electric vehicle segments

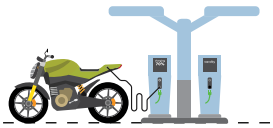
This section will focus on technological, infrastructural, and economic challenges confronted by the consumers, industry, and the government (as the supplier of infrastructure). As cost is one of the key barriers to the uptake of electric vehicles, the focus will be to identify alternate business and financing models which will help in addressing the cost barrier faced by users/fleet operators during the procurement and use of electric vehicles. The aim will be to assess the relative benefits and drawbacks of alternate models and suggest suitable business and financing models for different electric vehicle segments based on the resource availability and financial capacity of the buyers/city governments/fleet owners. The study will also identify policy and regulatory barriers towards implementation of these models.

The study will largely focus on assessing two alternate business models for electric buses (outright purchase and wet lease) and three alternate models for two-wheelers (financing over life, leasing, and financing batteries separately). This objective is covered in Chapter 8 of the report. The sub-objectives of the chapter are as follows:

a. Understand the innovative approaches to promote uptake of electric two-wheelers in India
b. Understand international innovative business practices to promote the uptake of electric vehicles

Scope

This study focuses on approaching towards faster adoption of specifically electric two-wheelers in India. The study uses Indian and international secondary



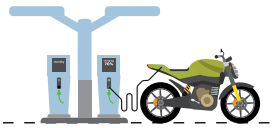
literature including TERI's previous work. The primary literature in this paper includes an online consumer survey and structured interviews conducted with the industry stakeholders. Modelling exercises were carried out for estimating energy and emission savings and also assessing the charging requirements and public charging business feasibility. These models were developed for Indian scenarios using assumptions derived from secondary sources. The temporal scope of the analysis carried in this study is limited to 2029–30 with 2019–20 as the base year. Geographically, the analysis is largely limited to India with the use of few International case studies. This study also focuses solely on electric technology for automobiles and does not explore the literature on other clean technologies. Within the automobile sector, this study limits itself to understanding the two-wheeler segment and its pathway to electrification.

Methodology

This study will mostly rely on literature review and discussions with the stakeholders in the industry, policy making, and financial institutions. Also, the current study will utilize earlier research undertaken by TERI on the subject and build upon the existing knowledge. Chart 1 explains specific activities that will be undertaken towards meeting the specific objectives of the study.

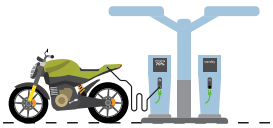
Chart 1: Study methods and components

S. No.	Objective	Methodology	Components
1	To understand the mobility scenario in India	Review of secondary literature	Mode shares in Indian cities vis-à-vis others Mode preferences and trip length for work (Census 2011) Role of various modes Transport-related externalities (global warming, energy security, air pollution) Fuel technologies
2	To understand the role of electric vehicles in India's mobility scenario	Review of secondary literature	Vehicle production and sales in India Policy framework supporting automobile electrification in India (national and state) Front runners vehicle segments in electric adoption
3	To estimate emission, energy, and cost impact of electrification of two-wheelers in India	Establishing analysis framework (spatial and temporal) Projecting travel demand and vehicle growth Modeling scenarios Review of secondary literature for assumptions	Energy savings Emission savings Cost savings
4	To understand perspective of consumers in electrification of two-wheelers	Review of international literature Review of Indian literature Analysis of electric two-wheeler market Primary online stated preference survey	Preferences of current electric two-wheeler owners Preferences of potential electric two-wheeler owners Preferences of potential petrol two-wheeler owners



S. No.	Objective	Methodology	Components
5	To assess business feasibility and overall expected charging infrastructure requirement	Review of Indian and international literature Review of Indian policies/ regulations on charging Estimating energy requirements Modeling scenarios for charging businesses	Private/home charging Public charging station Battery swapping systems
6	To understand industry's perspective in electrification of two-wheelers	Review of Indian literature Primary interviews with stakeholders	Expected effect on employment Effect on domestic value added Market of electric two-wheelers Policy support required at State and National Levels
7	To identify suitable business and financing models for different electric vehicle segments	Review of case Studies- Indian and international	EV leasing and rental models in India International business models

Note: The study will be restricted to analysing the passenger vehicle segment. Freight vehicle segment will not be covered as part of this study.



2 MOBILITY SCENARIO IN INDIA

Overview

India is witnessing urbanization at a pace experienced by no other country. Between 2001 and 2011, the urban population in the country grew by 90.99 million. According to 2011 Census, India's urban population is 377.11 million that is around 31.16% of the country's total population. Around 600 million people will start living in towns and cities in India by 2030 (McKinsey Global Institute, 2010). As a result of urbanization, cities are also experiencing a rise in their travel demand. While the role of transport as an enabler of economic growth is well recognized, mobility also remains critical to ensure well-being of citizens by facilitating their access to socio-economic opportunities.

Indian cities display a diverse mobility pattern. Larger cities have the higher mode share catered by public transport and non-motorized transport. The role of public transport, especially the mass transport services such as buses and metros, diminishes significantly as the city size decreases. Private vehicles especially two-wheelers assume an important role in fulfilling the mobility needs of the people. The same is also reflected in the spiralling population of cars and two-wheelers (2W) in the country, which have been witnessing a CAGR of 10.1% (see Figure 1) compared to 5.9% for buses (see Figure 2) between 2006 and 2016 (MoRTH, 2016).

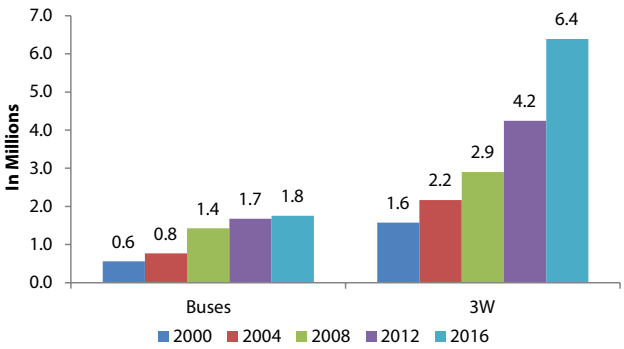


Figure 2: Registered public and Intermediate Pubic Transport (IPT) vehicles (in millions)

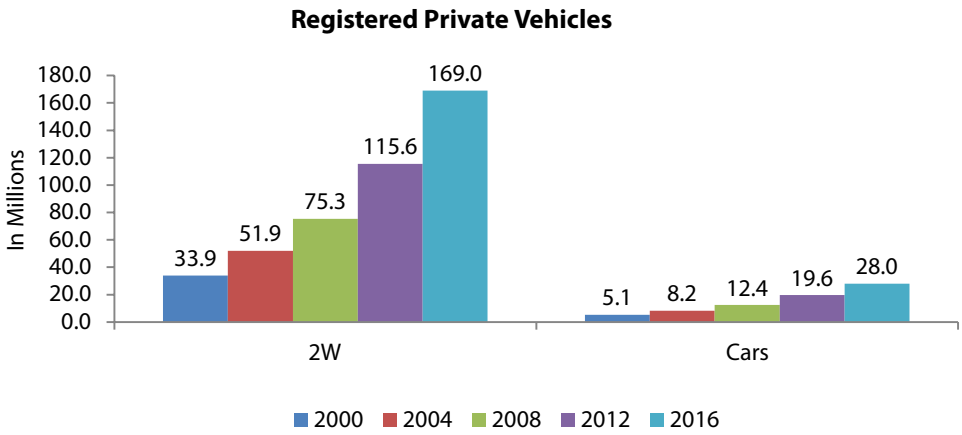


Figure 1: Registered private vehicles (in millions)

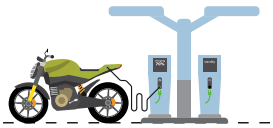


Table 1: CAGR of registered vehicles

Year	2W	3W	Cars and jeeps	Buses
2000–04	11.2%	8.3%	11.8%	8.3%
2004–08	9.8%	7.6%	10.5%	16.8%
2008–12	11.3%	9.9%	11.3%	4.1%
2012–16	10.0%	10.8%	9.3%	1.2%

As per TERI's transport projections, the on-road stock of passenger vehicles will be more than double, from 180 million in 2016–17 to 373 million in 2029–30 (see Figure 3a).

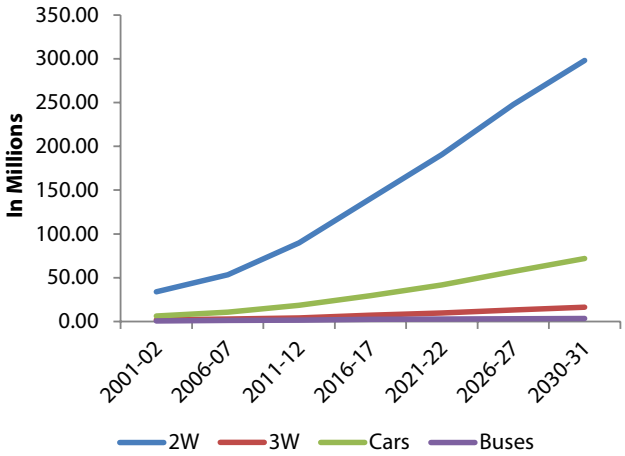


Figure 3a: On-road passenger vehicles stock in India from 2001–02 to 2016–17 and (projected) 2016–17 to 2030–31

It is estimated that the road transport contributed to approximately 213 Million Tonnes of carbon dioxide. Two wheeler segment contributed to about 20% of the emissions (see Figure 3b). Similarly, the road transport segment consumed about 2.9 Million Tera Jule of energy in 2017-18 and two wheeler segment contributed to about 21% of the energy consumed (see Figure 3c). The relative shares of two wheelers in energy consumed and emissions released is not estimated to change significantly till 2030.

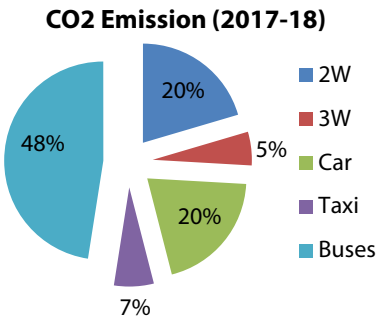
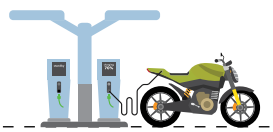


Figure 3b: Estimated CO2 emissions from vehicle segments in 2017-18



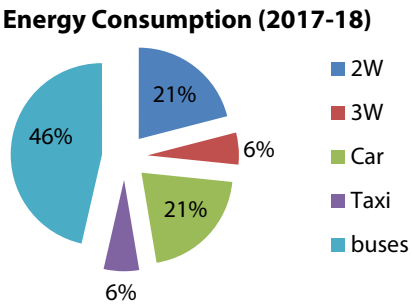


Figure 3c: Estimated Energy consumption from vehicle segments in 2017-18

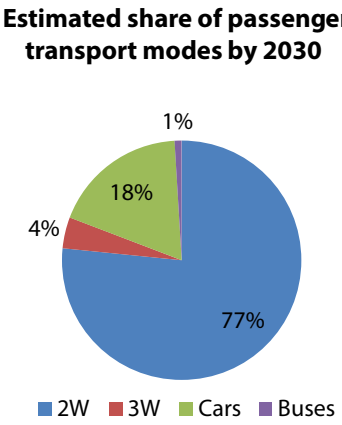


Figure 4: Estimated share of passenger transport modes by 2030
Source: TERI Estimates, 2018

It is estimated that two-wheelers constitute 78% of the total passenger vehicles stock at present and will account for 77% by 2030. This translates to approximately 285 million two- wheelers on-road by 2030. The share of cars is expected to grow up to 16% by 2030 while light motor vehicles (LMVs) or three wheelers (3W) expected to hold a constant share in the total passenger vehicle stock (see Figure 4).

India's automotive industry is the fourth largest in the world, contributing 7.2% to the Indian gross domestic product (GDP) in 2017.[2]

Lack of quality public transport in cities has resulted in growing dependence on private modes. Rapid economic growth, urbanization along with rising incomes and aspirations of the population are expected to further fuel the ownership and usage of personal automobiles

[2] Details available at https://www.steel-360.com/stories/the-changing-landscape-of-indian-automotive-industry

in Indian cities. It is, therefore, imperative to counter the negative externalities associated with the transport sector such as air pollution, emissions, noise pollution, congestion, and resultant loss of productivity, by expanding public transport and building non-motorized infrastructure, while also decarbonizing private cars and two-wheelers.

Electric mobility offers a potential solution to lower emissions and pollution while offering similar level of mobility to the people. Latest developments in some parts of the world demonstrate that the electric vehicle technology has reached a level where it is comparable to their ICE counterparts in terms of performance, such as speed, pick-up, and range. In some applications, it offers greater benefits especially in terms of operational cost savings given its better efficiency, lower maintenance requirement, and lower energy and emissions. While the electric vehicle market in India is still evolving, government support in terms of FAME-II and entry of large number of EV players in the market are a positive sign and indicate a large impending growth in the sector.

Electric technology may assume a greater market share in the two-wheeler vehicle segment, if it becomes affordable and cost competitive when compared to conventional ICE two-wheelers. Low dependence on public charging infrastructure may also contribute in higher acceptance of this product. Proliferation of public charging or provision of removable battery may lead to faster growth of electric two-wheelers among the consumers.

The next section of the chapter discusses the mobility pattern in different Indian cities and the role of different modes of transport in meeting the transport needs of the people. The analysis is mostly drawn from the information compiled from various comprehensive mobility plans for individual cities and the information on work-related mode use provided in the Census 2011.

Mobility Pattern in Indian Cities

The past few decades have seen a process of rapid urbanization globally with more than 50% of the world's population residing in urban areas since 2007 (UNDESA, 2015). In 2018, there were 33 megacities in the world with more than 10 million inhabitants. By 2030, it is projected that there will be 43 megacities, with most of them located in developing regions (UNDESA, 2015). India has been one of the fastest urbanizing countries in the world (Table 1). According to the Census 2011, India's urban population increased from 286 million in 2001 to 377 million in 2011. As of 2011, 31.1% of India's population resided in urban areas. It has been projected that by 2030, 40% (600 million) of the population will reside in urban areas and that by 2050 this figure will increase to 850 million, that is 50% of the total population (MoUD, 2016). As per Census 2011, there were 53 urban agglomerations (UAs) with population more than a million and 3 mega-cities with a population of over 10 million (Census, 2011). It is expected that by 2030, 63 UAs will have population greater than 1 million and 4 UAs (Chennai, Bangalore, Hyderabad, and Ahmedabad) will enter the 10 million plus population bracket in addition to Delhi, Mumbai, and Kolkata (UNDESA, 2015). The rapid pace of urbanization will also result in massive need for transport in Indian cities. Table 2 shows the rate of change of urban population amongst the BRICS nations.

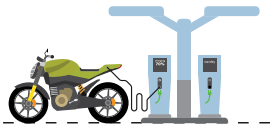
Table 2: Average annual rate (%) of change of the urban population

Country	1995–2000	2000–2005	2005–2010
Brazil	2.40	1.69	1.31
Russian Federation	–0.26	–0.36	0.02
India	2.51	2.67	2.47
China	3.63	3.98	3.55
South Africa	2.45	2.37	2.17

Source: MoUD (2016)

Mode share in Indian cities

Globally, SDG, COP 21, and New Urban agenda identify mobility as a foundation for sustainable development. Goal 3 and Goal 11 focus on promoting healthy lives and well-being for all at all ages, by targeting substantial reduction in air pollution and the need to adopt and promote safe, affordable, accessible, and clean transport systems for all by 2030 (11.2 UNSG, 2016). With rapid urbanization, the cities' spatial spread is increasing, leading to higher trip lengths and proliferation of personal vehicles around the world.



Although there has been phenomenal increase in population of private motor vehicles in the last 10 years, Indian cities are still, typically, catered by non-motorized transport and public transport. The share of non-motorized trips varies with the size of the city. The share of walking trips ranges from 37% in cities of 0.1 million population to 28% in mega-cities with a population of 10 million (Tiwari, 2006). In cities having a population range of 0.5 to 1 million, about 20% of trips are made through cycles in contrast to larger cities with a population more than 1 million where cycling trips account for less than 15% (Ghate, 2014). The share of public transport also varies as per the size of the city with Tier I cities such as Delhi having 31% public transport share (MoUD, 2016) and Mumbai having mode share as high as 67% of the total motorized trips (Lea Associates, 2016). The share of non-motorized trips has declined from about 40–60% of the total trips in the early 1980s (Kumar Kartik, 2015) to about 30–40% in 2008 (MoUD, GoI, 2008). The share of public transport has declined significantly too.

As illustrated in Table 4, the share of public transport has gradually declined since 1994.

Table 3: Mode share of public transport in different cities (%)

City category	Population range (in lakhs)	RITES, 1994	WSA, 2007
1	<5	14.9–22.7	0.0 –15.6
2	5–10	22.7–29.1	0.0–22.5
3	10–20	28.1–35.6	0.0–50.8
4	20–40	35.6–45.8	0.2 –22.2
5	40–80	45.8–59.7	11.2 – 32.1
6	Above 80	59.7–78.7	35.2 –54.0

Source: (MoUD, GoI, 2008)

Lack of adequate public transportation in Indian cities is reflected in rapidly rising shares of the personalized transport modes, especially two-wheelers. The share of two-wheelers ranges between 30% and 35% in medium-size cities which have limited public transport availability whereas it caters to 5% and 10% mode share in Tier I cities.

Table 4: Mode share of personalized modes

Tier	City	Population UA (in millions)	Cars*	Two-wheelers*
I	Mumbai	18.4	9.8%	7.1%
I	Chennai	8.7	7%	26%
II	Surat	4.6	2%	36%
II	Pune	5	11.8%	35%
III	Bhopal	1.9	3%	25%
III	Jaipur	3.1	8%	27%
III	Amritsar	1.2	7%	26%
III	Agra	1.7	1%	21%
IV	Ajmer	0.6	2.5%	20%
IV	Tirupati	0.5	3%	32%

*Mode share of motorized trips

Source: Compiled from comprehensive mobility plans of respective cities (year will be different for different city reports)

Trip lengths are a function of city size; with the sprawling cities, the trip lengths in Indian cities have been rising. Table 5 shows the trend in average motorized trip lengths in Indian cities. The same can also be corroborated from two-wheelers ownership data(Figure 5) which is around 45–50% for Tier II and Tier III cities whereas it is only 32% for Tier I cities.

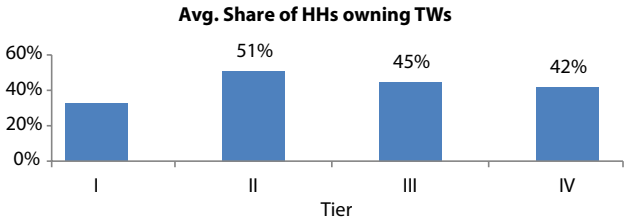
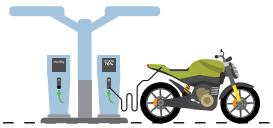


Figure 5: Average share of households owning two-wheelers

Table 5: Trend in average motorized trip length in Indian cities

S.no	Population range (in millions)	Motorized trip length (1994)	Motorized trip length (2011)
1	<0.5	2.1–3	3.83–4.53
2	0.5–1	2.6–4.5	3.58–7.2
3	1–2	4.1–5.5	5.87–3.81
4	2–4	5.51–6.4	5.6–8.03
5	4–8	6.4–7.62	8.03–11.35
6	Above 8	7.62–8.32	11.2–15.79

Source: (CSTEP and IUT, 2015) (MoUD, GoI, 2008)



As per CSTEP and IUT (2015), the average motorized trip length for cities with population above 8 million was in the range of 11 to 16 km; 8 to 11 km for city with 4–8 million population, 6 to 8 km for 2–4 million city, 6 to 3 km for 1–2 million city, and 4–7 km for city with less than 1 million population in 2011. Clearly, city size is closely correlated with the trip length in cities. It can be seen that trip lengths across cities have increased by 30–40% between 1994 and 2011 for larger cities (1 to 8 million).

Mode preference and trip length for work purpose

Census 2011 carried a question on the mode used by people for work, while this data does not provide an accurate picture of the mode share; however, it does provide a good understanding about the preferred mode choice of people. The response for this question was captured for 200 million people in India, of which 78% were males and 22% were females. Of the people surveyed, 42% resided in rural areas and 58% resided in urban areas. 17% of the urban work trips and 8% of rural work trips were attributed to two wheelers (see Figure 6).

Non-motorized modes remain a mainstay for mobility in India; 36% people in urban areas and 35% in rural areas rely on walking and cycling to go to work. Two-wheelers constitute the next most commonly used mode to reach the workplace. In urban areas, the number of people using two-wheelers exceeds the ones who rely on buses which are used by 11% of the people. In the case of Delhi too, the use of two-wheeler is 13%, compared to 11% of people using buses (Figure 7).

Trip length as per the Census, 2011

The analysis of distance travelled by motorized modes in rural India, urban India, and a metropolitan city (Delhi) shows that two-wheelers are used in a similar manner as cars and buses in terms of trip lengths. In rural areas, the trip lengths covered by two-wheelers are similar to the ones covered by cars (see Figure 9). Almost 80% of people using cars and two-wheelers travel in a range of 11 to 20 km. Buses cover distances as long as 31 to 50 km in rural areas. In the case of urban India, almost 80% of people used two-wheelers for travelling distances up to 6–10 km and cars and buses for 11–20 km(see Figure 10). In the case of Delhi, the trip lengths were found to be very similar for two-wheelers and buses (see Figure 11). More than 80% of people used them for covering 11–20 km, more than 80% of people using cars for travelling distances up till 21–30 km. Table 6 summarises the discussion here.

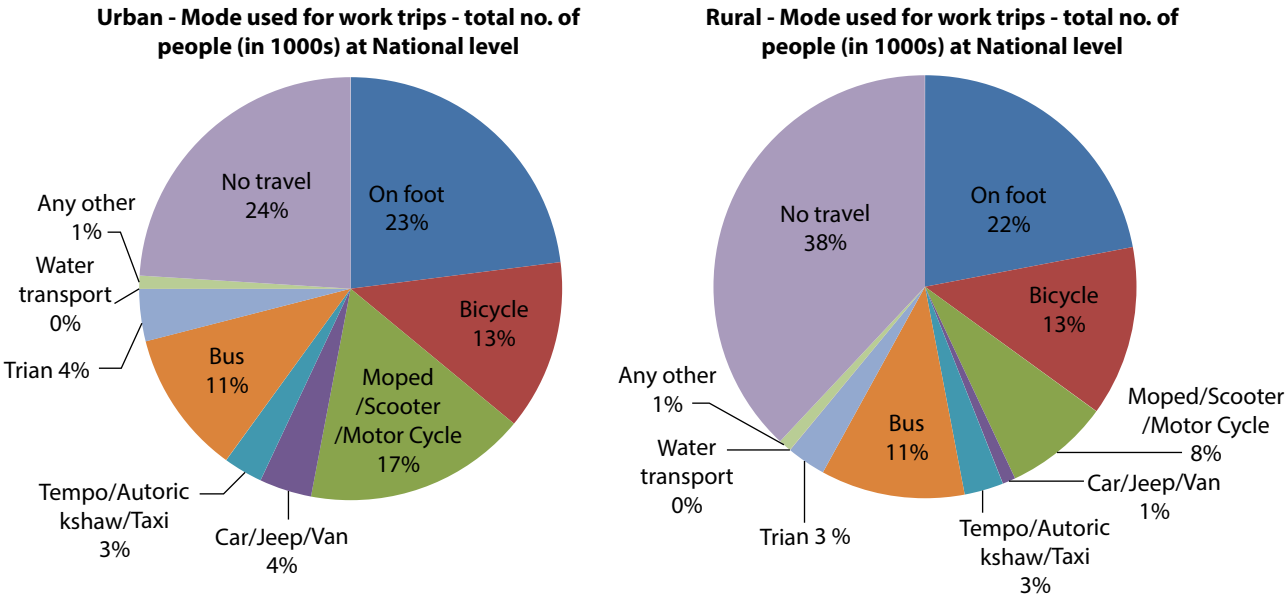


Figure 6: Urban and rural mode used for work trips in India

Source: Census 2011

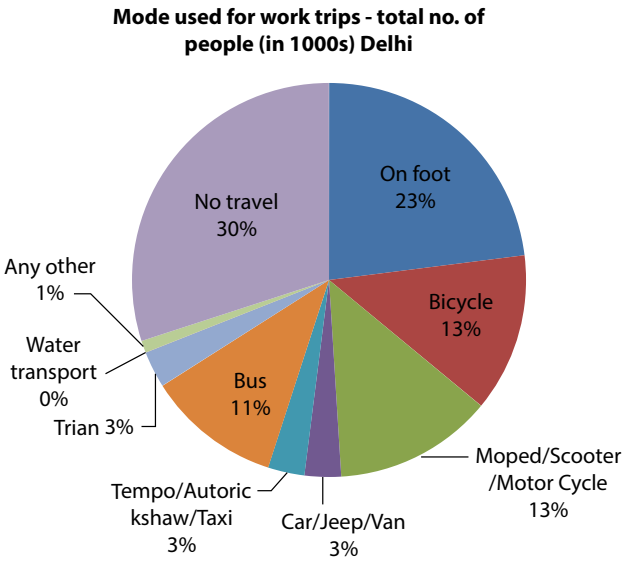


Figure 7: Mode used for work trips in Delhi

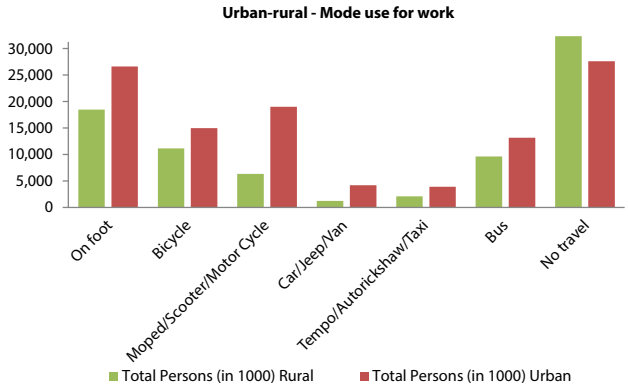


Figure 8: Urban–rural mode use for work

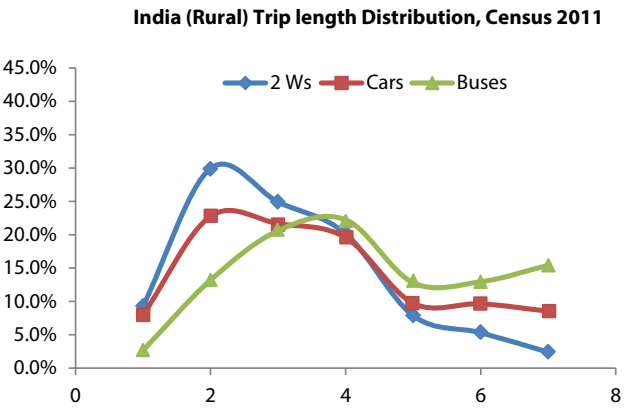


Figure 9: India (rural) trip length distribution

Source: Census 2011

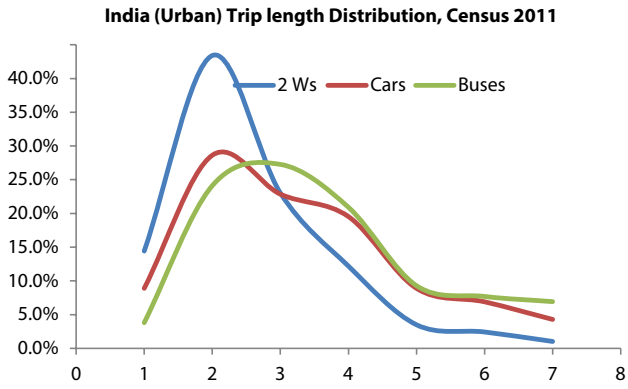
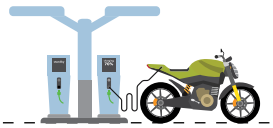


Figure 10: India (urban) trip length distribution

Source: Census 2011

Table 6: Distance travelled for work purpose

Distance	2 Ws (India - Rural)	Cars (India - Rural)	Buses (India - Rural)	2 Ws (India - Urban)	Cars (India - Urban)	Buses (India - Urban)	2 Ws (Delhi)	Cars (Delhi)	Buses (Delhi)
0–1	9.3%	8.0%	2.7%	14.4%	8.9%	3.8%	8.1%	5.4%	2.8%
2–5	30.0%	22.8%	13.2%	43.4%	28.6%	24.1%	29.8%	19.8%	22.2%
6–10	24.9%	21.7%	20.6%	23.0%	22.9%	27.3%	26.1%	21.9%	30.8%
11–20	20.2%	19.6%	22.3%	12.2%	19.5%	20.9%	23.6%	28.1%	27.8%
21–30	7.9%	9.7%	12.8%	3.5%	8.9%	9.3%	8.3%	14.8%	10.3%
31–50	5.3%	9.7%	13.0%	2.4%	6.9%	7.7%	3.4%	8.5%	4.8%
51+ km	2.4%	8.6%	15.4%	1.0%	4.3%	6.9%	0.8%	1.6%	1.2%



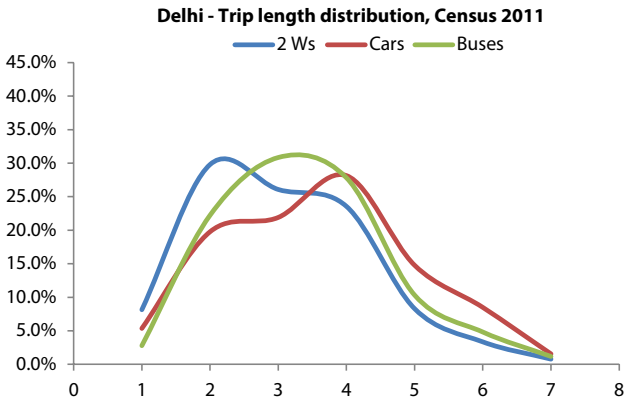


Figure 11: Delhi - trip length distribution (Census 2011)

Role of various modes

Cities depend on a range of transport modes, varying from non-motorized to motorized. While motorized modes are typically used to cover larger distances, buses and metro typically form the mass transport services in the larger cities in the country. There is also a large dependence on para-transit systems such as rickshaw, both motorized and non-motorized. They are typically used as a last mile solution in larger and medium cities where the mass transport services such as buses including BRTS and metro form the skeletal transport network. In the smaller and medium towns, where no such skeletal transport systems are available, these solutions are used for end-to-end line primary trips.

Expansion of public transport has taken place in a very limited manner in Indian cities. Formal bus systems operate in handful of cities. Most of the cities are catered by informal or poorly regulated transport systems which create externalities such as pollution, safety. In larger cities where some kind of public transport is present, comfort and convenience factors prevent people from using these modes. Non-motorized transport and public transport have been reduced to largely being a captive mode of use. People aspire to shift to a two-wheeler as soon as owning it becomes possible; the same is also applicable to two-wheeler users, who aspire to own a car.

As per Road Transport Year Book (MoRTH, 2015), 210 million vehicles are plying in Indian roads in 2015 out of which two-wheelers have highest share at 73.5%, followed by cars with 13.6% and the lowest share is of buses with 1%. As per Census of India, the average share of households owning two-wheelers is more than 30%, with highest share of 51% and 45% in Tier II and Tier III cities.

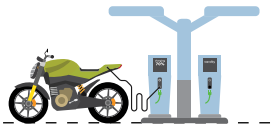
In order to curb the negative externalities associated with high personal vehicle use, it is important that cities invest in quality public transport systems that are affordable to the masses. The long distance trips in cities must be shifted to public transport. Intermediate public transport such as mini-buses, auto-rickshaws and non-motorized transport modes including cycle rickshaws, walking, and cycling should typically form the last and first mile solutions. Non-motorized facilities need to be strengthened so that people can walk and cycle for short distance trips, which the data shows are substantial in the case of Indian cities; 40% of people travel less than 5 km as per Census, 2011 for work. Census 2011 accounts only for the trips made by "other workers" from home to work. It defines 'other workers' as workers other than cultivators, agricultural labourers or workers in the household industry. However, in the absence of strong public transport, personal vehicles will continue to play an important role in fulfilling the mobility needs of Indian people.

Transport-related Externalities

While transportation stimulates economic growth and development, it also contributes to a significant share in energy consumption and consequent emissions. Adopting a low carbon and sustainable pathway for mobility in cities can play a key role in reducing the overall energy consumption and emissions in cities. Electrification of mobility solutions is one such option which has the potential of not only reducing carbon emissions and air pollution, but also enhancing energy security and, therefore, helps in promoting energy efficiency in cities.

Enhancing energy security

The on-road vehicles have been following an increasing trend in India. The number of registered motor vehicles in India has grown at a CAGR of 10% over the last 15 years with two-wheelers constituting the highest share (TEDDY, 2017). Presently, the growing demand for energy



is met largely through oil imports making India the fifth largest oil importer in the world (UNEP, 2014). In order to reduce the dependence on oil imports, it is important that India explores alternative fuel technologies such as electrification of transport. Adoption of electric vehicles (EVs) in road transportation will significantly limit India's need for importing fuels which can lead to self-sufficiency in terms of fuel requirement.

The gravity of the need for adoption of electric vehicles can be accessed by the fact that India can save 64% of energy demand from the road sector for passenger mobility through its EV programme (with 100% electrification) by 2030. This would result in a reduction of 156 million tonne of oil equivalent (MTOE) in diesel and petrol consumption for that year (NITI & RMI, 2017). Although, targets have been reduced to 30% electrification in the road transport sector, the adoption would entail a significant reduction in energy demand and GHG emissions.

Greenhouse gas mitigation

In 2015, according to the Biennial Update Report by the Government of India (submitted to the UNFCCC), India emitted 2137 million tonnes of CO_2 equivalent of GHGs in 2010 (MoEFCC, 2015). This makes India the fourth largest GHG emitter in the world (IEA, 2015). The report states that the energy sector is the prime contributor to GHG emissions with 71% to the country's total GHG emissions; 14% of the total emissions by energy sector are contributed by the transport sector, wherein road transport is the major contributor (88%) followed by the aviation sector. According to Nationally Determined Contributions (NDC) targets, India needs to reduce its carbon emissions by 33–35% from the base year of 2005. EVs have zero-tail pipe emissions and its convergence with renewable energy can significantly reduce carbon emission from the transport sector. As with continued dependence on fossil fuels, the emissions are expected to increase by nearly four times in comparison to the existing levels (NTDPC, 2014).

Moreover, after adopting the National Electricity Plan (NEP) in 2018, India remains on track to overachieving its '2˚C compatible' rated Paris Agreement NDC climate action targets. Estimates show India could achieve part of its NDC goals—a 40% non-fossil-based power capacity by 2030—more than a decade earlier than targeted (Climate Action Tracker, 2018).

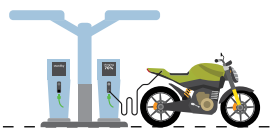
The government's policy has been clear to indicate inclination towards adoption of electric vehicles, which is also complemented by initiatives to ramp-up renewables in India which can provide access to affordable power at scale, and quickly. The government recently increased its previous 2022 capacity target for renewables from 175 GW to 227.6 GW (Climate Action Tracker, 2018). A report published by Coal India in 2018 highlights the declining future costs of solar and renewable electricity storage (Coal India, 2018), which is likely to foster low-carbon investments.

Reduce local pollution

Urbanization, transportation, industrialization, power generation, and agricultural activities are the key drivers that lead to air pollution through release of emissions (Sumit Sharma, 2017).Air pollution is a major concern in India cities, according to a study conducted by the Central Pollution Control Board (CPCB) for six Indian cities (i.e. Delhi, Kanpur, Bangalore, Pune, Chennai and Mumbai); the transport sector contributes 30-50% of the PM emissions in these cities and majority of NOx (NTDPC, 2014).

In fact, according to World Health Organisation (WHO), 14 out of 20 most polluted cities in the world are in India. Traffic related air pollution—especially PM and NOx—has been shown to lead to premature morbidity and mortality. Furthermore, according to Centre for Science and Environment, the alarming increase in the levels of pollution, is a public health emergency that confronts India today (Sunita Narain, 2018). From the perspective of promoting clean air in cities, it is critical to reduce the burden of vehicular emissions through use of low-polluting/clean transport technologies.

In order to address the growing concern of urban air pollution, Greenhouse Gas (GHG) emissions and an opportunity to enhance energy security of the country, it is imperative to explore alternative fuel-technologies which can minimise the externalities posed by the growing road transport sector. The following section aims to briefly discuss the various alternative



technologies and strategies that focus on enhancement in quality of fuels, technologies, and strengthening of the systems for control of pollution.

Alternative Fuel Technology Solutions

An alternative fuel technology may be defined as a technology solution which powers the vehicle by any fuel other than the conventional petroleum-derived fuels (diesel or petrol); it can be primarily referred to any technology of engine powering that does not entail solely petroleum (such as solar powered, electric car or hybrid electric vehicles). Such a vehicle is therefore "cleaner" and safer for the environment.

While it is widely agreeable that there is an urgent need to decarbonize the transport sector, the development and wide-scale use of alternative fuels is important due to a number of factors such as a) conventional fuels running out, b) reducing air pollution and greenhouse gas emissions, and c) sourcing these fuels domestically (J. Anastasia, 2015).

CNG

Natural gas, a fossil fuel comprised mostly of methane, is one of the cleanest burning fuel in terms of NO_x and soot (PM) emissions (CTCN, 2018). It can be used in the form of compressed natural gas (CNG) to fuel passenger cars and city buses or in the form of liquefied natural gas (LNG) to fuel heavy duty trucks. Usually, a CNG passenger vehicles emits 5 –10% less CO_2 than ICE passenger vehicles, and the NO_x and soot emissions of CNG powered vehicles are substantially lower (CTCN, 2018).

While CNG is widely used in passenger four-wheelers, buses, and trucks, they find limited use in two-wheeler segment. CNG might not be the most feasible technology for two-wheelers primarily because the installation of a CNG kit leads to higher upfront cost of the vehicle. Cost of an average 110–125 cubic centimetre (cc) is about Rs. 50,000 and the cost of a CNG kit adds-on to approximately Rs. 20, 000 per vehicle (Times of India, 2016), which makes the overall upfront cost of CNG-based two wheeler very high and a CNG kit may reduce power pick-up.

Bio fuels

Biofuels are liquid fuels that have been derived from other materials such as waste plant and animal matter. The two main types of biofuels currently in production are bioethanol and biodiesel. Bioethanol is used as a replacement for petrol and biodiesel is used as a replacement for diesel (BioEnergy Association, 2018).

Biofuels represent an immense growth opportunity around the world and have an important role to play in displacing the fossil fuels on which the world has relied upon in the past, with a cleaner, renewable alternative. To meet the increasing energy needs of the country, the Government of India announced its first Biofuel Policy in December 2009. The major goals of the policy are development, and utilization of indigenous non-food feed stocks raised on degraded or waste lands, thrust on research and development on cultivation, processing , and production of biofuels and a blending mandate of 20% ethanol and biodiesel by 2017 (Plinio Nastari, 2018).

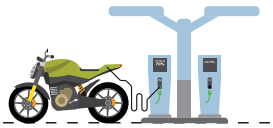
In 2018, Brazil substituted 42% of its petrol with ethanol and, the US which uses nearly half of the world's petrol, the level of substitution is 10%. Ethanol is economically competitive, and its cost today is about $1.3 per gallon, while petrol has a wholesale price of $2.1 per gallon. Therefore, it helps alleviate the price pressure on consumers (Chibber, 2018).

Average blending of ethanol in petrol in India was about 4.22% in 2017-18. However, India is set raise the ethanol blending to 7.2% in 2018-19. This steady rise in ethanol blending is not only expected to reduce the dependence on crude imports, but also reduce the vehicular air pollution. while efficiently utilizing cane juice and other raw materials.

The primary use of biofuels is in transportation sector, these fuels are not just energy dense (unlike electricity and batteries) but also function similar to petroleum-based fuels which in term requires no or little modification in the existing ICE power-train (Biofuel.org, 2017).

Electric Vehicles

The developments in the past decade have established electric vehicles as the most promising mode of transport all around the world. Electric Vehicles



(EVs) are almost five times more energy efficient as compared to ICE vehicles (BNEF,2017). EVs use only 25 to 30 moving parts as opposed to over 2000 moving parts in an ICE vehicle, amounting to far greater reliability. There are various other benefits of adopting electric vehicles such as reduced dependence on imports of crude oil, and reduction on greenhouse gas emissions and air pollution. The EVs are also believed to provide an indirect push to renewable energy due to the excess energy demand that would be created due to uptake of electric vehicles (TERI, Yes Bank, 2017).

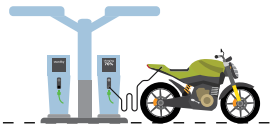
Despite the stated advantages of the EV technology, the deployment of EVs has not happened at a rapid rate. This has been primarily due to the high upfront cost of the battery, which in turn leads to higher cost of an electric vehicle. The cost of battery is a major deterrent in the uptake and mass production of EVs in India, presently; India doesn't have battery cell manufacturing plants and is only assembling the battery packs which are imported.

India stands at a critical juncture so as to either provide heavy financial incentive or proactively innovate (Plug-In-India, 2017).

Hydrogen Fuel Cell

The most recent advancement in the field of alternate fuel technology is discovery of hydrogen fuel cell. Hydrogen as a fuel has various advantages and disadvantages in its application for transportation and energy storage purposes. However, due to high cost involved in setting up an infrastructure for production, it has resulted in a lower inclination to use hydrogen as a fuel (OilPrice.org, 2019).

However, despite the high cost of the hydrogen fuel cell technology, academia and intelligentsia are keen to research and experiment on various method to harness this energy. The primary driver for this is that hydrogen can be produced by an environmentally friendly method called 'hydrolysis' or through the process of 'reforming' natural gas, which is the approach to produce 95% of the hydrogen on the market (IEA, 2015)



3 ELECTRIC VEHICLES AS A POTENTIAL SOLUTION

Overview of Indian Automotive Sector

The automotive industry has been rightly called as the 'industry of industries' since it utilizes the outputs of nearly all the manufacturing industries and also supports the upstream industries like steel and downstream industries like insurance (Drucker, 1946). Undoubtedly, it is widely considered as the driver of the nation's economy and is as a significant contributor to the global economy. According to the Society of Indian Automobile Manufacturers (SIAM), the industry has grown by 14.4% in the past decade. The industry contributes 7.2% of India's total GDP and about 22% of the manufacturing GDP (Supriyo, 2017). In 2017, with total vehicular production over 25 Million in numbers, India's auto industry was the fourth largest producer of cars and seventh largest producer of commercial vehicles in the world (SIAM, 2017a).

Vehicle production in India

The automotive industry produced a total of 29.86 million vehicles including commercial vehicles, passenger vehicles, tractors, three-wheelers, two-wheelers and quadricycle in the FY 17–18. The two wheelers are the dominant automobile manufactured in India, accounting for 79.7% of the total vehicles manufactured in the FY 2017–18, followed by passenger vehicles (13.7%), three-wheelers (3.5%), and commercial vehicles (3.1%) (SIAM, 2017a).

- Within the two wheeler segment, motorcycles accounted for 66% of the production followed by scooters (30%) and mopeds (4%).
- 71% of passenger vehicles produced in the FY 2017 – 18 were cars, followed by utility vehicles (24%) and vans (5%).
- Passenger carriers dominate the three-wheeler segment by constituting 86% of the production. The rest (14%) are goods carriers.
- 57% of the commercial vehicles produced in India during the FY 2017–18 were LCVs and 43% were M&HCVs. However, only 12% of these commercial vehicles produced were passenger carriers and 88% were goods carriers.

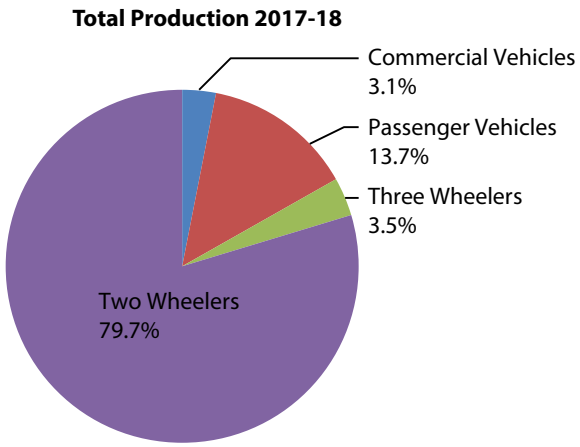
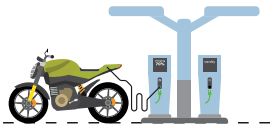


Figure 12: Total production of automobiles

Source: (ACMA, 2018)

Trend of production (SIAM, 2017a)**,** (ACMA, 2018)

In the past 10 years (2008-09 to 2017-18), vehicle production in India increased by 126%. The increase in the manufacturing volume was led by the two wheeler segment which increased by 139% in 10 years, followed



by commercial vehicles (92%), passenger vehicles (83%) and three wheelers (83%).

- The commercial vehicles segment saw a production increase by 10.4% in FY 17–18 over the FY 16–17 which was mainly due to the 19.9% and 17.8% growth in goods carriers and tractors respectively.
- The passenger carriers in the medium and heavy commercial vehicles in this segment, which includes mainly buses, witnessed a reduction in production by 24.1% during the FY 2017–18.
- Passenger vehicles segment witnessed an increase of 5.5% in FY 17–18 over the FY 16–17 mainly due to the 19.9% increase in production of utility vehicles.

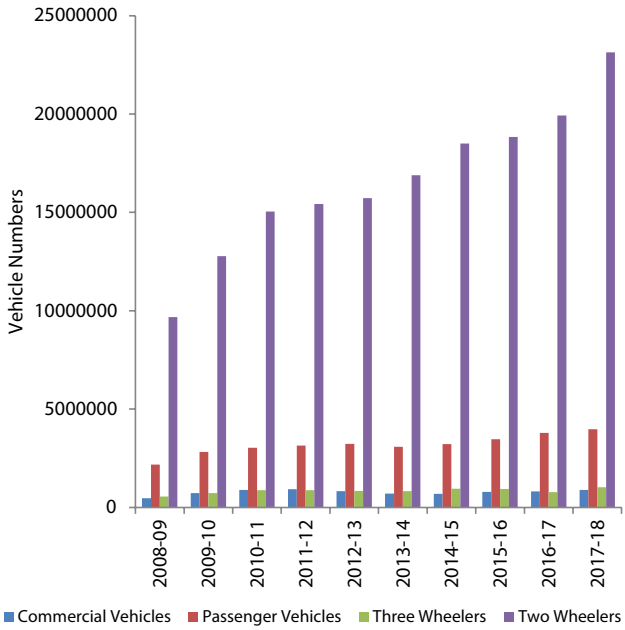


Figure 13: Segment-wise trend of vehicle production

Source: SIAM 2017b

As it is clear from the bar graphs, two-wheeler segment constitutes as a major part of the production volume of vehicles in India. Two wheelers increased from 76% of the total automobile production in 2008–09 to 80% in 2017–18.

Similar to the production in India, two-wheelers dominate the sales too. In the FY 2017–18, 82% of the market share belonged to the two-wheeler segment of the automobile industry.

Vehicle Sales in India

The automotive industry sold (including exports) a total of 27.6 million vehicles including commercial vehicles, passenger vehicles, tractors, three-wheelers and two-wheelers in the FY 16–17. Similar to manufacturing the two-wheelers are also the dominant automobiles sold in India, accounting for 79.2% of the total vehicles manufactured in the FY 2016–17, followed by passenger vehicles (14.4%), three-wheelers (3.2%) and commercial vehicles (3.1%) (SIAM, 2017a). 22.1% of the total sales composed of exports and 77.9% were domestic sales.

- Within the domestic sales in two-wheeler segment, motorcycles accounted for 63% of the sales followed by scooters (32%) and mopeds (5%).
- 69% of passenger vehicles sold in India were cars, followed by utility vehicles (25%) and vans (6%).
- Passenger carriers dominate the three-wheeler segment by constituting of 79% of the production. The rest (21%) are goods carriers.
- 58% of the commercial vehicles sold in the domestic market in India during FY 2016-17 were LCVs and 42% were M&HCVs. However, only 14% of these commercial vehicles produced were passenger carriers and 86% were goods carriers.

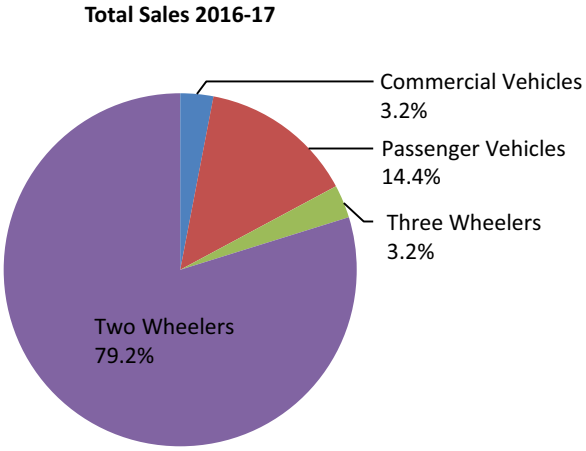
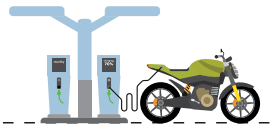


Figure 14: Total sales of automobiles (2016–17)

Source: SIAM 2017b



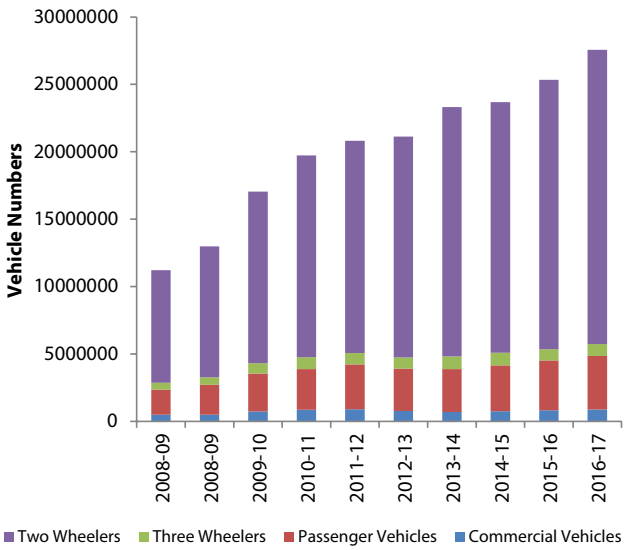


Figure 15: Segment-wise trend of vehicle sales

Source: SIAM 2017b

Trend of sales (SIAM, 2017a)**,** (ACMA, 2018)

In the past 10 years (2007–08 to 2016–17), vehicle sales (including exports) increased by 146%. The increase in the sales volume was led by the two-wheeler segment which increased by 161% in 10 years, followed by passenger vehicles (113%), commercial vehicles (80%) and three-wheelers (75%).

Policy Framework supporting electrification in India

According to the Climate Action Tracker, India is leading the G20 countries in closing the gap between the targets set and the trajectory followed. India aims to over achieve its NDC with the adoption of its National Electricity Plan released in April 2018. One of the important measures that can be adopted is to shift from carbon intensive fossil-fuel driven mobility to cleaner mobility solutions such as electric vehicles.

National Level Policies and Interventions

Some of the key policies undertaken by the Government of India over the last decade, which have provided support and push to EVs, are discussed below.

Alternate Fuels for Surface Transportation (AFST) Programme

The AFST programme of the Ministry of New and Renewable Energy promoted all types of BEVs, PHEVs, HEVs and Electric/ Exercise Bike Generator Inverters (E2BI). The programme aimed at providing support for dissemination of such vehicles, their research and development, pilot projects, and awareness related activities. The programme had been offering Central Financial Assistance to all such vehicles since 2010. The programme came to an end in 2012–13; with the launch of the National Electric Mobility Mission Plan 2020.

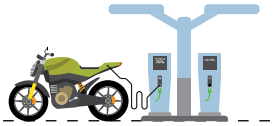
National Electric Mobility Mission Plan (NEMMP) 2020

The National Electric Mobility Mission Plan (NEMMP) 2020, was launched in 2013 by the Ministry of Heavy Industries and Public Enterprises in order to promote the demand of environment-friendly electric vehicle technologies. The primary aim of the Plan was to provide financial and infrastructural support to electric vehicle technologies in India. The budget outlay of the Plan was divided into a) Technology Platforms, b) Demand Incentive, c) Charging Infrastructure, d) Pilot Projects and, e) IEC/Operations (conductive charging)

The vision statement of NEMMP is mentioned below:

"To encourage reliable, affordable and efficient electric vehicles 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 EV two-wheeler and four-wheeler market in the world by 2020, with total EV sales of 6 – 7 million units thus enabling Indian automotive industry to achieve global EV manufacturing leadership and contributing towards national fuel security."

NEMMP was targeted to achieve expansion of domestic electric vehicle market, coupled with global leadership in vehicle manufacturing. The primary objective of NEMMP is to provide the initial boost to the EV industry in India



which will then in turn stimulate the manufacturing of these vehicles in larger volumes. The four key principles that guide the future roadmap for EVs penetration in NEMMP include the following:

1. Creating consumer acceptability for EVs
2. Developing infrastructure to support ownership and use of EVs
3. Development/acquisition of EV technology
4. Creation of local manufacturing capability

The Plan projected the total potential demand for full range of electric vehicles (mild hybrids to full electric) to be in the range of 5 –7 million units in new vehicle sales by 2020. The bulk of this demand has been anticipated to come from (pure) electric two-wheelers, followed by hybrid electric vehicles (HEVs) and pure electric vehicles or battery electric vehicles (BEVs). In order to achieve the objectives laid out in the NEMMP, the Government of India announced an incentive scheme, which provides subsidies on purchase of EVs – the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme.

Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME - India), 2015 Phase 1

The Ministry of Heavy Industries and Public Enterprises launched the FAME-India Scheme in April, 2015. The salient features of FAME India scheme are as under:

- The scheme was launched for the initial two years of the 12th Plan period– Phase I (2015-17), which was further extended till March 2019.
- The scheme had an outlay of Rs. 795 Crore under various plan heads for Phase I of the scheme, which was increased to Rs. 895 Crore due to the extension of Phase I
- The scheme covered all vehicle segments i.e. two, three, and four-wheelers, cars, LCVs, buses etc. and all forms of hybrid (Mild / Strong / Plug-in) and pure electric vehicles; the incentive on hybrids was withdrawn when the Scheme was extended after March 2017.

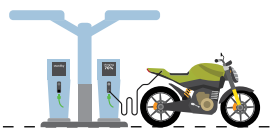
The demand incentive is availed by buyers upfront at the point of purchase and the same is reimbursed to the manufacturers from (Department of Heavy Industries) DHI on a monthly basis.

In January 2018, realizing the role of pilots in boosting the adoption of EVs, DHI approved pilots for 390 electric buses, 370 electric taxis and 720 electric autos spread across 11 Indian cities under the Scheme. While the nine big cities were given subsidy for 40 buses each, Jammu and Guwahati got subsidy for 15 buses each. In terms of taxis, subsidy was provided to Ahmedabad (20), Bengaluru (100), Indore (50) and Kolkata (200), based on their demand. Bengaluru was allotted subsidy for 500 three-wheelers, while Indore and Ahmedabad were offered subsidy for 200 and 20 three-wheelers, respectively. The amount sanctioned is Rs. 437 crore, out of which Rs. 40 crore is allotted for charging infrastructure. The implementation of these pilots are underway, for example electric bus pilot has been started in Ahmedabad-BRTS since January 2019.

Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME - India), 2019 Phase 2

The Government of India launched Phase-II of FAME or FAME-II in March 2019 with ten times the financial resources of FAME-I. FAME-II has an overall budget of Rs. 10,000 crore allotted for demand incentives, charging infrastructure and IEC activities. FAME-II deviates from its predecessor in the logic of demand incentive allocation. Unlike FAME-I, the subsidy in FAME-II is not based on the specific vehicle model but on the battery size. As it is the battery prices which drive the EV prices up, FAME-II offers a uniform incentive of Rs. 10,000 per kWh of battery for two, three and four wheelers. For buses, it offers a uniform subsidy of Rs. 20, 000 per kWh. The focus of FAME continues to be promoting purchase and sale of electric vehicles with almost 86% of this scheme's budget being allocated for demand incentives. FAME-II targets to provide the purchase subsidy to 10,00,000 two-wheelers, 5,00,000 three-wheelers, 55,000 four-wheelers and 7090 buses over a period of 3 years.

The scheme is mainly applicable to vehicles used as public transport or those registered for commercial purposes in three wheeler, four wheeler and bus segments. However, the scheme does not exclude privately owned two wheelers. Deriving learning from



FAME-I, the demand incentive in limited to vehicles with 'Advance Batteries', defined as 'Motor Vehicles' in CMVR(Central Motor Vehicle Rules) by Ministry of Road Transport and Highways. The scheme also lays down eligibility of vehicles for demand incentive based on proportion in domestic manufacturing, compliance to CMVR standards, fitting of monitoring device for mileage and display of DHI sticker indicating that the vehicle has been purchased under the scheme.

National Energy Storage Mission, 2018

In February 2018, an expert committee under the chairmanship of Secretary, Ministry of New and Renewable Energy, with representatives from relevant ministries, industry associations, research institutions and experts were constituted by the Ministry of New and Renewable Energy to propose draft for setting up National Energy Storage Mission (NESM) for India.

The primary objective of the NESM is to strive for leadership in energy storage sector by creating an enabling policy and regulatory framework that encourages manufacturing, deployment, innovation, and further cost reduction. Furthermore, India's NESM has proposed three-stage solution approach, which is:

- creating an environment for battery manufacturing growth
- scaling supply-chain strategies
- scaling of battery cell manufacturing

The mission also highlights the importance of energy storage with perspective of India in order to provide the much needed thrust to renewables and electric vehicles. The key areas that were identified as a part of the mission were:

- Integrating renewable energy with distribution and transmission grids.
- Setting rural micro grids with diversified loads or stand-alone systems. Developing Storage component of electric mobility plans.

National Policy on Electronics, 2019

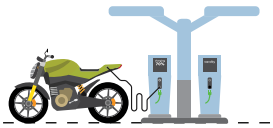
The policy envisions positioning India as a global hub for Electronics System Design and Manufacturing – (ESDM) by encouraging and driving capabilities in the country for developing core components, including chip-sets, and creating an enabling environment for the industry to compete globally. The policy would indirectly affect technological advancements and innovation in the field of electric vehicles.

The following are the salient features of NPE 2019:

- Create eco-system for globally competitive ESDM sector by promoting domestic manufacturing and export in the entire value chain of ESDM by providing incentives and support for manufacturing of core electronic components.
- Provide special package of incentives for mega projects which are extremely high-tech and entail huge investments, such as semiconductor facilities display fabrication, etc.
- Formulate suitable schemes and incentive mechanisms to encourage new units and expansion of existing units.
- Promote industry-led R&D and innovation in all sub-sectors of electronics, including grass-roots level innovation and early stage start-ups in emerging technology areas such as 5G, IoT/ sensors, Artificial Intelligence (AI), machine learning, Virtual Reality (VR), drones, robotics, additive manufacturing, photonics, nano-based devices, etc.
- Provide incentives and support for significantly enhancing availability of skilled manpower, including re-skilling.
- Special thrust on Fabless Chip Design Industry, Medical Electronic Devices Industry, Automotive Electronics Industry (primarily EVs) and Power Electronics for Mobility and Strategic Electronics Industry.

State-Level Policies

Realizing the important role electric mobility can play in addressing the air pollution and climate change concerns, many states in India have drafted Electric Vehicle Policy to accelerate the uptake of EVs. Karnataka, Telangana, Maharashtra, Uttar Pradesh, Kerala and Tamil Nadu have formulated EV policies promoting EV



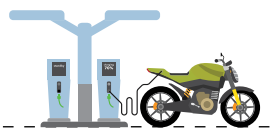
adoption and manufacturing in their respective states. Delhi has also come up with a draft EV policy. The Table 7 State-level EV policies and their targets, sums up the targets that the state polices have set up for their respective states.

Potential and Importance of Electrification of Two Wheelers

In terms of volume of production and sale, Indian two-wheeler industry is one of the largest in the world. The segment caters to the need of middle-and low-income

Table 7: State-level EV policies and their targets

State	Targets
Karnataka Electric vehicle and Energy Storage policy 2017	➲ 1000 e-buses by 2030 ➲ 100% three-wheelers / four-wheelers moving goods will be encourage to transit to electric mobility by 2030 ➲ Incentives for first 100 fast charging stations
Telangana Electric Vehicle Policy Draft 2017	➲ Telangana State Transport Corporation to set a target of 100% electric buses by 2030 for intracity, intercity, and interstate transport ➲ Government will set up first 100 fast charging stations in GHMC
Maharashtra's Electric vehicle and related infrastructure Policy 201	➲ Increase number of EVs registered in Maharashtra to 5 lakh ➲ To generate an investment of Rs. 25,000 crore in EV
Uttar Pradesh Electric Vehicles Manufacturing Policy 2018	➲ Public Transportation – 1000 EV buses by 2030 ➲ Private Transportation – State government will encourage electric 2-wheeler taxies for short distance mobility, and existing auto rickshaws will be encouraged to resort to EV technology ➲ Goods Transportation – Further, to promote adaptability of EV in Goods transportation, EV-3 wheelers, 4-wheelers mini goods vehicles will be encouraged in GB Nagar, Ghaziabad, Agra, Lucknow, Kanpur, Varanasi
Kerala EV Policy	➲ 1 Million EVs by 2022 ➲ Pilot Fleet of 200,000 two- wheelers, 50,000 three wheelers, 1000 goods carriers, 3000 buses and 100 ferry boats by 2020 ➲ Part of Public Transport fleet of 6000 buses to be made electric by 2025
Tamil Nadu EV Policy	➲ Attract ₹50,000 crore in investments and create 1.5 lakh new jobs ➲ 100 per cent road tax exemption for all types of EVs, capital subsidies, reimbursement of State GST, subsidy on land cost and special incentives for job-creating EV projects
Draft Delhi Electric Vehicle Policy 2018	➲ Battery Electric Vehicles (BEVs) 25% of all new vehicle registrations by 2023 ➲ 50% of the public transport bus fleet zero emission by 2023



users and provides cost-effective mobility service, due to the existing gaps between travel demand and public transport system. In reality, many India cities lack substantial and efficient public transport systems, as the income-level of people increases, they generally opt for private modes of transportation to meet their mobility needs on the basis of convenience and time-saving.

The two-wheeler form the centre-piece of the passenger mobility of India, the dominance of two-wheelers in evident can be understood by the sheer constitution of two-wheelers in the passenger vehicle sector. According to TERI estimates (based on the TERI Transport Model), two-wheeler are expected to constitute about two-third of total automobile demand in the country. Additionally, comprehending to the existing two-wheeler vehicle ownership, the trend is estimated to follow a similar pattern for the FY 2030-31 (see Figure 16).

The popularity of the two-wheeler can be understood from the following:

Affordability: A two-wheeler vehicle is always cheaper to use and maintain. The cost of service, repair, and spare parts, parking fees, and even toll fees are much lower than owning a four-wheeler passenger car. The cost-effectiveness is further enhanced by low cost of operation i.e. cost per kilometre.

Estimated share between transport modes in 2030-31

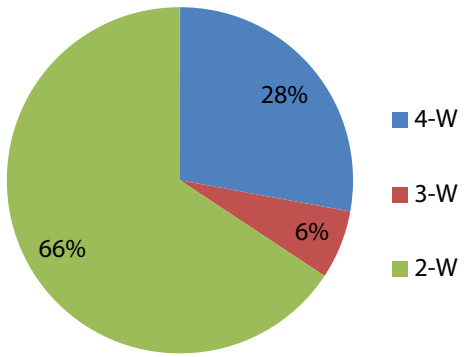


Figure 16: Estimated share of various transport modes in 2030

Convenience: Traffic congestion is of the major challenges that Indian cities are grappling with. The motorized two-wheelers provide convenience while zipping in and out of traffic. Two-wheelers are generally treated as the fastest mode of transport for short distances.

Parking: The parking requirement for two-wheelers is not as challenging considering that they do not require much parking space and can squeeze into tight spaces.

Mileage: For most consumers, mileage (which is how far a vehicle can travel on one litre of fuel) is one of the most important parameters. Two-wheelers provide advantage as their mileage is generally much better than four-wheelers. In a good condition, the former can go at least twice a distance on a litre than a car. of course, all this varies with the model, the condition of the vehicle / road, and the amount of traffic (BCG, 2017).

Hence due to the reasons discussed above, amongst the vehicular segments in India, two wheelers huge potential towards electrification. With an estimated share of 66% by 2030, they have a huge potential in reducing emissions and contributing to India's climate targets.

Assessment of two-wheeler segment for electrification

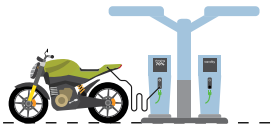
There is a general agreement that electric vehicles can deliver the triple benefits of reducing local air pollution, enhancing energy security, and reducing carbon emissions in India. However, despite the government's policies for enhancing electrification of motor vehicles, not much could be done in the ground. EVs barely constitute 1% of the total market share. In the FY 2017-18, about 1,71,000 electric vehicles were sold[3], out of which 1,200 were electric cars and 54800 were electric two-wheelers, under the FAME-India Scheme.

The government's emphasis on electric vehicles has to be complemented by investing and identifying front runners that can help upscale the According to an earlier analysis by TERI, key factors for enabling electrification were identified as

- Availability of public charging infrastructure
- Availability of vehicle models and range
- Presence of local manufacturing capabilities

Early adoption success: Electric two-wheeler and electric three-wheeler are among the vehicle segments

[3] SMEV-EV sales https://www.smev.in/ev-sales



which have recorded the maximum uptake from the inception of FAME-India Scheme. According to Society of Manufacturer of Electric Vehicles (SMEV), the electric two-wheeler sales were approximately 4,75,000 since 2015.

Although, the sales of electric two-wheeler is primarily constituted by Low-Speed (LS) electric vehicle, so much so that for the FY 2017-18 out of the 54,800 electric vehicle sold, 49,000 were LS electric two-wheeler and only 5,800 were High-Speed (HS) electric two wheeler. Even though the initial uptake suggests higher acceptability and consumer willingness, in comparison to other modes of transport, in this case, the adopted vehicle may not have necessarily replaced the ICE vehicles. Most low speed electric two wheelers purchased were for secondary uses, and the owners continued to use their ICE two wheelers for their primary use, especially the work trips. As these electric two wheelers are not classified as motor vehicles under CMVR, the regulators neither mandate a driving licence nor safety helmet. Hence, there is also a possibility that these lead acid two wheelers were used to replace the earlier non-motorised or public transport based trips by other individuals in the household.

Dependence on public charging infrastructure: According to TERI estimates the average distance that a two-wheeler covers in a day does not exceed 40– 45km, which makes home charging the most convenient charging mode. Conversely, public transport such as buses, commercial four-wheelers (i.e. fleet) and electric three-wheelers in particular are more dependent on public charging infrastructure. However, limited range and lack of charging facilities are still the major reasons impeding adoption of electric two wheelers. The same is revealed in the results of stated preference consumer survey presented in Chapter 5.

Local manufacturing capabilities: Indian two wheeler industry is the largest manufacturer of two wheelers in the world with over 25 Million units produced in 2018-19 alone. The matured ICE two wheeler industry in India has a vast understanding of the Indian customers as well as an established practice of local product development. The established two wheeler manufacturers in India have the ability to heavily invest and establish local supply chains for electric vehicles.

With the demonstrated customer understanding, commitment and capability, and with Government support, two-wheeler manufacturers are likely to successfully handle the phased adoption into electric.

Choice of models: The presence of local OEMs coupled with demand for the product, the electric two-wheelers have a range of models (variants) to choose from; this may lead to competitive prices in the market, but also ensures consumer satisfaction. Hero Electric alone has approximately six electric two-wheeler models as of now, while Okinawa and Electrotherm have four and five, respectively. However, most of these models are low power vehicles based on lead acid batteries.

Although relative to the ICE two wheeler market, there is limited availability of affordable models for Indian consumers. Even though there are a range of options available with respect to other segments like electric three wheelers and cars, there still are limited options of electric two wheelers which are acceptable for the buyer in terms of affordability, technology and performance.

Ease of implementation: The successful proliferation of EVs is also dependant on government control and ease of implementation. Introduction of electric buses will be primarily through the government's intervention as most of the public bus services are provided by public institutions (i.e. State Road Transport Undertakings). Similarly, other public transport modes such as electric autos, electric rickshaws, and electric taxis, which require government permits to exercise their operations in cities can be pushed by the government for their conversion to electric vehicle technology and also creating enabling policies for private investment on battery manufacturing, public charging etc.

Proliferation of private motor vehicles is dependent on many factors like consumer's choice and willingness, incentives for primarily for reduction in procurement cost and resale or end-of -life disposal.

The various vehicle segments were compared qualitatively on the basis of these criteria. The vehicle segments were rated on a scale of 1 to 5 based on their potential to qualify as the low-hanging fruits for a given criteria wherein 5 indicates the maximum potential and while, 1 indicates lowest potential.

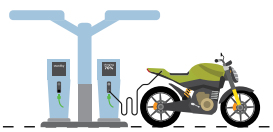
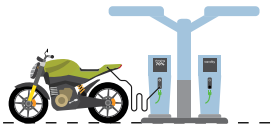


Table 8: Ranking of vehicle segments based on criteria used for identification of low-hanging fruits/front runners

Indicators	2-wheelers	3 - wheelers	4-wheelers		Bus
		Electric-auto rickshaws	Passenger segment	Commercial segment: Fleets	
Early adoption success					
Local Manufacturing capabilities					
Limited Dependence on charging infrastructure					
Choice of model					
Ease of implementation					
Government support					

5	4	3	2	1

The assessment clarifies that even though there is a huge potential for electrification of two wheelers, it is not easy. Adequate government support coupled with technological innovation is required to aid the Industry to nudge the consumers into shifting their primary modes from ICE two wheelers to electric two wheelers. The next chapter attempts to quantify the potential benefits from phased adoption of two wheelers in India into electric.



4 EMISSION AND ENERGY IMPACT OF ELECTRIFICATION OF TWO-WHEELER SEGMENT

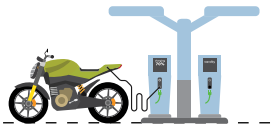
Fuel demand in India's transport sector is largely met by imports, which accounts for more than 85% of the total oil demand. India's future energy security is likely to face a serious challenge due to increasing oil prices and high import dependence. A high share of this demand largely comes from the transport sector. It is one of the most energy-intensive sectors in the country and accounts for 24% of the total energy consumption in the country (TERI, 2018), 98.5% of which is met by petroleum products (TERI, 2016). India's transport sector accounts for 99.6% of the total petrol and 70% of the total diesel consumption in the country (Nielsen, 2013). Transport sector in India accounts for 13.2% of the total CO_2 emissions from fuel combustion across sectors in the country (UIC / IEA, 2016). Within the transport sector, road transport with a share of 87% accounted for the highest share of the CO_2 emissions. The unprecedented growth in road transport sector has huge implications on the overall energy demand of the sector and the concomitant emissions. Considering the high reliance of the sector on fuel consumption coupled with India's high import dependence of crude oil, it is imperative to plan for sectoral policies that can manage fuel and energy demand from the sector in the coming decades and can influence the future carbon emissions (Pal, Singh, Wilson, & Joshi, 2015).

To this end, faster adoption of EVs is one of the key policy interventions that the Government of India has taken to increase the efficiency of transport sector and to mitigate the adverse economic and environmental impact from the sector. As India's road transportation sector is experiencing high rate of motorization, most of which is attributed to growth in demand for two-wheelers which account for 75% of the total registered vehicles (MoRTH, 2016); electrification of this segment of vehicle can significantly reduce India's dependency on fossil fuels in the long run.

This section provides results of the analysis undertaken to estimate the CO_2 emissions and energy savings that can be realized by electrification of two-wheelers. Considering future growth of India's transport sector and specifically the growth of two-wheelers, TERI analysis focuses on the potential of electric two-wheelers in decarbonizing this sector.

Analysis Framework

The TERI analysis follows a Bottom-up approach and projects the growth in two-wheelers by 2025 and 2030 across different segments. This is followed by estimation of energy consumption and CO_2 emissions. For arriving at the total two-wheeler passenger demand a multi-step approach is followed. Firstly, the vehicle ownership is projected based on socio-economic variables such as GDP and population. The vehicle ownership is then disaggregated at urban and rural level. Further, based on the assumptions of fuel type, fleet utilization and vehicle occupancy for different two wheeler segments (scooters, motorcycles, mopeds, electric-two wheelers) the annual BPKM is calculated for both urban and rural areas separately. Lastly, the total annual BPKM at pan India level is arrived at by summation of urban and rural BPKM. Post the estimation of the total BPKM; dynamic fuel efficiency coefficients are applied to BPKM to arrive



at the fuel consumption by two wheelers. The total fuel consumption is then converted to equivalent energy consumption and the concomitant CO_2 emissions.

Travel Demand and Vehicle Segmentation

As per TERI's model two-wheelers are expected to witness a CAGR of 9% between 2014-15 and 2029-30. The demand for two-wheelers is expected to saturate as a greater share of people choosing personal mobility would shift to cars over two-wheelers. Growth in income levels are expected to support this trend, primarily in urban areas. Travel demand by two-wheelers is expected to experience a CAGR of 9% between 2030 from 2015, as compared to 15% between 2001 and 2015 in two-wheeler sector. Currently, 52% of the share of this demand arises from urban areas and the rest by rural and intercity travel, which is expected to reverse by 2030, i.e. 48% by urban areas and 52% by rural areas. This reversal in trend is primarily associated with better connectivity, improved road infrastructure and availability of easy finance in rural areas. The market of two-wheeler segment is also expected to slow down in urban areas as compared to rural areas because it is assumed cities and towns would have improved public transport and shared mobility services, which would remain lacking in case of rural areas (ET Bureau, 2018).

Further, considering the market share of different segments in two wheelers[4], the projections have been made with regard to the growth of different categories of two-wheelers by 2030.

Assumptions for electric two-wheeler share

One of the key assumptions for estimating the impact of electric two-wheelers is the demand number and the market share that this segment will have in the horizon period. Typically, past trends are relied upon to make market projections; however, in the case of electric vehicles the past trends will certainly not provide a comprehensive foresight into the future. This is because a strict empirical analysis will not be able to accommodate for the fact that EV technology

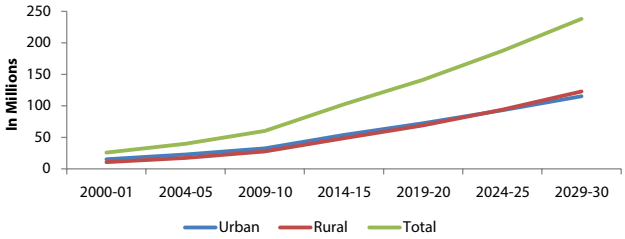


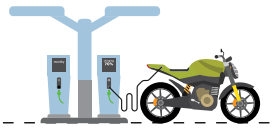
Figure 17: On-road stock of two-wheelers in urban and rural India

is a disruptive technology and once it reach a cost parity with the ICE technology, its growth is expected to witness a widespread adoption. The following sections provide a discussion on likely factors that will determine the market share of electric two-wheelers in the country. The discussion also highlights likely scenarios assumed by different agencies/organizations with respect to electric two-wheeler penetration in India. All of these parameters are factored into building market share assumptions for 2025 and 2030 for electric two-wheelers for India, which are further used to estimate the energy and emission impact of the same.

As per 2016–17 SIAM statistics, 82.4% of all the vehicles sold in the country are two-wheelers. The reasons for popularity of the two-wheeler segment in the country is primarily the level of affordability it offers, costing less than Rs 1.5 per km, which in many cases is even lower than the public transport fares in many regions. In addition, it offers benefits such as door-to-door accessibility, constant availability, and comfort. In the absence of affordable quality public transport, two-wheelers will continue to play a dominant role in meeting mobility needs of the people.

In 2010, the Ministry of New and Renewable Energy announced incentives for EV manufacturers for 2010–11 and 2011–12 to encourage the sale of electric vehicles. The scheme set aside a fund of Rs 950 million under the Eleventh Five Year Plan and gave incentives up to 20% on ex-factory prices of vehicles. Electric two-wheelers started becoming popular and gained some demand during this time. Their numbers peaked in 2012–13 when 102,000 electric two-wheelers were sold (SIAM, 2014-15). The scheme led to an upsurge in the sales of electric vehicles. However, it came to an end in March 2012 and as a result, the sales of electric vehicles dwindled. Only

[4] As discussed in Chapter 2 of the report



45,000 electric two-wheelers were sold in 2013–14 and 15,000 in 2014–15.

The uptake of electric two-wheeler segment has been slow but past experience shows that with favourable policy and regulatory support this segment can grow rapidly. Similar has been the experience with FAME-I. While majority of the 2W models sold under FAME-I and earlier schemes were low speed, lead acid battery models, the electric two wheeler market is changing as the government is only subsidizing advanced battery electric two-wheelers under the FAME-II. In fact, Department of Heavy Industries, MoHIPE, as per its notification vide 12 (14)/2017-AEI dated 27 September 2018, had withdrawn the FAME-I subsidy on conventional battery vehicles and unregistered vehicles from 30 September 2018 onwards. While advanced battery two-wheeler models are almost twice as expensive as the lead acid battery models, the falling lithium prices are expected to improve the cost competitiveness of lithium powered two-wheelers, resulting in growing market share of such models.

It is expected that with the lithium battery prices falling significantly, the tipping point in terms of costs of EVs becoming competitive with similar ICEVs will be achieved soon. As per (Bloomberg New Energy Finance) BNEF estimates, the total cost of ownership for BEVs will be cheaper even on an unsubsidized basis than ICE cars by the mid-2020s. BNEF predict this will happen despite the ICE vehicles improving their average mileage by 3.5% per year.

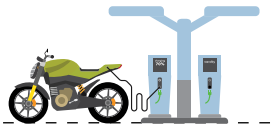
The lithium prices and performance remain the single important determinant of the tipping point for EVs and the trend in this direction seems to be positive. As per Bloomberg NEF's ninth Battery Price Survey, the lithium battery pack prices have been falling significantly: the cost of volume weighted average battery pack has declined by 85% since 2010– to an average of $176/kWh in 2018.

The demand for electric two-wheelers is also expected to pick up in the future as shared mobility is expected to assume greater share both for personal and commercial purposes. A report by Morgan Stanley 2017, predicts India to be a leader in shared mobility by 2030. High utilization rates along with low operating expense of EVs become particularly attractive for delivery services such as e-commerce and fast food services. High demand for affordable mobility options, low vehicle ownership per capita, young demography, high penetration of mobile phones, rapidly growing e-commerce industry, greater environmental awareness, stricter air quality regulations and vehicle emission standards, and fuel norms are expected to drive the demand for electric two-wheelers in Indian cities.

NITI Aayog in its report on India Leaps Ahead: Transformative Mobility Solutions for All, in the BAU scenario, assumes 5% as the share of electric two wheelers in new sales in 2030. In its transformative scenario, the report assumes the share to go up to 40% contingent on high electrification, shared vehicle fleets and high public transit in well designed urban environments.

As per IEA's EV Outlook 2018 report, in the new policy scenario, two-wheelers and three-wheelers are together assumed to account for 40% of the market share by 2030. As per the EV30@30 Scenario outlook wherein the country is expected to further boost momentum for electric mobility transition, two- and three-wheelers are projected to constitute 70% of sales by 2030. The New Policies Scenario (NPS) of the IEA's World Energy Outlook incorporates existing and announced policies and measures that governments around the world have put in place in terms of their official targets or plans. As per this scenario, India is assumed to achieve 11% EV market share by 2030 (excluding two- and three-wheelers). In the EV30@30 scenario, India is assumed to achieve 25% EV market share by 2030 across all modes (excluding two- and three-wheelers). In this scenario it is assumed to rapidly leapfrog from a low personal vehicle ownership rate to a high shared mobility scenario.

A good indication of the market share that electric two-wheelers might capture the Indian market can also be obtained by analysing the support that the FAME-II scheme is offering. FAME-II offers a subsidy support for 10 lakh two-wheelers with effect from April 2019 for the next 3 years. needs to be noted that while FAME-I was beneficial in reviving the growth of electric two-wheelers, the growth has remained slow in this segment, recording a 0.54% CAGR between 2014–15 and 2017–18. In the Business as Usual (BAU) scenario, a similar



slow growth trend for this segment is assumed. The other two scenarios being framed are the technology improvement scenario and the high ambition scenario which will assume a high degree of policy push along with technological improvements.

As per NITI Aayog's another 2019 report on India's electric mobility, very high penetration for two- and three- wheelers is expected to happen by 2030 as a result of supportive policies such as FAME-II. Both NITI Aayog, 2019 and IEA's best case scenario projections seem to be highly optimistic for the Indian market.

Alternate electric two-wheeler uptake scenarios

In order to estimate the decarbonization impacts of electrification of two-wheelers, three scenarios have been developed, namely, the Business-As-Usual Scenario, technology upgradation scenario, and high ambition scenario.

1. Business-As-Usual (BAU) Scenario (or Reference Scenario)

It is assumed that in the BAU Scenario, the penetration of electric-two-wheelers in the market will remain negligible due to limited policy push and lack of technological improvements. Under the BAU scenario, scooters and motorcycles dominate the total demand with their share in on-road stock being 46% and 52% respectively, by 2030. It is also estimated that the market share of electric two-wheelers will reach up to 1.71% by 2025 and then increase up to 7% by 2030. Subsequently, the CO2 emissions from two-wheelers are estimated to increase from 38.59 million tonnes in 2015 to 76.92 million tonnes in 2030.

2. Upgraded Technology Scenario

The upgraded technology scenario assumes that technological improvement will result in better performance and price competitiveness of the electric two-wheelers. It is assumed that post-2025, the cost parity between electric and ICE two-wheelers would have been reached. Hence post-2025, an exponential growth in the electric two-wheelers segment is assumed. With this scenario, the share of electric two-wheelers of the new two-wheeler registrations is expected to become 5% in 2025 and 15% in 2030, respectively. This increase in the market share will reduce emissions by 1.3% and 2.7% by 2025 and 2030, respectively.

3. High Ambition Scenario

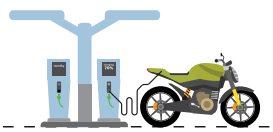
In the High Ambition Scenario, it has been assumed that along with strong focus of the central government the role played by various state-level policies will play a crucial role in increasing the uptake of electric two wheelers in India. It is assumed that, the benefits offered in FAME-II, benefits from the State governments along with a reduction in battery prices can lead to increased penetration after 2025. Considering all the factors fall in favour of EVs along with the preferences of consumers, this could imply a 5% penetration in 2025 followed by 30% in 2030.

It is assumed that in the high ambition scenario, cities and states will aggressively pursue the FAME-II targets. Efforts by various states and cities already point towards this direction. Several states are boosting the uptake of electric two-wheelers by providing incentives at various levels, such as Gujarat is providing subsidies to students for purchasing electric two-wheelers, Kerala has proposed a pilot fleet of 200,000 e-2W, Telangana has provided a designated EV cluster for component manufacturing of e-2W. This scenario assumes the policy targets as announced by Government of India will be exceeded/over-achieved. A greater push will be given to electric services with increased support in terms of financial and non-financial incentives.

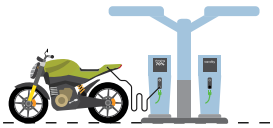
It is expected that post-2025, when the cost parity would have been achieved between the ICE and electric two-wheelers, with the continued policy push, electric two-wheelers would grow exponentially and a share of 30% in new two-wheeler vehicle registrations is assumed to be achieved by 2030. As a result the emissions are expected to reduce by 1.3% and 6% by 2025 and 2030 respectively, as compared to the BAU scenario.

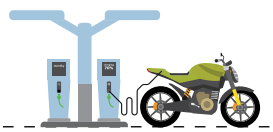
A Brief Review of Life Cycle Emissions of EVs and ICEs

The energy and emissions estimates presented in this report are 'Tank to Wheel' estimates of the use phase



of the vehicle. There are emissions released and energy consumed also at the manufacturing and end of life stage of the vehicle. Further, carbon is also emitted throughout the value chain of the energy consumed by the vehicles. That is, the extraction, distribution and conversion of energy before it reaches the vehicle, makes a significant impact on the 'well to wheel' emissions of the vehicle. IEA (2019) has estimated that at a global level, plug in electric cars emit similar amount of Green House Gases (GHG) as hybrid vehicles and less GHGs as compared to global average ICE vehicles using gasoline over their life cycle. However, the impact significantly differs with respect to the country, based on the low-carbon sources in the power generation mix and average fuel consumption by ICE vehicles. The IEA Global EV Outlook 2019 states that in countries where power generation is dominated by coal, very efficient ICEs like hybrid vehicles exhibit lower emissions than EVs. However, the potential for emission reduction over the life cycle of EVs will increase with faster decarbonisation of electricity generation.





5 CONSUMERS' PERSPECTIVE

Current e-2w market

According to DHI, as on June 2019, a total of 168,633 two-wheelers have been sold through the FAME scheme in India. The electric two-wheelers which have availed the FAME subsidy in the past can be classified into the following three categories as given in Table 9.

Table 9: Electric two-wheeler sales through FAME subsidy

Two-Wheeler category	Sales (DHI, June 2019)
Max speed not exceeding 25 kmph and max power not exceeding 0.25 KW	113,424
L1 Category (CMVR) – vehicle maximum speed not exceeding 40 kmph and max power not exceeding 0.5 KW	27,701
L2 Category (CMVR) – other than L1	27,508
Total	**168,633**

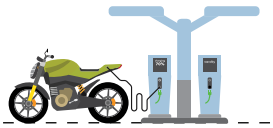
Of the two-wheelers, 67% (113,424 vehicles), which have availed the FAME subsidy, are not even classified as motor vehicles in the CMVR. These two-wheelers are all powered by sealed lead acid batteries and do not require a driving licence or a helmet to operate. The phase-II of FAME does not offer subsidy to this category of 'low speed' and 'conventional battery' vehicles. The 'high speed' and 'advanced battery' vehicles constitute 16% of the electric two-wheeler sold through subsidy from FAME-I and FAME-II in India. Other than subsidy offered in FAME-I, the penetration of the lead acid two-wheelers is high primarily because they are significantly cheaper than lithium ion powered electric two-wheelers. The reasons for the government to discontinue the subsidy offered for these vehicles are that these 'low speed' electric vehicles may be replacing non-motorized trips and also promoting substandard quality products as they have drastically low performance and range levels compared to ICE two wheelers in the market.

E-2w Sales trend

Uttar Pradesh has the highest uptake of electric two wheelers in India, followed by Haryana, Maharashtra and Gujarat. However, majority of the two wheelers sold in Uttar Pradesh are lead acid powered. Gujarat has the highest number of high power lithium battery electric two wheelers sold through fame, followed by Uttar Pradesh, Maharashtra and Haryana. With the same dataset, the 'lithium battery' vehicle sales to 'lead acid battery' vehicle sales was also assessed. Of the states where there is significant uptake electric two wheelers, Karnataka has the best lithium to lead ratio with 1.4 lithium two wheelers for every 1 lead acid battery powered two wheelers. West Bengal and Tamil Nadu have relatively higher sales of electric two wheelers but most of them are lead acid two wheelers. The lead to lithium ratio for West Bengal and Tamil Nadu are 0.19 and 0.16 respectively.

Consumer Survey

TERI conducted an online survey of existing electric two-wheeler owners and potential owners of petrol and electric two-wheelers. The survey was conducted through online automotive discussion platforms like



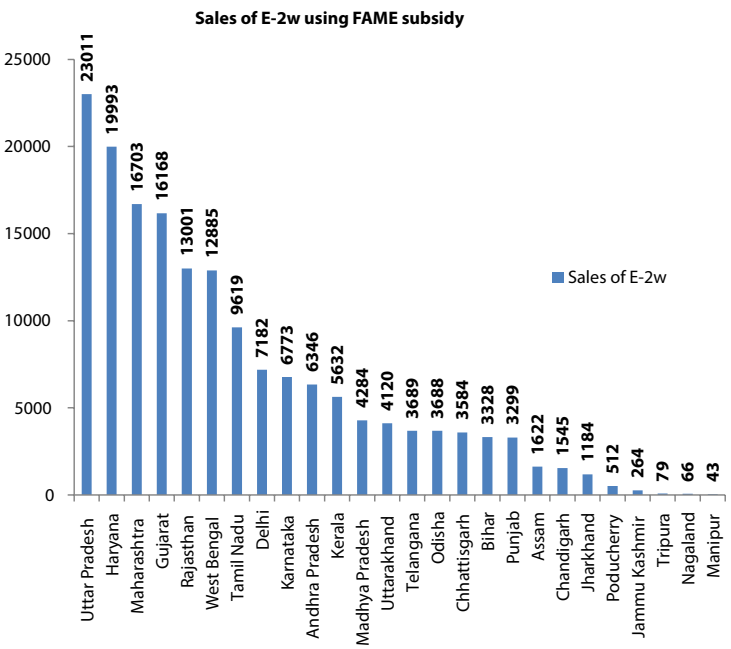


Figure 18: Sales of E-2w using FAME subsidy (April 2015 to June 2019)

Source: Fame-India.gov.in

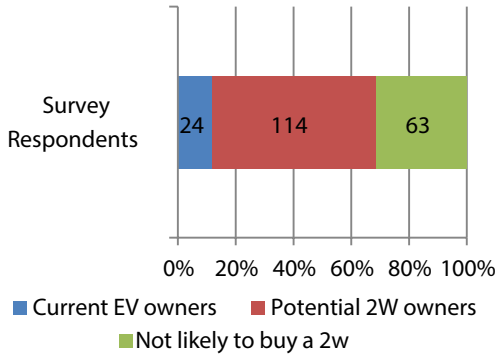


Figure 19: Summary of online stated preference survey of respondents

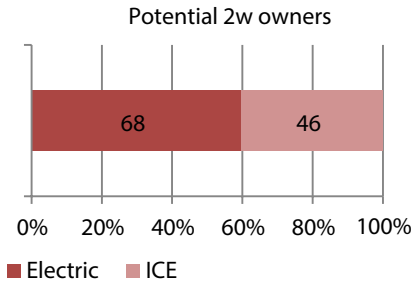


Figure 20: Summary of respondents planning to buy a two-wheeler in the near future

team-BHP. The survey collected responses from 212 individuals across India. The following were three categories of individuals whose preferences were to be understood using the online stated preference survey:

1. Electric two-wheeler owners
2. Potential owners of electric two-wheelers
3. Potential owners of petrol two-wheelers

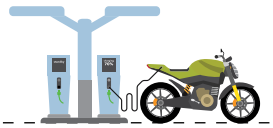
114 respondents selected yes to the question asking whether they wish to purchase a two-wheeler in the near future. Out of the 114 respondents, 68 selected electric as the type of two-wheeler they were planning on buying, whereas 46 were planning on buying an ICE two-wheeler. 24 respondents in the survey stated themselves to be existing owners of electric two-wheelers.

The following section summarises the results regarding the preferences of 24 electric two-wheeler owners and 68 potential owners of electric two-wheelers.

Survey results of potential and existing electric two-wheeler owners

All electric two wheeler owners surveyed owned lead acid based two wheelers. 75% of the respondents in the survey stated environment friendliness of EVs as the topmost reason for choosing electric two-wheelers. The second best motivation was stated as the low running costs of electric vehicles. The availability of government subsidies was not recognized as a significant motivation behind the purchase of electric vehicles by the surveyed owners of electric two-wheelers. High income levels might be the cause for the same as 46% of the EV owners in the survey earned more than fifty thousand per month.

Similar to existing electric vehicle owners, the potential electric two-wheeler owners also stated environment friendliness of EVs one of the main reasons for choosing electric. About 19% of the potential electric two-wheeler owners stated environment friendliness as the topmost reason for them to choose electric. Around 25% of them stated low running cost (fuel cost) of electric vehicles as the second most important reason for choosing electric. The third most important reason according to 19% of potential e-2w owners was again environment friendliness. Another 19% stated low maintenance needs of electric two-wheelers as the primary reason for choosing electric.



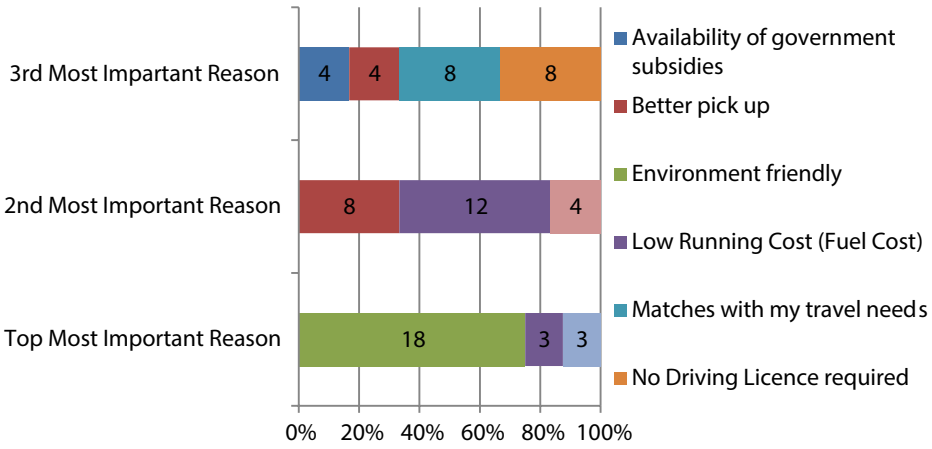


Figure 21: Motivation present e-2w owners for their choice of e-2w

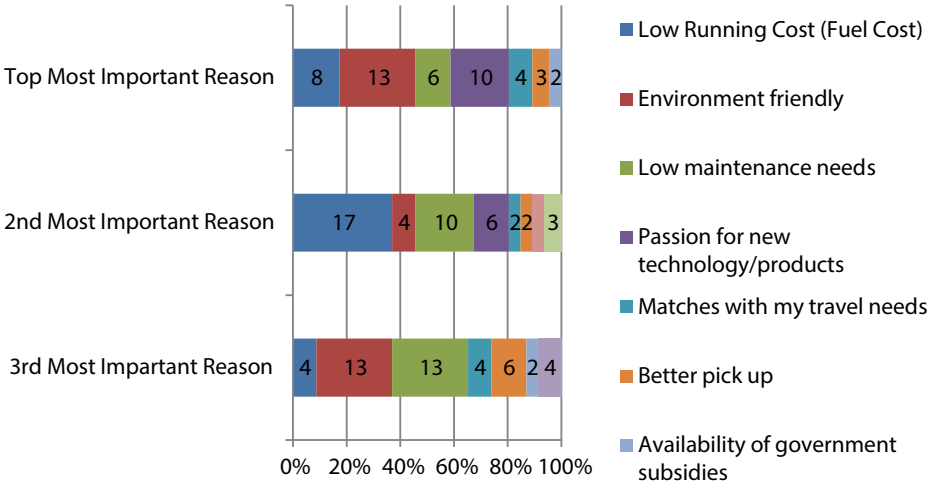


Figure 22: Motivation potential e-2w owners for their choice of e-2w

Another interesting observation from the survey is that only one of the 24 electric two-wheeler owners surveyed had electric two-wheeler as the sole two-wheeler in his household. That is, most electric two-wheeler owners had other ICE two-wheelers in their household. This reinforces our findings from the industry stakeholders that electric vehicle is a second vehicle in most households, with the primary being the 'reliable' ICE. Further discussions on the same will be done in the next chapter. Even though the availability of government subsidy was not stated as a significant motivation for selection of electric two-wheelers, the government subsidy was availed by 62% of surveyed EV owners.

Potential and existing EV owners were asked to state their anxiety levels as: 'not anxious at all', 'somewhat anxious' and 'very anxious' regarding the attributes of the electric vehicle ecosystem as range of vehicles, availability of charging facilities, top speed of EVs and so on. We have expressed the average results of the responses on a scale of 0 (not anxious at all) to 2 (very anxious). It is interesting to observe that the anxiety level of potential e-2w owners is more than current e-2w owners for all the attributes assessed in the survey. Range is the main cause of anxiety for existing owners and battery replacement is the main cause of anxiety for potential e-2w owners.

The second significant attribute causing anxiety among EV owners is the availability of charging facilities. The second factor is closely linked with the first one. If the market provides EVs with high range per kWh,

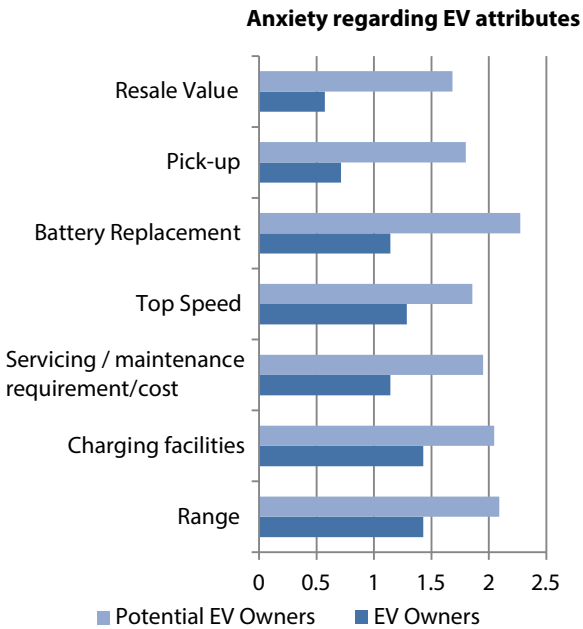
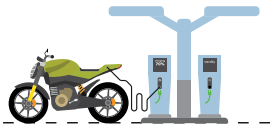


Figure 23: Anxiety regarding EV attributes: present and potential e-2w owners



the required density of charging infrastructure in the ecosystem will obviously be lesser. Similarly, existence of a dense network of charging infrastructure reduces the range anxiety in EV users.

The limited market visibility of electric vehicles may be the reason for high differences in the stated anxiety about e-2w attributes between existing and potential owners. Owing to the lack of clarity regarding battery life and as battery contributes to a significant cost of e-2w, the anxiety in potential e-2w owners in high.

The existing and potential owners of e-2w were asked to indicate the level of convenience in a scale of 1–5 from 'not convenient at all' to 'very convenient'. The

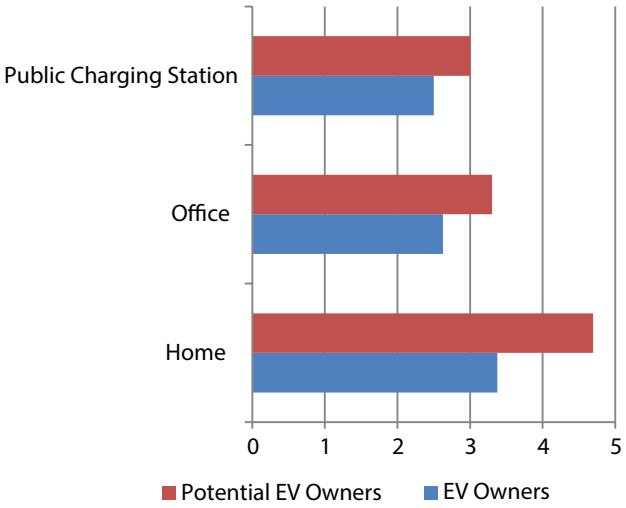


Figure 24: Convenience of location for charging: present and potential e-2w owners

average score of all respondents (existing and potential EV owners) for convenience in charging at home, office and public charging station (PCS) is shown in Figure 24. For both existing and potential owners of e-2w, on an average, home charging came out to be the most convenient place of charging an electric two-wheeler, followed by charging at office and charging at a public charging station.

The existing and potential e-2w owners were asked how much they were willing to pay for public charging with respect to the costs of home charging. The margins to be charged for electricity by a public charging station for sustaining the business were discussed in the preceding chapter. Here, we discuss the willingness of the existing and potential electric two-wheeler owners to pay a premium over home charging at a public charging station.

62% of the EV owners in the survey were not willing to pay any premium at a public charging station. As most EV owners find charging at PCS lesser convenient than home charging, they are obviously also not willing to pay a premium for lower convenience. However, there

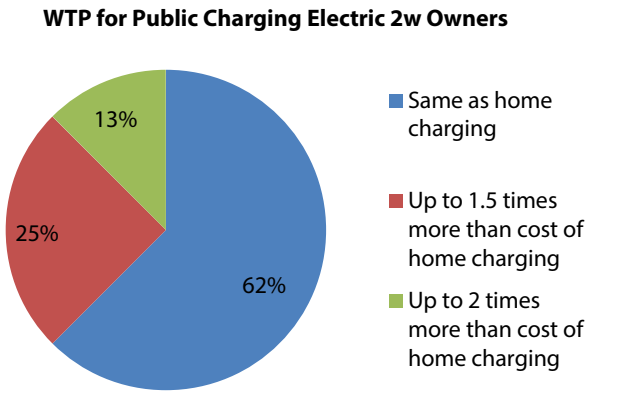


Figure 25: Willingness to pay at the public charging station: present e-2w owners

exists a small proportion (13%) of EV owners who are willing to pay up to two times more at a PCS than home charging.

Approximately 48% of the surveyed potential owners of e-2w were not willing to pay any premium for public charging. Similar to existing owners of e-2w, the potential owners also rated the convenience to

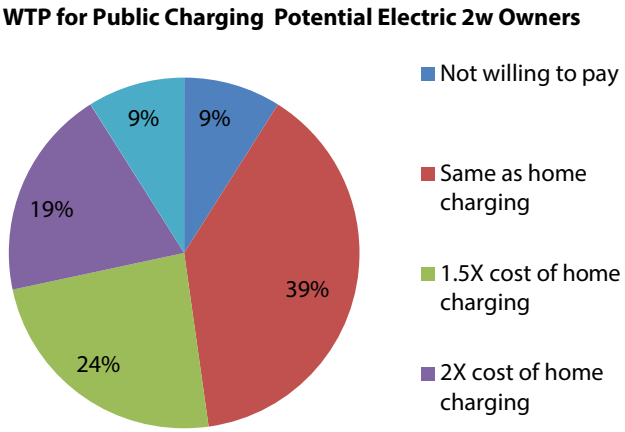
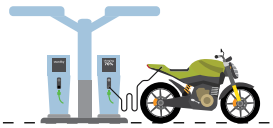


Figure 26: Willingness to pay at the public charging station: potential e-2w owners

charge at PCS to be lower than the convenience at home and office. Hence, it can be understood why



the majority of the respondents are not willing to pay any premium over home charging for public charging.

Willingness to Wait at Public Charging Station

The existing and potential e-2w owners were asked the time they are willing to wait at a public charging station to charge their electric two-wheelers.

Existing e-2w owner

38% of the existing owners were willing to wait only 5–10 min, which is equivalent or lesser than the time spent at petrol station. 71% of the respondents were willing to wait less than 20 min. We assigned weights to the responses and the results indicate that, on an average, an existing EV owner in the survey is willing to wait approximately 18 min at a charging station. This is a bright picture for charging stations.

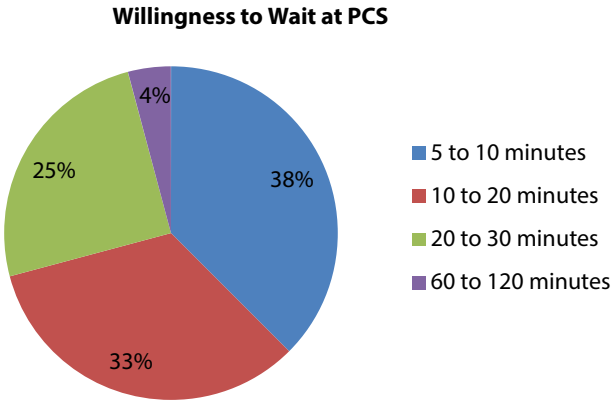


Figure 27: Willingness to wait at a public charging station: present e-2w owners

As most of the EV owners surveyed do not use their electric two-wheelers for regular work trips, their patience at a PCS may not be indicative of the patience of a regular EV using population.

Potential e-2w owner

24% of the potential e-2w owners surveyed were willing to wait less than 10 min at a PCS. Another 39% were willing to wait between 10 and 20 min.

We assigned weights to the responses and the results indicate that, on an average, an potential EV owner in the survey is willing to wait approximately 4 min at a charging station. This is a major deviation from the patience level of the existing EV owners, which was 18 min.

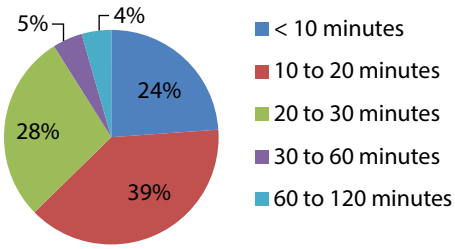


Figure 28: Willingness to wait at a public charging station: potential e-2w owners

Survey Results of Potential ICE 2w Owners

Figure 29 shows the results of 46 respondents who stated that they had plans of buying an ICE 2w in the near future. The respondents were asked about the motivation behind choosing an ICE 2w.

33% of the respondents stated that the topmost reason for planning to buy an ICE 2w over electric is the higher top speed. 20% stated the proven technology as the main reason for selecting petrol-driven two-wheelers. 26% of the respondents stated 'proven technology' as the second most important reason for choosing

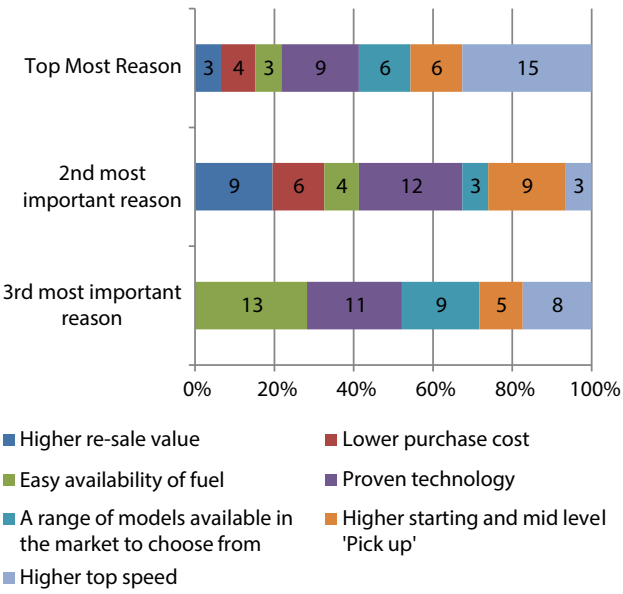
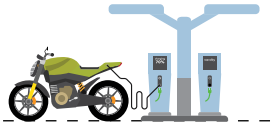


Figure 29: Reasons for not choosing electric: potential ICE 2w owners



ICE. Easy availability of fuel was cited as the third most important reason for choosing ICE by 28% of the respondents.

Other than the reason for choosing ICE, the potential owners of ICE 2w were also asked to state their reasons for not choosing electric.

The respondents were asked to rate each of the attributes of electric vehicles on scale of 1 to 5 indicating 'not at all

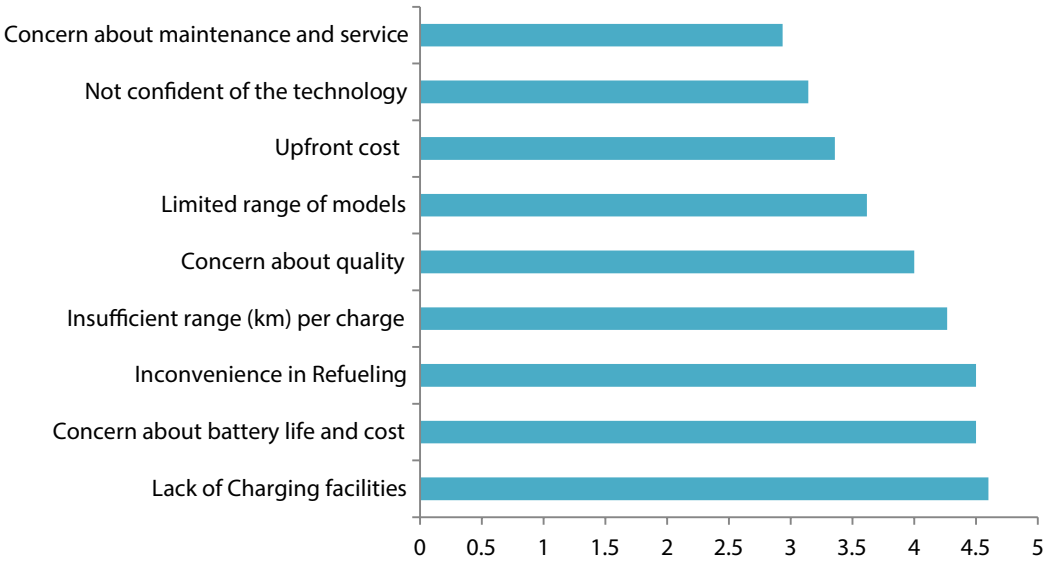


Figure 30: Perception of concerns regarding e-2w (potential ICE 2w owners)

important' to 'very important'. The main reason for not selecting electric 2w came out to be lack of charging facilities, followed by concern about battery life and cost, inconvenience in refuelling and insufficient range. All the main reasons of not choosing electric 2w are closely linked. The inconvenience in refuelling, insufficient range and lack of charging facilities are interconnected issues. As it was observed that the anxiety regarding range and battery was high even amongst the respondents who plan to buy electric, it is clear that this is a major barrier impeding the adoption electric vehicles in India.

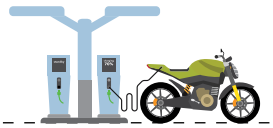
Perception of EV versus ICE

The potential owners of ICE 2w were asked about their perception of electric two-wheelers with respect to ICE counterparts. The respondents were shown attributes for which they had to express their perception of that attribute for EV being 'higher', 'lower', 'the same' against an ICE counterpart. Majority of the respondents considered EVs in general to have lower range, performance, speed and safety than ICE counterparts. A significant proportion of respondents also perceive electric vehicles to have lower maintenance and running cost. The potential owners of ICE 2w are aware about most aspects of electric vehicles, including knowing that its price and environment friendliness higher than ICEs.

Willingness to pay

The potential owners of ICE 2w were asked how much premium they were willing to pay for an electric two-wheeler.

40% of respondents were not willing to pay extra at all for an electric 2w instead of the planned ICE 2w. However, 27% of the respondents were willing to spend up to Rs 2000 as a premium for an electric vehicle. Surprisingly, 33% of individuals who were planning to buy petrol 2w were willing to pay Rs. 20,000 more for an electric vehicle with the same performance as the ICE counterpart.



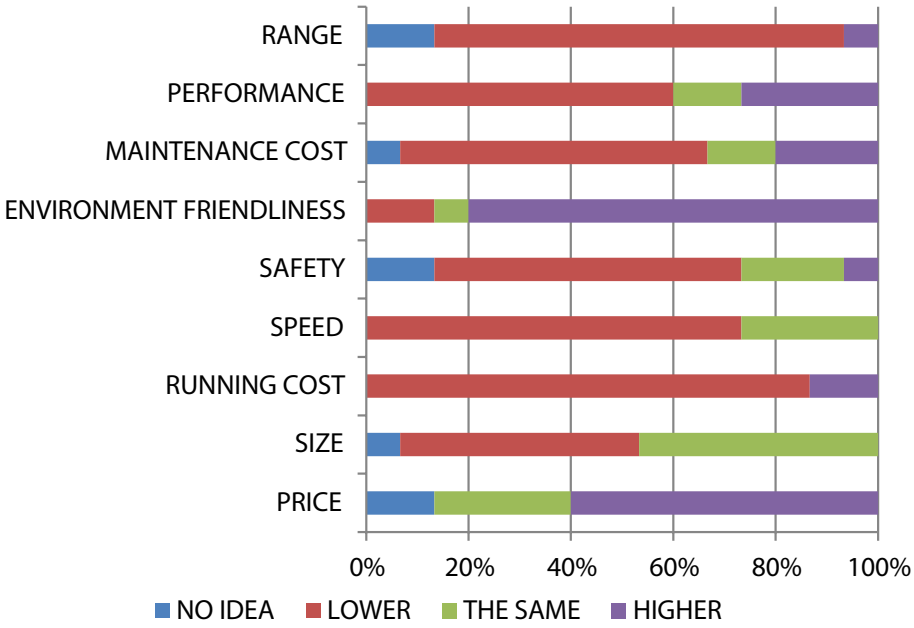


Figure 31: Perception of EV in relation to ICE (potential ICE 2w owners)

Willingness To Pay Extra for Electric Two-Wheeler

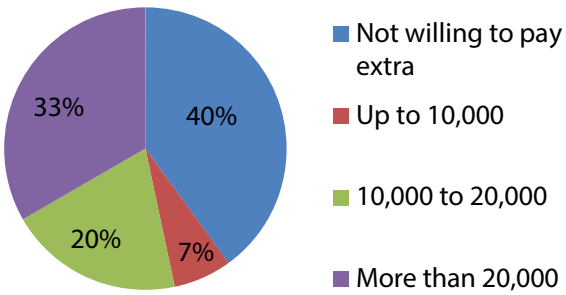


Figure 32: Willingness to pay for similar performing e-2w (potential ICE 2w owners)

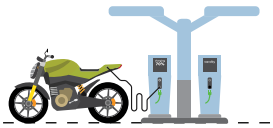
Summary Results of SP Survey

The following may be considered as the major findings from the online stated preference survey.

1. Most electric two-wheeler owners also owned another ICE two-wheeler. None of them used the electric two-wheelers for work trips.
2. The potential and existing e-2w owners stated environment friendliness as the main reason for choosing electric vehicles over ICE. This clearly indicates that the present e-2w owners as well as the ones thinking to buy one right now are the early adopters of the new technology.
3. The range and lack of charging facilities were the major sources of anxiety for existing and potential e-2w owners. However, the degree of anxiety amongst the potential e-2w owners was much higher than the existing e-2w owners.
4. The respondents who were planning on buying a petrol two-wheeler in the near future stated lack of charging facilities and concerns about battery replacement as the main reasons for not choosing e-2w.
5. About one-third of the potential petrol two-wheeler owners were willing to pay up to Rs. 20,000 extra for an electric vehicle that offered similar performance as its preferred ICE counterpart.

From analysis of the survey and the other secondary literature discussed here, the following two main barriers to EV adoption are identified:

1. High upfront costs
2. Inadequate charging infrastructure



6 AN ECOSYSTEM FOR ELECTRIC TWO-WHEELERS (FEASIBILITY STUDY)

Charging infrastructure will remain a critical driver for the success of EV adoption. Electrical two-wheelers can typically be charged at home, at a PCS or at a battery swapping station (BSS). This section attempts to assess the costs of setting up of each of these charging solutions in order to derive which of these mechanisms would likely become popular due to favourable economics.

Private charging

At present, there are two primary modes of private charging: charging at home and charging at office. This section discusses the private charging scenario for individual electric two-wheeler owners. Although (Original Equipment Manufacturers)OEMs are offering solutions for home charging along with the EV purchases, taxation, theft and accounting remain major challenges for private charging.

It is well acknowledged that convenient home charging will increase the EV adoption. Home charging is also supposed to result in longer battery life and grid balancing (Yilmaz, 2013). It leads to effective utilisation of electricity as the electric vehicles are usually charged at night in off-peak hours. Appropriate and convenient home charging is an essential catalyst for the transition of vehicle stocks into electric.

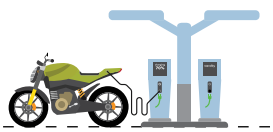
Key Assumptions

- All electric two-wheelers are charged at home.
- The cost of home charging is Rs. 5 per kWh.
- Each two-wheeler covers 30 km per day for 300 days in a year.
- Each two-wheeler has a 1.5 kWh battery with a capacity to cover 60 km on full charge.

Discussions with various electricity experts have helped discover that load of extra 231 crore kWh from 1.03 crore electric two-wheelers by 2030 can be absorbed by the existing infrastructure, with no extra cost, if the demand is well managed and distributed across off-peak hours. Considering a nominal cost of electricity, the annual cost of charging an e-2w comes out to be Rs. 1125 only.

The home charging solution for individual housing units is not challenging. Individual households can charge the electric two-wheeler as they charge any other electronic commodity in the household. The level 1 chargers in households are adequate for charging electric two-wheelers. However, the challenge arises in multiple dwelling units or multi-unit residential blocks (MURBs) defined as residences with three or more dwelling units and common interior and exterior areas. A significant population of Indian metropolitan cities live in such units. Tier II and tier III cities in India mostly have individual homes, but tier I cities such as Delhi, Mumbai and Bangalore have more of multi-unit residential blocks (Pethe, 2014).

For destination charging, a key challenge is to ensure that the parking spaces in residential, commercial and institutional places are EV ready. Government has already recognised the challenges and Ministry of Housing and Urban Affairs has issued specified guidelines in Model Building By-Laws. The Government of National Capital Territory of Delhi (GNCTD) also plans to modify



the building bye-laws in Delhi to make it mandatory to install three chargers for every 10 equivalent car spaces in each new residential building.

The state or city level building codes should be modified without setting high standards and creating unnecessary costs to the building in establishing EV infrastructure. A typical building's power distribution system, which is composed of a series of electrical energy carrying components to carry electricity in a safe and efficient manner, is not usually designed to cope with additional EV loads. However, electric two-wheelers with average 1.5–2 kWh batteries are not expected to challenge the load capacity of most compliant buildings. But the experts recommend assessment of building's wiring and metering configuration on a case-by-case basis. Individual meters might be required in parking lots to calculate electricity consumption of each end user. For the existing buildings to retrofit the EV charging infrastructure, adequate incentive schemes may be designed by the state of local governments. The installation of charging infrastructure by the existing building is dependent on the proportion of EV owners among the households as non-EV owners may be against installation of the same as the costs are variable and rewiring disturbing.

Private charging is a crucial component for boosting the initial uptake of electric vehicles, State and local governments must critically assess the plan for the same in terms of regulation, incentives, standards, metering and billing.

Public Charging Station

Although private charging might remain the most convenient method of charging e-2w, the availability of PCS will also remain critical to tackle the level of anxiety, support unplanned trips by EV and also support EV charging in areas where private/home/destination charging might not be feasible due to lack of EV parking spaces.

In order to assess the financial feasibility of PCS, it is assumed that 3.3 kW chargers for normal charging and 22 kW Type 2 AC charger for fast charging should be sufficient as recommended by Ministry of Power (MoP). Higher configuration chargers have not been considered for the PCS assessment here.

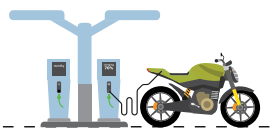
Key Assumptions

Each charging station consists of three 3.3 kWh chargers and one 22 kW Type 2AC charger specified in the Ministry of Power notification of December 2018.

1. All charging stations are the same.
2. All electric two-wheeler users rely on PCS for 11% of their charging needs (Li Zhang, 2013).
3. The business model for a public charging station assessed here does not include CCS, ChadeMo, and Bharat DC-001 charging points. The setting costs are also discounted proportionately (10% of the costs in). The maintenance costs remain the same.
4. The manpower is assumed to simultaneously service three PCS.
5. Each charging station is operated for 20 h per day for 360 days.
6. The operations cost does not include the cost of electricity procured from the electricity distribution company.
7. The average revenue is the margin earned per kWh electricity sold by the PCS.
8. Full utilisation of the PCS is expected to be made from the sixth year of operation.

Results

The feasibility of public charging stations is assessed under two main cases: including land cost and excluding land cost. The rental cost of the land in which the public charging station has to operate is a significant variable cost for operations of any public charging station. Public charging stations have to be situated centrally in the urban areas in order to effectively cater to EV charging demand. However, the land rental and purchase rates are enormous in such prime locations in the Indian cities. This land cost significantly affects the business feasibility of vehicles. Hence, we have assessed the business feasibility of PCS in both scenarios, that is, where land costs are incurred and where they are not.



Covering Average Variable Costs, including Land Costs (6 Lakh/Year)

- The average variable cost flattens as Rs. 3.8 for each unit of electricity sold.

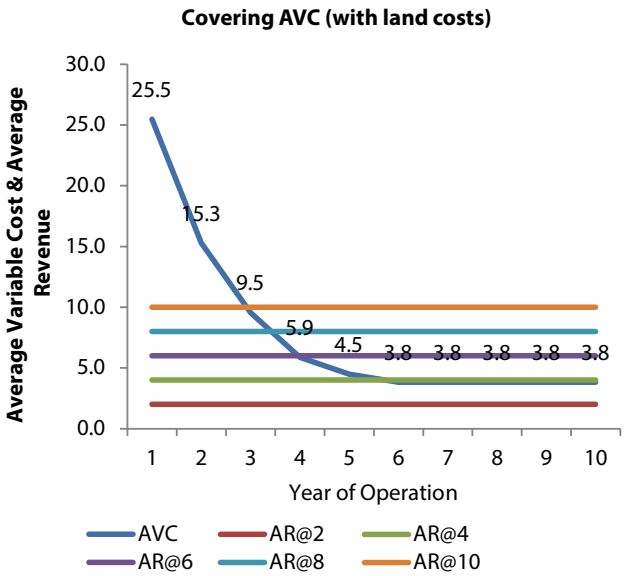


Figure 33: Feasibility of public charging station (with land costs)

- The average revenue per unit sold must be at least Rs. 3.8 to cover the (Average Variable Costs) AVC from the sixth year at least. Average revenue in this model is the margin earned on each unit of electricity sold by the charging service provider.
- The average revenue per unit electricity sold must be greater than Rs. 3.8 to reach break-even sometime in the future. In other words, the business will never cover the costs if the earning per unit of electricity sold in Rs. 3.8 or lesser.
- If the business earns Rs. 6 for each kWh of electricity sold, it will reach break-even in 8 years.
- If the business earns Rs. 8 for each kWh of electricity sold, it will reach break-even in 6 years.
- If the business earns Rs. 10 for each kWh of electricity sold, it will reach break-even in 5 years.

Feasibility of Public Charging Station (Without Land Cost)

- The average variable cost flattens as Rs. 1.2 for each unit of electricity sold.
- The average revenue per unit sold must be at least Rs. 1.2 to cover the AVC from the sixth year at least.

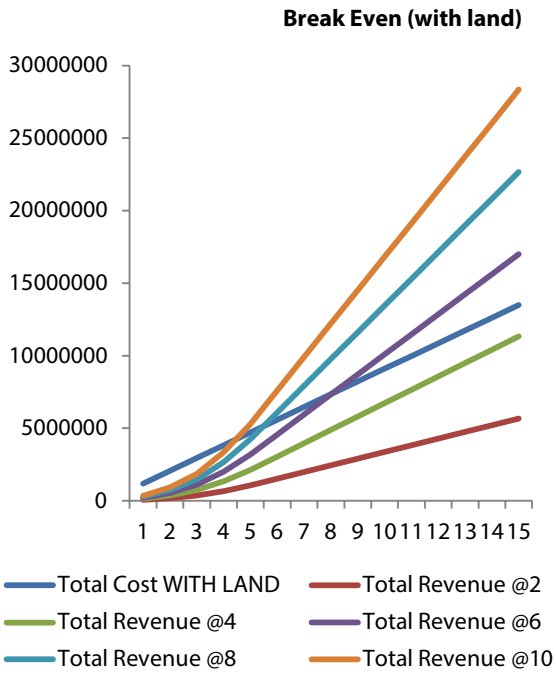


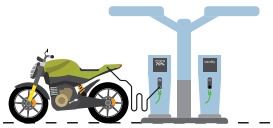
Figure 34: Covering AVC (without land costs)

Average revenue in this model is the margin earned on each unit of electricity sold by the charging service provider.

- The average revenue per unit electricity sold must be greater than Rs. 1.2 to break even sometime in the future. In other words, the business will never cover the costs if the earning per unit of electricity sold is Rs. 1.2 or lesser.
- If the business earns Rs. 2 for each kWh of electricity sold, it will reach break-even in 9 years.
- If the business earns Rs. 4 for each kWh of electricity sold, it will reach break-even in 5 years.
- If the business earns Rs. 6 for each kWh of electricity sold, it will reach break-even in 4 years.
- If the business earns Rs. 8 for each kWh of electricity sold, it will reach break-even in 3 years.
- If the business earns Rs. 10 for each kWh of electricity sold, it will reach break-even in 2 years.

Summary of PCS Business Feasibility Results

The above model of a public charging station is not an attractive one for investors as the returns are miniscule and the demand is uncertain. However, we see that when the land prices are excluded, the business of running a public charging station becomes more feasible. In a



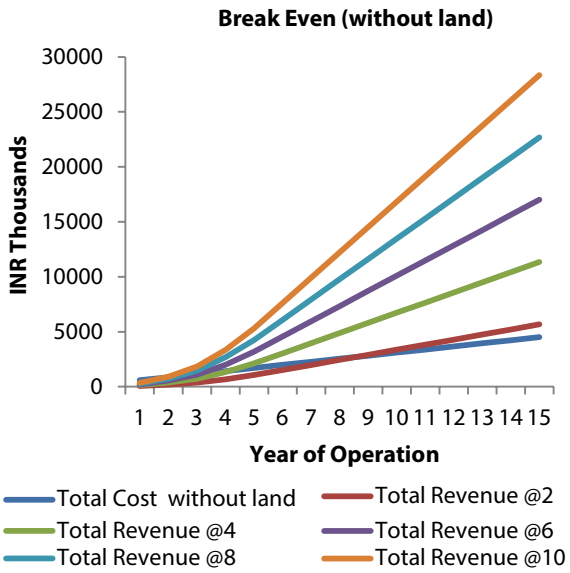


Figure 35: Break-even (without land costs)

scenario with no land costs, a public charging station can cover its variable costs by earning around 4 Rs. per kWh of power sold. It must be noted that it still does not make an attractive business proposition for investors. Hence, large public sector enterprises and electricity distribution companies capable of handling heavy losses may be the front runners in setting PCS in Indian cities. Chapter Seven on the Industry's perspective will elaborate more on the possible interventions from central, state and local governments to make PCS more attractive to private investors.

Table 10 summarises the results of the business feasibility assessment carried out for a PCS.

In the case where land costs are completely borne by the PCS, the best case to break even is to charge at Rs. 10 margin over purchase price per kWh. The business in this case will start covering the annual operational expenditure from the third year onwards and will break even the total investments in less than 5 years. Similarly, if the PCS charges a margin of Rs. 10 in the absence of land rental costs, it would start covering its operational expenses from the very first electric two-wheeler charged and break even before 2 years of operation.

The question that arises at this point is whether the consumers will be willing to pay such a margin. We have explored the stated preferences of potential and current owners of electric two-wheelers regarding the same in the next chapter.

Cost to the economy for PCS ecosystem

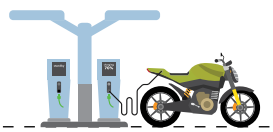
The costs of setting up and operating a single PCS were evaluated in the last section. Now, we attempt to understand how many such PCS will be required to be set up to cater to the electric two-wheeler demand projected in the New Policy Scenario and what will be the costs for the same. In this section, we also express the costs in terms of cost per electric vehicle.

1. Assumptions

1. All the PCS are the same and consist of three 3.3 kW Bharat AC-001 chargers and one 22 kW Type 2 AC charger as specified in the Ministry of Power notification.

Table 10: Summary of PCS feasibility study

Costs	Margin (earnings for PCS per kWh sold)	With land		Without land	
		Years till covering annual variable cost	Years to cover total cost (break-even)	Years till covering annual variable cost	Years to cover total cost (break-even)
Total capital cost Rs. 302,586 Variable cost Rs. 880,000	2	Never	Not feasible	5th year	9 years
	4	6th year	More than 15 years	4th year	5 years
	6	5th year	9 years	3rd year	4 years
	8	4th year	6 years	2nd year	3 years
	10	3rd year	5 years	1st year	2 years



2. Each PCS operated for 20 h a day and for 360 days in a year.
3. Each two-wheeler covers 30 km per day for 300 days in a year.
4. Each two-wheeler has a 1.5 kWh battery with a capacity to cover 60 km on full charge.
5. Annually, each electric two-wheeler requires 225 kWh or 150 full charges.
6. From assumptions 2, 3, 4 and 5, it can be deduced that one PCS operating at the maximum capacity can meet the annual demand of 1024 electric two-wheelers.
7. All PCS are assumed to be established in 2019–20.
8. The utilisation of all PCS is assumed to be as given in Table 10.

Table 11: Assumed utilisation rates at a PCS

Utilisation (%)	Year
15	2019–20
25	2020–21
40	2021–22
65	2022–23
85	2023–24
100	2024–25
100	2025–26
100	2026–27
100	2027–28
100	2028–29
100	2029–30

9. Annual capital costs are accounted for all new charging stations set up in that year.
10. Annual variable costs are accounted for all operational charging stations in that year.
11. The derived annual cost per electric two-wheeler does not include the charging costs of the two-wheeler.
12. Other assumptions made in business feasibility assessment continue to hold true here.

1. Results

Figure 36shows the annual charging costs, including all annual capital and variable costs. The annual charging costs include all capital and operational costs of all charging stations set up or operating in that year.

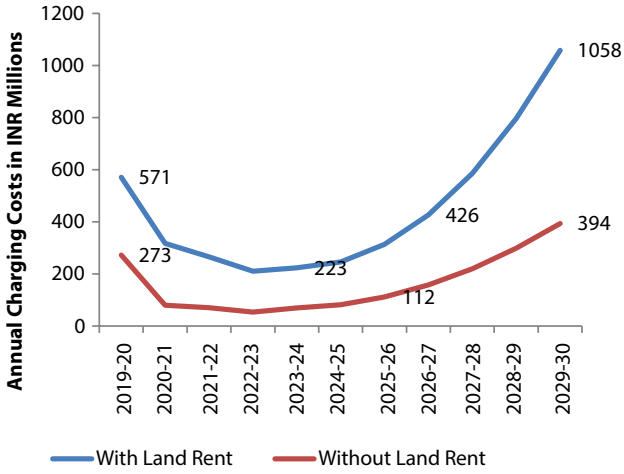
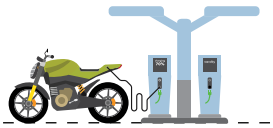


Figure 36: Annual charging costs to ecosystem, including all annual capital and variable costs

- An expenditure of Rs. 1600 crore must be made to facilitate setting up of public charging stations and their operations till 2025. In the case where PCS businesses do not have to spend on land rents, an expenditure of Rs. 570 crore must be made to facilitate setting up of public charging stations and their operations till 2025.
- The annual cost per e-2w is the annual charging cost divided by the total e-2w stock in that year. These values were estimated to determine the hypothetical financial burden on the electric two-wheeler owners from the costs of charging ecosystem.
- The annual cost per electric two-wheeler for the PCS ecosystem stabilises only after higher utilisation levels achieved in 6–7 years of operations of PCS.
- The annual cost per electric two-wheeler does not include the cost to be incurred in charging the electric vehicle.
- From 2019–20 to 2029–30, costs per electric two-wheeler fall from Rs. 823 to Rs. 103 in the case of businesses incurring land rents in contrast to the fall from Rs. 393 to Rs. 38 per electric two-wheeler in the absence of land rents.



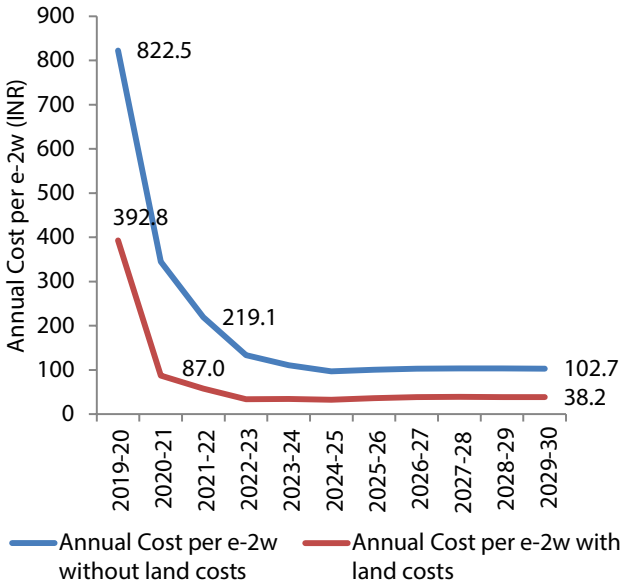


Figure 37: Annual charging costs to ecosystem per e-2w, including all annual capital and variable costs

Table 12: Cost per km for 2w sourcing energy from different sources

Margin charged by PCS (Rs.)	Cost per kilometer (Rs.)	
	Electric vehicle From GRID	ICE
2	0.19	1.17
4	0.24	1.17
6	0.29	1.17
8	0.34	1.17
10	0.39	1.17

[a]It is assumed that the fuel efficiency is 60 kmpl and the fuel price is Rs. 70.

Even when the PCS charges a margin of Rs. 10 over the base price, the two-wheeler commuter has a fuel cost saving of 66% if she switches to electric. In this case, the cost per kilometre comes out to be just Rs. 0.40 if charged from PCS in comparison to Rs. 1.17 per kilometre for an ICE two-wheeler.

One main conclusion to be inferred from this analysis could be that operations cost, especially land costs, dominate the costs of PCS. The cost recovery period of PCS significantly improved after excluding the land costs. It is necessary for state and local governments in India to promote PPP models in PCI (Public Charging Infrastructure) in urban areas till there is adequate utilisation of facilities. The industry must continue to provide vehicles easily compatible with the existing residential electric infrastructure to continue the wave electric mobility in India. This coupled with adequate building bye-laws and public charging infrastructure will determine the future of electric vehicle charging infrastructure. The future of charging infrastructure will depend on the following:

- PCI implementation by the government
- Battery size of vehicles
- Utilisation of personal vehicles

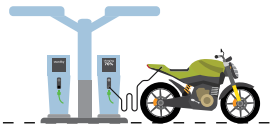
The planning and implementation of the charging need of electric vehicles is accrued not to the transport sector, but to the energy sector. There has to be planned coordination in research, policy and implementation segments of both the sectors of energy and transport for successful phased adoption into electric vehicles.

Battery swapping ecosystem

In this part, we assess a battery swapping ecosystem for the charging needs of the projected electric two-wheelers in the New Policy Scenario. A battery swapping system is the one where instead of charging the battery, the vehicle user exchanges his power drained battery with a fully charged one.

The inventory of batteries at the BSS is an optimization problem contingent on various factors. When all vehicles are homogeneous, the worst case scenario for BSS is where the entire fleet starts the BSS subscription at the same point of time and have the exact same driving pattern. This would indicate that all return at the same time to swap their batteries. In this case, considering infinite simultaneous swaps, the BSS must hold an extra battery for each of its subscribers. Hence, for X vehicles dependent on the BSS, there must be 2X batteries in the ecosystem.

Whereas, in the case of a homogeneous fleet, the best case would be that the BSS must hold just a single battery. This happens when all the subscribers are distributed in such a way that the difference in time between two users visiting the BSS is less than or



equal to the sum between time taken to charge and swap the battery.

Key Assumptions

1. Each battery is swapped in 20 min.
2. A battery swapping station (BSS) is operational for 20 h/day for 300 days to conduct 18,000 battery swaps annually.
3. Each electric two-wheeler needs a battery swap after every 60 km.
4. Each electric two-wheeler travels 30 km/day for 300 days to cover 9000 km annually.
5. Entire stock of electric two-wheelers has standard 1.5 kWh swappable batteries.
6. The swapping ecosystem is set up 2019–20 onwards.
7. Each kWh of power costs Rs. 5, and hence cost of charging a 1.5 kWh battery is Rs. 7.5.
8. The number of swapping stations is determined based on the swapping requirement of the stock of electric two-wheelers.
9. The costs of charging the batteries are included in the variable costs.
10. The total annual cost includes the costs in the table below and the costs of battery purchases less the costs of scrapping.
11. The Battery scrap value is assumed to be 25% of the Battery cost of the corresponding year(Melin, 2018).
12. Battery swapping station

Annual land rent (Rs. 50,000/month)	600,000
Annual maintenance cost	50,000
Annual manpower cost (Rs. 20,000/month)	240,000
Capital cost of charging infrastructure	200,000

The costs of batteries have a significant effect on the business feasibility of a battery swapping station. Hence, we have analysed two scenarios for a BSS ecosystem based on optimistic and pessimistic predictions of battery prices in the literature.

Table 13: Lithium battery prices scenarios

Financial year	Scenario 1 (BNEF, 2017)		Scenario 2 (IEA, 2017)	
	Battery cost (Rs./1.5 kWh)	Battery scap value	Battery cost (Rs./1.5 kWh)	Battery scrap value
2019–20	26,318	6579	26,318	6579
2020–21	24,212	6053	25,265	6316
2021–22	21,054	5264	24,212	6053
2022–23	20,001	5000	23,159	5790
2023–24	17,896	4474	22,107	5527
2024–25	16,843	4211	21,054	5264
2025–26	15,791	3948	20,001	5000
2026–27	14,738	3684	18,949	4737
2027–28	13,685	3421	17,896	4474
2028–29	12,632	3158	16,843	4211
2029–30	11,580	2895	15,791	3948

Results

Business feasibility assessment of battery swapping station

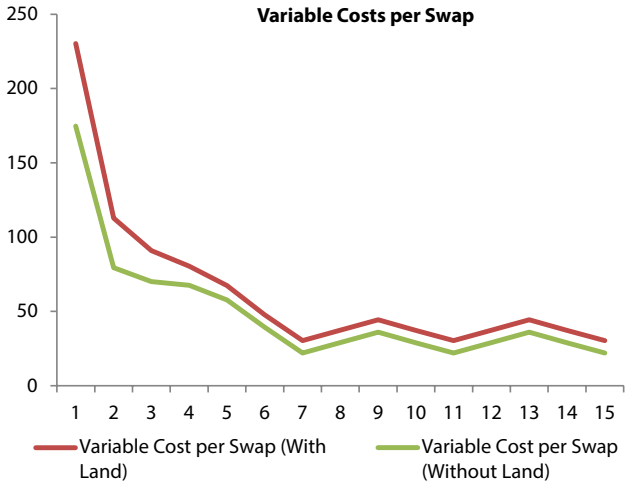
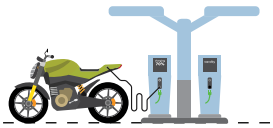


Figure 38: Variable costs per swap (optimistic scenario battery swapping station)

Scenario 1 (optimistic) (BNEF, 2017)

The annual variable cost per swap includes all costs of a BSS except purchase of chargers and setting up costs.



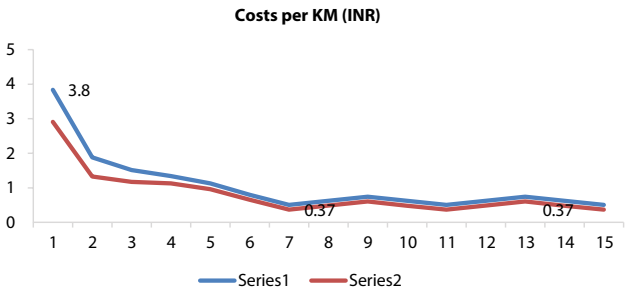


Figure 39: Costs per km for e-2w in a swapping ecosystem (optimistic scenario)

The cost per km for e-2w is the variable cost per swap divided by the assumed range of e-2w (60 km per charge).

Scenario 2 (pessimistic) (IEA, 2017)

The annual variable cost per swap includes all costs of a BSS except purchase of chargers and setting up costs.

The cost per km for e-2w is the variable cost per swap divided by the assumed range of e-2w (60 km per charge).

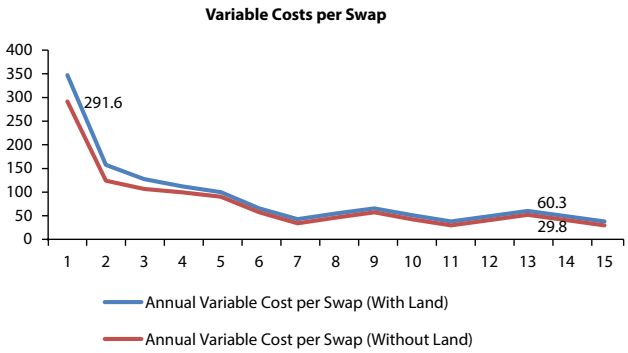


Figure 40: Variable costs per swap (pessimistic scenario battery swapping station)

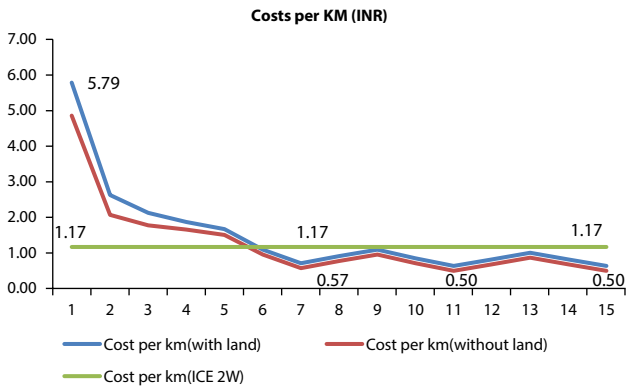
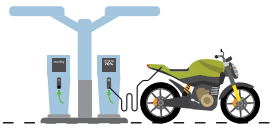


Figure 41: Costs per km for e-2w in a swapping ecosystem (pessimistic scenario)



Here, we expressed the total annual cost of a battery swapping ecosystem in terms of costs per swap and costs per electric two-wheeler. The results of the BSS ecosystem feasibility assessment for both scenarios are summarised next.

Scenario 1

Scenario 1 (BNEF, 2017)	Cost per swap (Rs.)		Annual cost per electric two-wheeler (Rs.)	
	With land costs	Without land costs	With land costs	Without land costs
Maximum	269	261	40,365 (in year 2020)	26,208 (in year 2020)
Minimum	89	81	39,115 (in year 2030)	12,131 (in year 2030)

The cost of the battery swapping ecosystem per swap ranges from Rs. 269 in 2019–20 to Rs. 89 in 2029–30 when the land costs are included.

- When land costs are excluded, the BSS ecosystem cost per swap ranges from Rs. 261 in 2019–20 to Rs. 81 in 2029–30.
- The costs per swap are huge and give a straightforward conclusion that battery swapping cannot be the singular solution for creation of a charging ecosystem.
- The same assessment shows that the BSS operators must charge at least Rs. 24 per swap to cover their variable cost (which does not include battery purchase cost). Considering per kWh charge of Rs. 5, the user will need just Rs. 7.5 to charge the vehicle at home and might not utilise the swapping infrastructure.
- The annual cost of the battery swapping ecosystem per electric two-wheeler ranges from Rs. 40,365 in 2019–20 to Rs. 17,047 in 2029–30 when the land costs are included.
- When land costs are excluded, the annual BSS ecosystem cost per electric two-wheeler ranges from Rs. 39,115 in 2019–20 to Rs. 15,797 in 2029–30.
- These costs include the charging and battery costs.

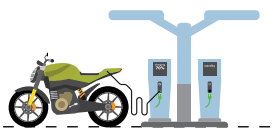
Scenario 2

Scenario 2 (IEA, 2017)	Cost per swap (Rs.)		Annual cost per electric two-wheeler (Rs.)	
	With land costs	Without land costs	With land costs	Without land costs
Maximum	269	261	40,365 (in year 2020)	39,115 (in year 2020)
Minimum	114	105	17,047 (in year 2030)	15,797 (in year 2030)

- The cost of the battery swapping ecosystem per swap ranges from Rs. 269 in 2019–20 to 114 in 2029–30 when the land costs are included.
- When land costs are excluded, the BSS ecosystem cost per swap ranges from Rs. 261 in 2019–20 to Rs. 105 in 2029–30.
- The costs per swap are huge and give a straightforward conclusion that battery swapping cannot be the singular solution for creation of a charging ecosystem.
- The same assessment shows that the BSS operators must charge at least Rs. 24 per swap to cover their variable cost (which does not include battery purchase cost). Considering per kWh charge of Rs. 5, the user will need just Rs. 7.5 to charge the vehicle at home and might not utilise the swapping infrastructure.
- The annual cost of the battery swapping ecosystem per electric two-wheeler ranges from Rs. 40,365 in 2019–20 to Rs. 17,047 in 2029–30 when the land costs are included.
- When land costs are excluded, the annual BSS ecosystem cost per electric two-wheeler ranges from Rs. 39,115 in 2019–20 to Rs. 15,797 in 2029–30.
- These costs include the charging and battery costs.

Policy takeaway

- The economics of running a BSS does not seem favourable in comparison to PCS or home charging.
- The costs per swap for best and worst cases vary between 208 and 136.
- BSS might find applications in specific cases such as high utilisation commercial operations where high turnaround time is reduced.
- Commercial applications for two wheelers like in e-commerce and food technology has a potential for Battery Swapping as fleets maybe homogeneous and driving patterns, predictable.
- BSS will also cause/put forth new safety risks as batteries would need to be moved around for completing the swapping are a long way from automation.
- For wider application of Battery Swapping, standardisation of battery sizes is necessary. However, this may lead to sub optimal vehicle design, limitations in advancements in battery technology and proliferation of malpractices in open network.



7 INDUSTRY'S PERSPECTIVE

The automobile industry and the auto component industry which have evolved over 100 years in ICE vehicle manufacturing contribute to 7.1% and 2.3% of the GDP, respectively. These industries also directly employ 18 million and 3 million people, respectively. An EV drastically differs from an ICE vehicle. The composition, size, and weight are different. The kind of potential hazards are different. While shifting from ICE vehicle to EV, the powertrain composed of engine, transmission, and drivetrain will shift to battery, motor, controller, and charger.

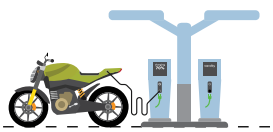
Employment Effects (NSDC 2016)

The 50% of the auto industry workforce which is engaged in engine manufacturing is at risk here. Further, a large population of unorganized workforce catering to the after-market sales and services of ICE is also at risk as the sophisticated electric vehicles will be maintained mostly by authorized service centres. Over a 5-year period, 40–42% of an ICE vehicle's periodic maintenance cost is spent on engine related parts and consumables. It also requires cleaning of particulate filters, turbochargers, mufflers, and the like. As the number of moving parts inside an EV are considerably lower compared to an ICE vehicle, the need for regular servicing and maintenance is significantly reduced. So, EVs certainly do not mean more business for the local unorganized workshops.

Effect on Value Added (SIAM 2017a, ACMA 2018)

The transfer to EV will increase the usage of materials like semiconductors, copper, and rare earth metals such as cobalt and lithium. The contribution of raw materials in value addition in an EV vehicle is certainly higher than their contribution in an ICE vehicle. The most important metal in an EV is lithium on account of its usage in batteries. The major deposits and large-scale economic extraction is mainly in Bolivia, Chile, and Argentina. The battery cost constitutes of more than 40% of the vehicle cost and presently most OEMs either import the battery or source it through a supplier. Even though there are some battery manufactures in India, they still have to import the lithium ion cells. Presently, the Chinese automobile industry is the leader in EV technology and offers the EV components at far lower prices than domestic manufacturers in India. Chinese OEMs account for approximately 43% of global PHEV and BEV sales.

Due to high costs of EVs coupled with stiff competition in the industry, the Indian OEMs would obviously prefer importing the parts from the Chinese auto component industry to cater to the subsidy induced demand for EVs in India. So the shift of an ICE to EV will reduce the emissions, but will also reduce the role of the Indian automobile industry in value addition to the product. Hence, at least 70% of the cost of an EV currently sold in India is accrued to import cost.



SIAM, White Paper 2017

The white paper on Adopting Pure Electric Vehicles: Key Policy Enablers by Society of Indian Automotive Manufacturers (SIAM) was presented in December 2017. The white paper emphasizes on the need to reduce energy demand and decarboniz ation of the auto sector in India, along with the requirement of EV penetration and techno-economics of electric vehicles in various segments. The paper presents the vision of the Indian automobile sector which is represented by SIAM and envisions that ' There is a need to expand policies and boundaries to have a future of all electric vehicles'.

While the paper finds that in comparison to other segments, the total cost of ownership of electric two-wheelers is the closest to the conventional technology vehicles, it also highlights that 98% of the total electric two-wheeler on road are low-speed electric two-wheelers. According to SIAM, these vehicles have limited performance like drivability, acceleration, gradability etc. which in turn has largely resulted in low-acceptance by the consumers.

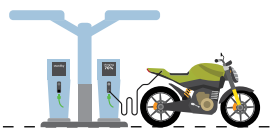
The paper elucidates the total cost of ownership of various vehicle segments and states that the single major factor for slow penetration of EVs is their high price which is around 2 to 2.5 times more than a comparable conventional vehicle. According to the paper, another reason of low EV penetration is the limited range, in order to promote up-take of electric vehicles, these vehicles must be equipped with higher battery capacity while maintaining the price parity between electric vehicles and conventional vehicles. Although as compared to a personal vehicle, commercial vehicles like taxi fleets, bus fleets, three-wheelers run four to five times longer distance per day. Therefore, for such higher mileage vehicles savings on operating cost will pay back the initial high purchase price faster than low mileage vehicles. Attractive power tariff can play a significant role to offset the capital cost of buying EV with lower operating cost at a faster pace.

For various segments:

- Electric two-wheeler: A majority (84%) of two-wheelers sold have engine capacity between 100 and 125 cubic capacity and are priced in the range of Rs 60,000 – 90,000. In India, the total vehicle of electric two-wheelers in 2017 were about 210,000, out of which 98% were low powered and low speed variants (maximum power not exceeding 250 Watts and maximum speed not exceeding 25 kilometres per hour). Even though these are priced in the range of Rs 30000 to 50000 they are not being accepted by consumers at large due to their sub-par performance.
- Electric three-wheeler: Any electric 3W with near equal performance to ICE vehicle costs approximately twice in price of a conventional vehicle. Moreover, limited range and inadequate charging infrastructure will lead to a number of externalities in the market, such as opportunity and revenue loss. The paper suggests that for electric three-wheelers, battery swapping may be encouraged to strengthen the possibility of overcoming range limitations in inner cities.
- Electric four-wheelers: As majority (99%) of Indian passenger car market is constituted by small and mid-size cars, therefore, purchase price of the car / vehicle is one of the most important factors in consumer decision. An additional electric powertrain component such as battery, motor, controller and charging infrastructure coupled with the initial high upfront cost of an equivalent EV, makes it about 70% higher in comparison to an entry level sedan. This translates in to electric cars being unviable even for a seven-year ownership period, given cars daily use is 40 to 50 km with battery costs of 50 USD/kWh (which is a very aggressive assumption).

The paper also proposed the following recommendations:

- The GST rates for electric vehicles may be brought down from 12% to 5% and road tax may be fully exempted for which Motor Vehicle Act can act as an enabler
- Accelerated depreciation of 40% instead of 15% on EVs to be considered for income tax deduction as is being given for plant and machinery.
- Power tariff for charging of EVs could be 50% of the existing domestic tariff rate for home and



workplace charging. Attractive power tariff rate at public charging infrastructure could be considered to enhance utilization.

- Phased mandate of conversion of public fleets in cities (including e-commerce delivery vehicles) to electric. CNG fleets in India are an example that could be emulated with a phased plan.
- Electric two-wheelers to be allowed to be used as taxis, nationwide. Motor Vehicle Act may be amended to that effect.
- Energy companies (like IOCL, HPCL, IGL etc.) may invest in providing a charging network, specially the fast charging stations at inter-city routes like state and national highways. This could also be based on renewable electricity source.
- Battery swapping infrastructure for three-wheelers and buses may considered. Standard for battery swapping may be formulated to ensure safety and functional requirements.
- For city buses, depot and opportunity charging mechanisms need to be carefully evaluated based on techno-commercial feasibility and route planning. Regulations need to be put in place to ensure availability of stable and good quality power for EV charging.
- Linking public chargers with an IT network for interoperability and proper usage.

Results from Industry Stakeholders Interviews

TERI conducted interviews of electric vehicle and ICE vehicle manufacturers; representatives from industry lobby bodies like ACMA, SMEV, SIAM, and FADA; charging solution providers; and other stakeholders in the e-mobility scenario in India. The industry's opinion on different sections of electric mobility is discussed here.

Market for electric two-wheelers in India

Most electric two-wheelers adopted in India are low speed and are powered by sealed lead acid batteries. These vehicles are not performance based competitive with current ICE two-wheeler vehicles and hence it may be deduced that the purchase of lead acid electric two wheelers was as second vehicles for very short distances, probably replacing trips earlier catered by non-motorized modes. Presently the demand for electric two-wheelers is limited to short trips in urban areas.

The rural demand in India for two wheelers is for higher load bearing and longer trips than urban areas. Further, as rural areas have unstable power supply, electric vehicles are yet to receive adequate visibility.

Indian consumers have upgraded their preferences form 100cc category of two-wheelers to 125cc–150cc models categories. This is a major drawback for electric vehicles as they have to compete with the higher performing ICE two-wheelers for improving the market penetration. The lack of noise from electric vehicles may be considered as an environmental benefit, but numerous potential consumers see it as drawback as it doesn't give the 'racing feeling' like ICE vehicles. Limited range is a major factor impeding the adoption of electric vehicles. Even the individuals with routine jobs and fixed routes do not prefer electric vehicles because of the lack of flexibility in mobility.

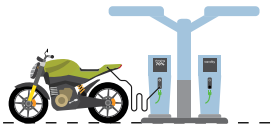
To approach towards faster adoption of electric vehicles, the technology must be competitive, at least regarding range of the vehicle.

Issues from the paradigm shift to electric

The paradigm shift to electric vehicles will affect the entire supply chain of automobiles, starting from the mining industry, metal industry, and auto component manufactures to automobile manufactures, dealers, and after sales service providers.

Dealership

Federation of Automobile Dealers Associations has a network of 15,000 dealers with 25,000 dealerships covering 85–90% of the automobile market. They employ 2–5 million people directly and about 2.5–3 million indirectly. There is a large population of people employed in auto retail alone. For example, just top 5 dealers of Maruti employ more than 20,000 people. Although the jobs at dealerships are not at a direct



threat by electric vehicles, there is a massive reskilling required in the auto retail industry to be able to sell and improve the market penetration of electric vehicles.

Domestic Component Manufacturing

There is a belief amongst the industry that even though electric vehicle penetration increases the demand for ICEs will not decrease. However, 50% of the revenue of the auto component industry is accrued from engine manufacturing. The paradigm shift from combustion engine to battery, motor, controller, and charger will challenge the highly evolved Indian auto component industry. The Chinese component industry is far more attractive for electric vehicle manufacturers for bringing down the comparative costs of EVs. Although there are component manufacturers like Motherson Sumi systems and Lucas-TVS investing in electric vehicle technologies. For power electronics and other components of electric motors and battery, Indian suppliers can potentially offer a cost effective solution if the OEMs start outsourcing the sub-components in large scales. However, majority of the component suppliers lack comprehensive strategies for xEV components.

After Sales Service

An electric vehicle has 80% lesser moving parts inside as compared to an ICE. This significantly brings down the need for maintenance and the corresponding costs for the user. However, the huge after sales service industry, which caters to demand for auto parts and servicing of ICE vehicles may not be needed or may not be able to cater to electric vehicles. As the technology is new and unknown to the large informal automobile after sales service economy, the little maintenance need of EVs will have to be catered by authorized dealership. There is a massive reskilling required for this informal sector to adapt to serving electric vehicles along with ICEs.

Issues from current policy at national and state levels

The shift to electric vehicles is a topic concerning areas of energy, technology, and transport. There are multiple ministries at the centre and departments at the State involved in improving the adoption of electric vehicles in India. The Ministry of Heavy Industries launched the scheme providing purchase subsidy to electric vehicles, The Ministry of Power published the mandatory guidelines for public charging infrastructure and the Ministry of Housing and Urban affairs released the model building bylaws which facilitated provisions for private charging infrastructure. The Ministry of Power mandated 5 different types of chargers in all Public charging stations installed after December 2018, when the publication was released. The mandatory charger requirement adversely affects the business feasibility of a public charging station and put a halt into private players independently setting public charging stations. A coordinated effort from the central ministries and state departments with adequate feedback mechanisms for improving the policies will certainly aid in improving the adoption of electric vehicles in India.

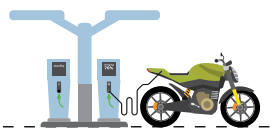
Policy support required for faster adoption of electric vehicles

While governments can improve the demand from the consumers by purchase subsidies, they can help the manufacturers with tax exemptions and other policy support.

- The state governments can provide road tax for electric vehicles.
- The state departments may have a partial or full waiver of toll taxes.
- The state also has a significant role in establishing the charging infrastructure to nourish the effective adoption and usage of electric vehicles.
- At the city level, the government can discount the registration fee for EVs, facilitate faster registration and develop reserved/free parking spots for electric vehicles.

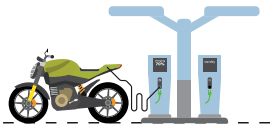
For the manufacturers, the Governments at the city, state, and national level can significantly aid in improving the adoption of electric vehicles.

- At the national level, the government can make long-term roadmaps to mitigate investment risks for OEMs and release more grants for R&D for improved domestic production of EVs and EV components.



- At the State level, the governments can aid in provision of land electric vehicle charging facilities and also subsidize the supply of electricity of such stations.
- At the City level, the land costs for charging stations could be brought down by concessions in municipality related taxes like property tax.

The two-wheeler segment is one of the preferred motorized modes of travel in Indian cities. Electric two-wheelers in India are facing various challenges such as high upfront cost, lack of charging infrastructure, subpar performance, limited range, and limited model variants.



8 BUSINESS AND FINANCING MODELS

Innovative approaches to promote uptake of electric two-wheelers

This section discusses different innovative models adopted in different cities to overcome different barriers and promote the use of electric two-wheelers.

Leasing & Renting Models in India:

Ather Energy- In order reduce the upfront cost for the consumers, ATHER offers a leasing solution to electric twowheeler users. ATHER is leading manufacturer of electric two-wheelers in India. Bengaluru-based start-up is also providing electric vehicle charging infrastructure ATHERGrid. In order to promote faster adoption of electric two-wheelers, ATHER offers consumers both pure lease and lease to own models. Along with the vehicle ATHER also provides a home charging set up with a charging cord for the user. The stakeholder discussion brought forward that the market has been responding positively to this model with many users opting to purchase the vehicle eventually.[5]

> ***Learning:*** The model offers rent-based financial mechanism to reduce the upfront cost. ATHER also facilitates provision of charging infrastructure to increase the acceptability and reduce the range anxiety of the users. Addressing the upfront cost barrier through easy financing models and the issue of range anxiety through charging infrastructure will remain critical to the success of EVs in India.

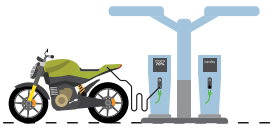
Leasing by third party logistics (Model by Go Green BOV Bengaluru)- The Bengaluru-based company Go Green BOV works on an innovative mechanism where the company is manufacturing and offering its electric scooter on a lease model to logistics, e-commerce, and hyper local delivery companies. The company is working on B2B lease-based model and supports other companies in reducing their cost of logistics. Go Green BOV's lease model includes an annual fee for charging the vehicle's battery, servicing, and maintenance. Go Green BOV scooters are running a pilot of 15 vehicles in Bengaluru with SWIGGY and Road runner. It provides an average running time of 120 km per charge. Also, its scooters come with a hardware component (that doubles up as a key) — a dashboard that tracks the delivery person remotely, provides real-time data on performance of the vehicle, quality of the ride, amount of charge in bike, and a route map for navigation.[6]

> ***Learning:*** The third party logistics model offers higher profits for delivery executives as the fuel cost is reduced by approximately 65%, thereby creating greater penetration in the commercial segment and inducing shift to electric two-wheelers due to lower operation costs.

Rent an e-Scooter (Model by Electrotherm in Pune)- ET Elect-Trans Ltd, a subsidiary of e-bike manufacturer, Electrotherm India Ltd along with Maharashtra transport authority has approved a scheme called *Switch*, a rent a motorcycle scheme, under which residents of Pune can hire, use, and drop electric scooters.

[5] https://www.atherenergy.com/

[6] http://www.gogreenbov.com/



50 e-scooters have been rented to individuals, express delivery services, and corporate houses on a monthly rent of Rs 3,350.[7] Electrotherm scooters are of 750 Watts and run at speed of 50 km per hour. Presently, these scooters are working on home charging but with the expansion of the project the charging station will be required by the state government. After the success of the project in Pune, it is now expanding to other states also, one of which is Chhattisgarh. The Government of Chhattisgarh has offered to set up charging stations for launching Switch in its four cities.

Learning: Collaboration of Government and private sector can prove to be mutually beneficial. The e-scooter sharing scheme can help conventional two-wheeler users to ride and test the electric two-wheelers. Such schemes can help improve visibility of electric two-wheelers and raise awareness about this new technology among general public.

13. **Zoomcar partnership with Mahindra Electric:** Self-drive car rental company Zoomcar and Mahindra Electric have entered into a partnership to roll out electric vehicles in various Indian cities. Through the agreement, customized financing will be provided to Zoomcar from Mahindra Finance. Mahindra Electric has also developed fast charging services for Zoomcar's customers.

    Zoomcar also works through the business model wherein customers can buy and list the Mahindra electric cars on Zoomcar Associate Program (ZAP). Through this programme, customers can lease their purchased electric cars to Zoomcar on a revenue sharing model.

    Learning: Close collaboration among different actors and innovative models is enabling risk reduction for these actors. Such partnership are resulting in greater usage of electric vehicles and proving to be a win-win strategy. The market will need to rely on such innovations to promote the use of new technology.

International Cases

1. Employer led initiative: In Spain, Iberdrola (a public multinational electric utility company) has taken an initiative to promote use of electric vehicles by its workforce. Under the programme, the company is offering three types of grants to its employees:[8]

- Special advance payment of €4,000 to purchase EV
- Non-refundable grant of up to €500 to install charging points
- €6,000 for employees that agree to include Iberdrola brand advertising on their vehicles for three years

Impact: Additionally, Iberdola is also promoting the use of electric vehicles by employees in company's sales division for undertaking professional tasks. It is estimated that this will enable the company to reduce its CO_2 emissions by 12,600 tonnes per annum.[9]

1. Leaseplan, which is a Dutch origin company, is promoting the use of electric vehicles by encouraging its employees as well as its customers to switch to electric vehicles. To support its corporate customers, it offers them the option to use the vehicle for pilot runs which can be later permanently bought by customers. It provides the vehicles, the charging infrastructure at offices and homes, and the impact assessments for its corporate customers. The model has been positively accepted by consumers as most of the customers are permanently incorporating EVs into their fleets, and registrations of battery EVs in LeasePlan's customer fleet has grown by 77% in those countries where EV pilots are offered. For the entire vehicle customer fleet, Lease Plan expects a 40–60% annual growth in EVs for the upcoming years.

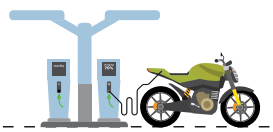
2. ***Learning:*** Such models can be adopted by Indian manufacturers also to increase the uptake of electric two-wheelers by first targeting their own employees and customers.

Lease Plan has also financed the vehicles procured by Zoomcar from Mahindra Electric. Through this model, Zoomcar has obtained 100 electric vehicles in New Delhi and 50 in Pune.

[7] https://www.downtoearth.org.in/coverage/rent-an-escooter-34017

[8] https://www.iberdrola.com/press-room/news/detail/iberdrola-first-spanish-company-to-launch-an-electric-car-sharing-initiative-for-its-employees-2054056120110621

[9] https://www.iberdrola.com/press-room/news/detail/iberdrola-first-spanish-company-to-launch-an-electric-car-sharing-initiative-for-its-employees-2054056120110621



9 CONCLUSION

This report explores the role of electric vehicles towards the goal of sustainable mobility in India. Upon assessing the mobility needs and patterns in Indian cities, it was deduced that in absence of adequate and reliable mass transit options, two-wheelers have a significant role to play in India's mobility. They not only provide an affordable and reliable means of transport but also means of livelihood to millions of people in urban and rural areas of the country. However, the predicted growth of two-wheelers in India also puts light on its impact on local air pollution, national energy security, and global warming. As proven through modelled scenarios in this report, a phase-wise adoption of electric two-wheelers can mitigate these local, national, and global concerns to some extent. But in order to make a significant and sustainable impact, electric vehicles will have to be complemented with wide spread charging infrastructure, green sources of energy, increased coverage of public transport systems and localization of the EV manufacturing in India.

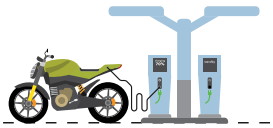
Even after interventions by the National and State governments, the proportion of electric two-wheelers remains at a miniscule level of 0.001% of the overall two-wheeler market in India. The report therefore makes an attempt to understand this conundrum and develop enablers for adoption of EV two-wheelers through primary customer survey, interviews with industry executives, and real business case analysis.

The online stated preference survey conducted in this study revealed that the electric vehicles are not looked upon as primary vehicle, and only used for short irregular trips. The current consumer's perspective is mainly because of concerns about limited range and lack of charging facilities. The anxiety about limited range gets further accentuated among prospective EV and ICE buyers. This finding necessitates the need for widespread charging facilities.

The feasibility study of public charging stations showed running of public charging stations (PCS) as an expensive prospect due to large operational costs in terms of land rentals. The PCS becomes economically viable only at high tariff for customers. However, the survey conducted showed that most vehicle users were not willing to pay more than the household energy rates for public charging.

To make charging infrastructure viable for initial low demand scenario, measures such as enabling real estate procurement at key locations at lower costs, capital subsidy, or interest subvention on capital expenditure should be considered. The minimum charging station requirements to be eligible for incentives as per ministry of power guidelines should also be brought down. Support from state authorities and local DISCOMs for single window approvals and providing power infrastructure to bear additional electricity load is also needed. Finalization of charging standards for all vehicle categories will be helpful in reducing demand uncertainty for type of charging equipment and yielding higher utilization of charging infrastructure.

Further analysis shows Battery Swapping Stations (BSS) as an unviable economic model. Besides being unviable solution, BSS and battery standardization for

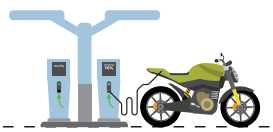


BSS operations also has significant demerits. A standard battery will limit the product experience options for the customers and discourage innovation in battery technology advancement. The OEMs emphasize that integral battery design by them is crucial for optimal vehicle safety, reliability and performance.

Higher upfront cost of electric vehicle with ICE comparable performance is another major barrier. The higher scale of domestic production has the potential to reduce the upfront vehicle cost for customers. Achieving the critical mass for EV therefore becomes important for supply chain localization and economies of scale. Direct financial incentives such as laid out in FAME II is a right step towards achieving this critical mass. However, to enable a faster and sustainable adoption, specific use cases for which EVs are currently viable should also be focused upon. Use cases with higher daily vehicle running such as commercial usage of electric two-wheelers for food & goods delivery, shared rental services etc can specifically be targeted. For the personal use case cost effective leasing and other financial products can be explored. Measures such as lower taxes, lower tolls, and special parking provisions can further aid the EV selling.

As per discussion with various industry leaders, it is evident that the industry is supportive of enabling EV adoption and is continuously investing in EV research and manufacturing capabilities. The EV technology is costly and is still evolving. Therefore there is a general concern that a forced adoption might not be sustainable. Moreover the majority of EV value chain lies outside India. The forced adoption might therefore result in import of low quality products leading to erosion of industry's current global competitive advantage. This will pose huge risk to millions of jobs supported by this industry and GDP of the country.

Phase wise local EV manufacturing plan linked to financial incentives as laid out in FAME II is thus appreciated as the right path to mitigate this risk. Battery amounts to almost 40~50% of the EV cost. Localization of cell manufacturing will therefore help in reducing EV costs, and achieving self- sufficiency to ensure a sustainable EV growth. A national level strategy to secure critical raw material sources for cell manufacturing, and to incentivize local cell manufacturing through capital subsidy, favorable trade & FDI policies, and investment models such as PPP is need of the hour.



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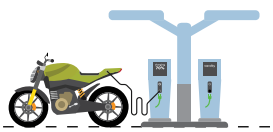

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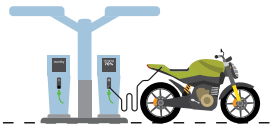

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