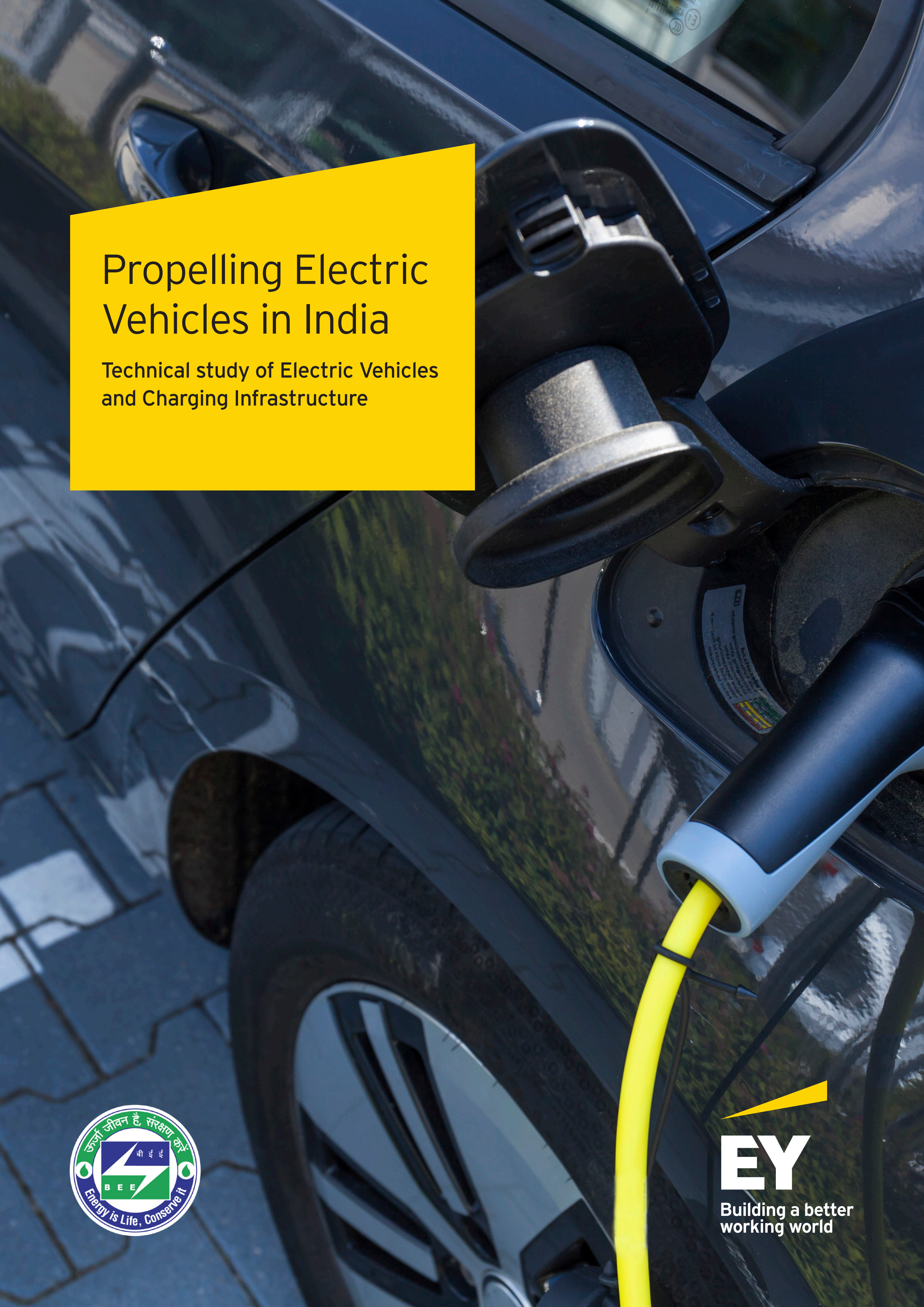

Propelling Electric Vehicles in India

Technical study of Electric Vehicles and Charging Infrastructure

ऊर्जा जीवन है, संरक्षण करें
बी ई ई
BEE
Energy is Life, Conserve it

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Foreword

The transition towards electric mobility offers India not only an opportunity to improve efficiency and transform the transport sector but also addresses several issues that the country is currently grappling with. The concerns regarding energy security and rising current account deficit (CAD) on account of rising fossil fuel imports can be addressed with the uptake of electric mobility. India is a power surplus country and is currently witnessing lower plant load factors due to lower capacity utilization. As per the conservative estimates, demand from electric vehicles (EV) could greatly improve the utilization factor of underutilized power plants, as charging pattern of EV users is considered to coincide with power demand during the non-peak hours in the country.

Moreover, India has a clear intention of multiplying its generation from renewable energy (RE) sources which are inherently intermittent. Several reports suggest that EVs can complement the intermittent nature of power generated from RE by absorbing power at off-peak hours. The batteries in EVs can act as ancillary services for the proliferation of distributed generation resources (DER). Apart from supporting RE generation, EVs with feasible vehicle to grid technology can act as a dynamic storage media and can enhance the grid resilience through ancillary market. This can reduce the burden of exchequer to create static energy storage systems, especially in distribution networks, to support proliferation of grid-connected roof top solar and DERs.

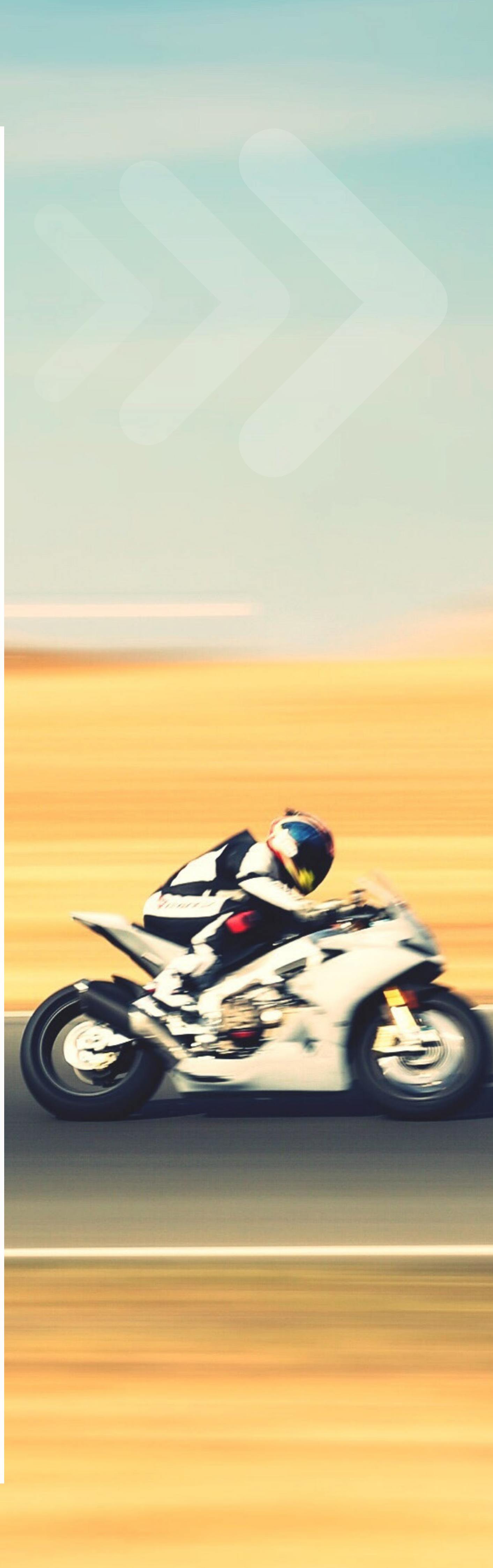
The new ecosystem offers India the opportunities to become a leader in domestic manufacturing and job creation as electric mobility is still in nascent stages in many advanced markets around the globe. Further, transition to electric mobility can undoubtedly help India achieve its global commitments of reducing carbon footprint and greenhouse gas (GHG) emissions. However, to accelerate the adoption of electric mobility in India, a lot of preparation needs to be done so that the market grows in a self-sustainable manner with minimal federal support and interventions.

The Bureau of Energy Efficiency (BEE), an agency established under the provision of Energy Conservation Act, 2001, is transforming the way energy is consumed by running several programs to efficiently use the energy and ensure its conservation by providing policy framework and coordinating and implementing several programs that demonstrate robust delivery mechanisms through public-private partnerships. BEE, in consultation with the Ministry of Power (MoP), Government of India (GoI), took an initiative to study techno-commercial challenges in proliferation of electric vehicle (EV) charging infrastructure, which is considered an essential spoke without which the wheel of electric mobility cannot roll. A lot of deliberation has taken place in several forums on the chicken and egg situation of EV and charging infrastructure. Subsequently, it has been concluded that charging infrastructure (both fast and slow) needs to come first to ensure a smooth transition for end-users, especially when range anxiety and charging time are considered major barriers to adoption.

The study undertaken by BEE involved a consortium of consultants led by Ernst & Young LLP to conduct a study encompassing the technical and commercial aspects of sustainable operations of EV charging infrastructure by taking a cue from business models that are prevalent globally, technological interventions as well as technical and testing standards. It also includes assessments on the degree of federal support required and the role distribution utilities play in facilitating the growth in advanced markets such as United States (the US), Germany, Finland, China and Japan. The study further dives into development and assessment of commercial viability of business models for EV charging infrastructure. Moreover, assessment of readiness of the industry was undertaken by conducting a consultation with several stakeholders to identify the challenges and barriers in embracing the transition to the era of electric mobility. An analysis on the impact of transition to electric mobility on distribution infrastructure of Delhi, Lucknow and Nagpur was assessed using statistical models followed by a development of a city-agnostic implementation model. Key findings of the study are mentioned below:

- To boost EVs' demand in India, the government should focus on both fiscal and non-fiscal impediments.
- Initial deployment of charging infrastructure should not be seen from the lens of generating profits rather as an opportunity to build a market and get customers accustomed to the e-mobility ecosystem.
- The government should consider providing financial and non-financial incentives to charge point operators (CPO) to encourage charging infrastructure deployment at the center, states and cities.
- Early adopters are expected to be from urban ecosystem with major sales coming from the metro cities led by mass-mobility requirements and considerably high disposable income levels. City level ecosystem development initiatives are likely to play an important role in adopting electric mobility solutions and supporting their uptake.
- In a zero-subsidy scenario, the government may consider providing tax rebates and tax holidays, lower Goods and Service Tax (GST) on electric vehicles, charging stations and associated components, and on services rendered by charging infrastructure operators. Waivers on road tax and income tax benefits may also be considered.
- Special tariff category including Time of Use (TOU) for residential chargers and blended tariff for public chargers is recommended.
- Non-fiscal measures such as exemption of permit fee, free parking spots and toll exemption may be adopted.
- Indigenous manufacturing of electric vehicle supply equipment (EVSE) and EVs are likely to be considered under "priority sector lending".

For ensuring viable and sustainable business models, states may consider facilitating access to land at a subsidized price for initial years to agencies interested in setting up charging infrastructure for electric vehicles.



Acknowledgement

The transition towards electric mobility has become one of the major initiatives undertaken by the Government of India (GoI) to strengthen its effort towards the reduction of carbon emissions. The "Technical Study of Electric Vehicles and Charging Infrastructure" has been conducted by the consortium led by Ernst and Young LLP (EY) under the directions of the Ministry of Power (MoP) and the guidance of the Bureau of Energy Efficiency (BEE).

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The study was formulated by Shri Abhay Bakre (Director General, BEE), Shri Pankaj Kumar (Secretary, BEE), Shri Sameer Pandita (Director, BEE) and Shri Rajeev (Project Engineer, BEE) from Bureau of Energy Efficiency (BEE).

The study was collectively executed by Ernst & Young LLP (EY), led by Shri Somesh Kumar (Partner and Leader, Power & Utility), Shri Shuvendu Bose (Associate Partner), Shri Ashish Kulkarni (Associate Partner) and Shri Kanv Garg (Director), and supported by the delivery team comprising of Kaustuv Mohapatra, Harsh Jain, Sushovan Bej, Gagandeep Singh, Tanmay Tyagi and Tanmay Nag. The EY team was also supported by the team from pManifold Business Solutions Pvt. Ltd., led by Shri. Rahul Bagdia and supported by Ashish Balki, Kunjan Bagdia and Rishabh Badlani. We would also like to extend our gratitude to EY Global Knowledge team members comprising of Shikhar Gupta, Yoon Jae Heo, Young Zhu, Amit Gupta and Anjushi Joshi, who supported us extensively with the compilation of data on policies, market developments and market projections for the international case studies.

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Abbreviations

3GPP	3rd Generation Partnership Project
AFV	alternative fuel vehicle
AIHA	American Industrial Hygiene Association
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ATC	Advanced Transportation Controller
BESCOM	Bangalore Electricity Supply Company Ltd.
BHEL	Bharat Heavy Electricals Limited
BLDC	Brushless DC
BMBF	Federal Ministry for Education and Research (Germany)
BMTC	Bengaluru Metropolitan Transport Corporation
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Germany)
BMVI	Federal Ministry of Transport and Digital Infrastructure (German)
BMWi	Federal Ministry for Economic Affairs and Energy (German)
BSES	Brihanmumbai Suburban Electric Supply
BWP	Burbank Water and Power
CAEATFA	California Alternative Energy and Advanced Transportation Financing Authority
CAFC	corporate average fuel consumption
CAISO	California Independent System Operator
CalCAP	California Capital Access Program
CAN	controller area network
CARB	California Air Resources Board
CATARC	China Automotive Technology and Research Center
CATL	Contemporary Amperex Technology Co. Limited
CCA	community choice aggregators
CCS	combined charging system
CEA	Central Electricity Authority

CHAdeMO	Charge de Move(Japanese standards organization)
CO2	carbon dioxide
CPCFA	California Pollution Control Financing Authority
CPO	charging point operators
CPUC	California Public Utilities Commission
CSPG	China Southern Power Grid
CVRP	Clean Vehicle Rebate Project
DSO	distribution system operators
EMC	electromagnetic compatibility
EnWG	Energy Industry Act (Energiewirtschaftsgesetz)
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	electric service providers
EV	electric vehicle
EVI	electric vehicle initiative
EVSE	electric vehicle supply equipment
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
GB/T	Guobiao standards (Chinese national standards - Recommended)
GGEMO	Joint Agency for Electric Mobility (German)
GHG	greenhouse gases
HEV	hybrid electric vehicle
HOT	high occupancy toll
HOV	high occupancy vehicle
HMRL	Hyderabad Metro Rail Limited
ICC	International Code Council
ICE	internal combustion engine
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

IETA	International Electrical Testing Association
IMA	input measurement apparatus
INR	Indian Rupee
ISA	International Society of Automation
ISO	International Organization for Standardization
JAMA	Japan Automotive Manufacturers Association
JARI	Japan Automotive Research Institute
JEWA	Japan Electric Wiring Devices and Equipment Industries Association
JRS	Japan Revitalization Strategy
JSAE	Society of Automotive Engineers of Japan
LADWP	Los Angeles Department of Water and Power
LIB	Lithium-Ion batteries
mb/d	Millions of Barrels per Day
METI	Ministry of Economy, Trade and Industry (Japan)
MEXT	Ministry of Education, Culture, Sports, Science and Technology (Japan)
MIIT	Ministry for Industry and Information Technology (Japan)
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MNRE	Ministry of New and Renewable Energy
MoF	Ministry of Finance of the People's Republic of China
MoH&UA	Ministry of Housing and Urban Affairs
MoHIPE	Ministry of Heavy Industries and Public Enterprises
MoP	Ministry of Power
MoRT&H	Ministry of Road Transport and Highways
MoST	Ministry of Science and Technology
MSRC	Mobile Source Air Pollution Reduction Review Committee's
Mt	Million Ton
Mtoe	Million Tons of oil equivalent

NAESB	North American Energy Standards Board
NCS	Nippon Charge Service
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NECA	National Electrical Contractors Association
NEDO	New Energy and Industrial Technology Development Organization
NEKRTC	North Eastern Karnataka Road Transport Corporation
NEMA	National Electrical Manufacturers Association
NEMMP	National Electric Mobility Mission Plan
NFPA	National Fire Protection Association
NGV-CIDPP	Next-Generation Vehicle Charging Infrastructure Deployment Promotion Project
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Science and Technology
NITI Aayog	National Institution for Transforming India
NWKRTC	North Western Karnataka Road Transport Corporation
OEM	original equipment manufacturer
OSHA	Occupational Safety and Health Administration
PACE	Property-Assessed Clean Energy
PEV	plug-in electric vehicle
PFPP	Public Fleet Pilot Project
PG&E	Pacific Gas and Electric Company
PLCC	Power Line Carrier Communication
PPP	Public Private Partnership
PRC	People's Republic of China
REC	Rural Electric Cooperative (USA)
RESS	rechargeable energy storage system
RH	relative humidity

RMI	Rocky Mountain Institute
SAC	Standardization Administration of China
SAE	Society of Automotive Engineers
SASAC	State-owned Assets Supervision and Administration Commission
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SEP	Strategic Energy Plan
SGCC	State Grid Corp of China
SJVAPCD	San Joaquin Valley Air Pollution Control District
SLM	Straight Line Method
SoCalGas	Southern California Gas Company
SRM	Switch Reluctance Motors
TEPCO	Tokyo Electric Power Company
TOD	time-of-day
TOU	Time-of-use
TSO	transmission system operators
UL	Underwriters Laboratories
UN	United Nations
US$	United States Dollar
USDoT	United States Department of Transportation
VEM	vehicle emulator module
VW	Volkswagen Group
WACC	weighted average cost of capital
WDV	Written Down Value Method
WP.29	World Forum for Harmonization of Vehicle Regulation
ZEV	zero emission vehicle
2W	two-wheeler
3W	three-wheeler

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Executive summary

What challenges are driving India's electric mobility initiatives?

Today, India is one of the fastest growing economies in the world, but its increasing dependency on oil imports, rising environmental concerns and growing need for sustainable mobility solutions are posing serious economic and social challenges for the country.

Rising crude oil imports – an energy security challenge

Since the early 2000, India's crude oil imports have risen exponentially reaching a record high of 4.3mb/d in 2016. The demand for oil grew by 5.1% in 2016, higher than the world's largest net importers, the US (0.7%) and China (2.9%), making India the world's third largest crude oil consumer[1].

India's crude oil deficits stood at US$52 billion in 2017 and accounted for almost 50% of the total trade deficit of US$109 billion. This crude oil deficit is further expected to almost double to US$100 billion against the total trade deficit of US$202 billion in 2019[2].

Rising pollution levels – an environmental challenge

India ranks as the third largest carbon emitting country in the world accounting for 6% of the global carbon dioxide emissions from fuel combustion[3]. According to the WHO Global Air Pollution Database (2018), 14 out of the 20 most polluted cities of the world are in India[4].

Rising population – a sustainable mobility challenge

India's current population of 1.2 billion is expected to reach 1.5 billion by 2030. Out of the 1.5 billion people, 40% of the population is expected to live in urban areas compared to 34% of 2018 population projection[5]. The additional 6% population growth is likely to further add strain on the struggling urban infrastructure in the country, including a rise in demand for sustainable mobility solutions.

[1] International Energy Agency (IEA) - https://webstore.iea.org/download/direct/2262?fileName=Oil_Information_2018_Overview.pdf
[2] Commerce ministry; ICICI Bank
[3] https://www.ucsusa.org/global-warming/science-and-impacts/science/each-countrys-share-of-co2.html
[4] http://www.who.int/airpollution/data/cities/en/
[5] http://www.un.org/en/development/desa/population/

Today, India is one of the fastest growing economies in the world, but its increasing dependency on oil imports, rising environmental concerns and growing need for sustainable mobility solutions are posing serious economic and social challenges for the country.

Evolving global automotive market – a manufacturing transition challenge

India is the world's fourth largest producer of internal combustion engine (ICE) based automobiles. The growth in automotive market in India has been the highest in the world, growing at a rate of 9.5% in 2017[6]. The recent shift in global automotive technology and an increasing uptake in electric vehicles is likely to pose a challenge to the existing automotive market if the country does not plan its transition towards newer mobility solutions and develop the required manufacturing competencies

Electric mobility - a potential solution for India

In India, majority of the oil demand comes from the transport sector. The sector accounts for over 40% of the total oil consumption with around 90% of the demand arising from the road transport. By 2020, 330 mt(million tons) of carbon emissions are expected to arise from the transportation sector, 90% of which may be from road transport alone[7].

The premier think tank of GoI, NITI Aayog (National Institution for Transforming India), reports that India can save 64% of anticipated passenger road-based and mobility-related energy demand and 37% of carbon emissions by 2030 if it pursues electric mobility in future. This would probably result in an annual reduction of 156 MToE in diesel and petrol consumption for 2030, saving INR3.9 lakh crores (or ~US$60 billion (at US$52/bbl of crude)). The cumulative savings for the tenure 2017-2030 is expected to reach 876 MToE of savings for petrol and diesel, which totals to INR22 lakh crores (or ~US$330 billion), and 1 gigaton for carbon-dioxide emissions.

Perspective of change – how are stakeholders aligned?

The electric mobility sector, though growing rapidly, is still in its nascent stage in India. A primary barrier towards mass adoption of electric vehicles (EVs) is the lack of reliable, accessible and affordable charging infrastructure. In 2017, the total installed publicly accessible chargers in India stood at 222[8] . The adoption of EVs and deployment of charging stations is often described as the chicken and egg problem, i.e., the need for ample EV penetration as a prerequisite for EV charging infrastructure deployment versus the need for abundant EV charging infrastructure as a prerequisite for EV adoption. However, recent studies confirm that availability and accessibility of reliable public charging infrastructure must precede widespread EV penetration. In the absence of a robust charging infrastructure, the growth in EV adoption will be difficult, as observed in the global markets and extensively covered in the report.

The development of a sustainable electric mobility ecosystem requires a multi-stakeholder collaborative effort. It is imperative to develop a common understanding among the stakeholders (mentioned below) and identify challenges of the concerned stakeholders, critical for the uptake:

Government and regulators

The central and state governments as well as nodal agencies that are driving the policy levers are always considered to be the primary stakeholders in the development of a new technology or sector. With electric mobility, the central and state governments as well as nodal agencies must identify the policy and regulatory barriers to facilitate private sector investments in the sector. Subsequently, the stakeholders must identify ways to promote the transition of the existing automotive industry in adopting newer technologies, preserving jobs and maintaining its economic contributions. The government should also proactively identify the future trends of the rapidly changing sector to promote the adoption of the best and efficient technologies.

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6 Society of Indian Automobile Manufacturers
7 International Energy Agency (IEA) - World Energy Outlook 2018
8 International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

OEM

To predict a sustainable growth, it is imperative for established original equipment manufacturers (OEMs) and start-ups to identify the actual demand and adoption trends for the electric mobility ecosystem. The adoption trends will subsequently determine the development of supply chains and upskilling of the workforce from conventional technologies to the emerging ecosystem. Further, newer business models need to be developed for transitioning and sustaining the change.

Power utilities

The role of the power utilities will be the forefront for the successful development of a sustainable electric mobility ecosystem. Though the rise in electricity demand from EVs presents an opportunity for the utilities with increased revenue, the additional investments required for strengthening or augmenting the present infrastructure to cater to the intermittent demand refers to a financial challenge.

Oil and gas

With the overall push towards reducing emissions, oil and gas players are likely to face the brunt if the investments towards cleaner and greener products are not part of their future business models.

Real estate

The availability of affordable (for charging infrastructure operator) and accessible (for consumers) land is one of the major cost drivers that affects the business viability of the charging infrastructure operations. Real estate plays one of the critical parameters that impacts the development of an electric mobility ecosystem.

Consumers

Consumer perceptions on newer technologies determine their adoption trends. The range anxiety of an EV is an outlook challenge that has resulted in the low uptake of EVs, further resulting in low investments from the private sector.

How is this study important?

The Bureau of Energy Efficiency (BEE), under the Ministry of Power (MoP), envisaged this study to address the challenges of the emerging electric mobility sector and identify possible solutions. The study includes assessment of techno-commercial and regulatory aspects for setting up charging stations, review of best practices followed in mature markets, and review of global electric vehicle supply equipment (EVSE) and testing standards. With an aim to achieve grassroot solutions, city level assessments have been conducted for Delhi, Lucknow and Nagpur to assess the impact of expected EV uptake on the grid.

In order to identify the multi-stakeholder initiative required for the development of a sustainable electric mobility ecosystem, a comprehensive stakeholder consultation exercise was carried out across governments, regulators, OEMs, DISCOMs and academic/research institutions. The study covers an extensive review of global landscape and success stories from Germany, the US, Finland, China and Japan. This was followed by an assessment of Indian market including a review of policy and regulatory landscape, readiness assessment of market players for EV adoption and review of existing EVSE and testing standards. Based on the best practices identified in a global study and observations from assessment of Indian market landscape, techno-commercial assessments were carried out to study the viability of setting up charging stations. This includes analysis of PPP models. In addition, analytical models were developed to study the impact of EV growth on grid in Delhi, Lucknow and Nagpur.

How are the international markets shaping up?

Globally, it has been understood that for a sustainable uptake of EVs, charging infrastructure is a vital key. In 2017, the total number of electric vehicles crossed the three million mark accompanied by EV chargers crossing the two million mark, globally. As of December 2017, the world had seven times the number of electric vehicles than the number of available public chargers. The number of publicly available chargers saw a 70% increase in 2016.

China is leading the deployment of public charging infrastructure, accounting for 50% of the total public chargers deployed worldwide. China is followed by the US accounting for just 10%; amongst the rest, 34% comes from 19 countries such as The Netherlands, Japan and Germany, further 6% is attributed to others[9] . One of the primary reasons for this rapid deployment of the electric vehicle chargers was due to a conducive policy and regulatory environment created by the governments.

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Various fiscal and non-fiscal incentives have increased value proposition of EVs globally

[9] International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

> A technology agnostic approach shall be considered allowing adoption of charging standard as per the market demand.

A market assessment study of the US, Germany, China, Japan and Finland has shown that apart from the subsidy support, various fiscal and non-fiscal incentives have played a defining role in improving the business viability of setting up a charging infrastructure. The table listed below gives a brief of the key growth drivers in each of these countries:

Country	Key growth drivers							
	EV Policy	Tax holidays	Unregulated tariff	Utility involvement in deployment	EV purchase incentives	Incentives for public charging infrastructure	Time of Use tariff	Indirect incentives (access to reserved lanes)
California	✔	✔	✔	✔	✔	✔	✔	✔
China	✔	✔	✕	✔	✔	✔	✔	✔
Japan	✔	✔	✕	✔	✔	✔	✔	✔
Germany	✔	✔	✔	✔	✔	✔	✔	✔
Finland	✕	✔	✔	✔	✕	✔	✔	✕

In addition to the fiscal and non-fiscal incentives, adoption of standards for EV, EVSE and testing has been an important factor influencing the growth. However, most of these markets (except China) have been technology agnostic, i.e., charging station operators choose the charging standard based on the local market conditions.

As per the global assessment study, it can be observed that the electric mobility markets have been driven by utilities and network service providers, both playing critical roles in the development.

Role of power utilities

Utilities are playing a critical role in EV ecosystem in the assessed markets. They have launched various electric mobility programs specifying the number of chargers to be installed, total budget, names of the eligible agencies for setting up charging infrastructure, minimum number of chargers required on each site and modes of pricing as well as business models.

Most of the utilities follow two modes of pricing, namely, pass-through pricing and custom pricing. In pass-through pricing, the charging point operator/host passes the TOU tariff directly to the EV owner.

The host has the option to include a rate added above the TOU rate being charged. The rate added represents the non-energy additional charges such as demand charges, meter charges, etc. Site hosts are required to revise the rate added based on the historic EV charger utilization to ensure that the site hosts do not overcharge the customers. In custom pricing, the host creates a customized pricing structure. For e.g., US$ per unit time rates, flat fees pricing and free charging.

In addition, the prevalent business models in the studied countries have been utility-centric. Role of utilities varies based on the power market structure of the region. In California, a region having regulated market structure, utilities are responsible for deploying grid infrastructure and billing the consumers. Expenditure for installing the requisite infrastructure is recovered through the tariff (expenditure is accounted for in the tariff filings). However, in Germany, a region having unregulated power market, power retailers charge the charging point operators (CPOs) for supplying electricity. CPOs are free to choose the retailer for procuring the power.

For billing CPOs, a smart meter is installed at the point of connection of each charging station. The various models adopted in mature markets have been mentioned below:

1. **Charging point operator provides free public charging:**

   CPO is a commercial entity (restaurant/ retail store owner). The EV owners are offered free charging at their premises. Accordingly, the CPO benefits through increased customer attraction at the site.

2. **CPO charges EV owners at market driven tariff:** EV owners are charged as per their usage (per kWh) in accordance with the Time- of – use regime. Payment is done either through a direct transaction between EV owner and CPO or through the network service provider.

3. **Pay per click model:** Utilities collaborate with shopping malls, restaurants or gas stations to install fast chargers in their premises. They can receive a fixed sum of money from the owner of the premises, each time the charger is used by the customers.

4. **Utilities providing IT services (Franchise model):** Utilities can provide IT support to customers like municipalities, car-sharing companies that have EV fleets to better manage their own networks of charging stations. Ex. RWE is providing IT support to select customers in Germany. Fortum Charge and Drive provides cloud based services to to customers to locate nearest charging point.

5. **Subscription model:** Utilities can own and operate charging infrastructure in this model. They can charge a subscription fee from customers for using their charging facility. The subscription fee could include free charging, or a lower price on charging, or a number of included charges.

Most Prevalent Business Models in Selected Geographies

California	China	Germany	Finland	Japan
1, 2, 3, 5	1, 3, 5	1, 2, 4	1, 2, 4	1, 3, 5

Role of network service providers (NSPs)

Network service providers (NSPs) have also played an important role in e-mobility ecosystem. These cloud service providers have been instrumental in addressing key concerns of EV owners by providing real-time information such as nearest stations, service charge and expected waiting time. They also provide services such as advanced booking of charging slots and payment options. In addition to these, NSPs provide visibility to DISCOMs on real-time basis to enable them to implement demand response and TOU/TOD tariff regimes.

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NSPs have been instrumental in increasing operational efficiency by providing real-time data visibility to DISCOMs.

Taking a cue from the internationally prevalent models of deploying charging infrastructure globally, it is inferred that federal support in forms of subsidy and stringent policy measures have been instrumental in proliferation of electric mobility. However, in India's case, the story could be completely different where the consumers are price sensitive and adoption pattern is driven by commercial viability of the solution.

How can India lead the change towards electric mobility?

The availability of EV technology has gradually increased in India. The established players across value chains have invested more than five years to develop EV related technologies. The automobile industry is working on technologies to increase the range, shorten the charging time and make electric vehicles affordable for masses. Hence, if we consider global EV market, it can be said that technology and supply may not be as a bigger challenge as demand. This is primarily because India is a price sensitive market. The battery and EV prices are expected to fall further and come at par with other competing technologies once the demands picks up.

However, policy and regulatory level initiatives are required to give a further boost to both supply and demand-side stakeholders. This includes finalizing standards, regulations and key incentives required to improve the supply-side readiness. In addition, to boost the demand aggregation initiatives are required. State governments are likely to act as facilitators by providing an easy access to land for setting up EV infrastructure.

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Central and state governments to act as facilitators to mitigate risks of supply and demand-side stakeholders.

Supply side

To improve business viability for supply-side stakeholders (such as OEMs, EVSE/battery manufacturers), standardization and effective alliances are likely to be crucial. Key recommendations on standards and modes of collaborations based on industry readiness study are mentioned in the section below:

a. Standardization

India is a diverse market that provides substantial growth opportunities for players across the value chains. This is primarily due to two reasons. Firstly, Indian market provides a wide consumer base ensuring scope of various technology options ranging from vehicle types (2W, 3W, 4W and buses) to IT-based services (digital services). Secondly, growing aspirations of potential consumers, driven by an increase in per capita income levels, provide considerable investment opportunities to private sector investors.

As Indian market is suited to various technological options, policymakers may face a challenge to carve out an option in the initial phase to enhance private sector participation. Accordingly, all options may be allowed to play out as per the existing market conditions. As the market matures, key learnings derived from market and investment trends may be utilized to adopt India specific standards.

Vehicle adoption patterns and India's ambient temperature will be critical considerations for finalizing the standards. India is a tropical country and witnesses high temperatures across the year. Presently, the standards for charging infrastructure are as per European ambient conditions. Hence, India may consider modifying existing standards so that the products comply with Indian conditions, without compromising on the efficiency.

Further, the adoption of electric vehicles in India has been largely in the light vehicle category, with smaller battery packs and lower power requirements. As of 2017, e-3W and e-2W accounted for 99% of the total EVs in India, with e-3W estimating 78% (17.5 lakhs) and e-2W estimating 21% (4.75 lakh)[10] . Therefore, it is imperative to define the standards or charging methodologies for such category of vehicles.

Standardization primarily requires the connectors between the EV and EVSE, and specification of communication protocols apart from defining the level of voltage/power. India is looking forward to deploying a modular charging infrastructure giving all the available options such as Bharat Chargers, CCS and CHAdeMO to EV users. Further for grid resilience, existing standards of grid connectivity, quality of power and registrations needs to be amended as per the following recommendations:

a.1. Energy performance standards

The recommendations made by the CEA are:

"The stored energy available shall be less than 20 J (as per IEC 60950). If the voltage is greater than 42.4 V peak (30 Vrms) or 60 V DC, or the energy is 20 J or more, a warning label shall be attached in an appropriate position on the charging stations".

a.2. Grid connectivity regulations

The following recommendations were made by the CEA, regarding standards for charging station, prosumer or a person connected or seeking connectivity to the electricity system are:

- Applicant shall provide a reliable protection system to detect various faults/abnormal conditions and provide an appropriate means to isolate the faulty equipment or system automatically. The applicant shall also ensure that fault of his equipment or system does not affect the grid adversely.
- The licensee shall carry out an adequacy and stability study of the network before permitting connection with its electricity system.

a.3. Power quality standards

- The limits of injection of current harmonics at point of common coupling (PCC) by the user, method of harmonic measurement and other matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.
- Prosumer shall not inject direct current greater than 0.5% of the rated output at interconnection point.
- The applicant seeking connectivity at 11 kV or above shall install power quality meters and share data as and when required by the licensee.

[10] SMEV

- Users connected at 11 kV or above shall comply with this provision within 12 months of notification of these regulations.
- In addition to harmonics, the limits and measurement of other power quality parameters like voltage sag, swell, flicker, disruptions, etc. shall be as per relevant BIS standards or as per IEC/IEEE standards if BIS standards are not available.
- Requirement under Rule 102 of the Petroleum Rules, 2002 lays down that no electrical wiring shall be installed, and no electrical apparatus shall be used in a petroleum refinery, storage installation, storage shed, service station or any other place where petroleum is refined, blended, stored, loaded/filled or unloaded unless it is approved by the chief controller of explosives. It is in this context that electrical equipment, which has to be used in a hazardous area covered under Petroleum Rules, 2002 shall require an approval from the chief controller of explosives.
- For installation of electrical equipment, the areas have been divided into three categories under hazardous areas, namely:
    - Zone "0" area, where inflammable gas and vapors are expected to be continuously present, e.g., inside the tank.
    - Zone "1" area, where inflammable gas and vapors are expected to be present under normal operating conditions, e.g., on the mouth of the vent pipe or near the fill point, unloading point, etc., during the operation.
    - Zone "2" area, where inflammable gas and vapors are expected to be present under abnormal operating condition, e.g., during the failure or rupture of the equipment.

a.4. Considerations for V2G, integration of solar PV and storage

- Globally, low level EVSE does not require communication. However, for India it is essential for low level EVSEs or slow chargers to also have a provision for communications. EVs, being charged with a slow charger, can better support in grid stability through V2G application as these vehicles would be parked for longer duration and connected to grid. As time of connection to grid is longer as compared to EV connected through fast chargers, higher reliability is likely to be achieved. Users of fast chargers are likely to be connected for very short duration and could support only minimally.
- The peak hours of solar and wind might match with EV charging patterns. Power generation with the help of GRPV to cater to the demand of EV charging could help address technical losses and stability concerns of distribution utilities.
- With applications such as vehicle to home or vehicle to the grid that utilizes batteries of EVs as dynamic storage media, multiple points of injection of power in the distribution network is likely to take place. If the system is designed well, managing the multiple injection points could aid the grid in enhancing its resilience.
- However, power flow studies and load flow analysis would need to be conducted to understand if the network nodes are resilient enough to absorb the impact of a sudden power injection and drawls. There is a need for holistic assessment of the impact of VRE, storage and EV charging on distribution networks.
- Hence, the regulations also need to be evaluated as the points of reverse power flows in the network could increase drastically, that too with a lot of uncertainties.

a.5 The following regulation shall be added after Regulation 13 of the principal regulation:

Registration in the registry maintained by CEA

- The applicant shall get its generating unit(s) of 500 kW capacity and above registered after which a unique registration number gets generated online from the e-registration facility at the portal of Central Electricity Authority when such scheme is made available.
- No applicant shall be granted connectivity with the grid without the unique registration number subsequent to implementation of the registration scheme.
- The users shall comply with the above-mentioned provision within a period, specified by the authority separately, of implementation of the registration scheme

Improving supply side readiness through effective alliances

The large volumes of electric vehicles are bound to disrupt the existing supply chain of the automotive industries. This transition from ICE to electric engines is also likely to open new opportunities for the technology companies and start-ups. Hence, the established players need to re-invent themselves to adapt to new EV technology before they start losing their businesses.

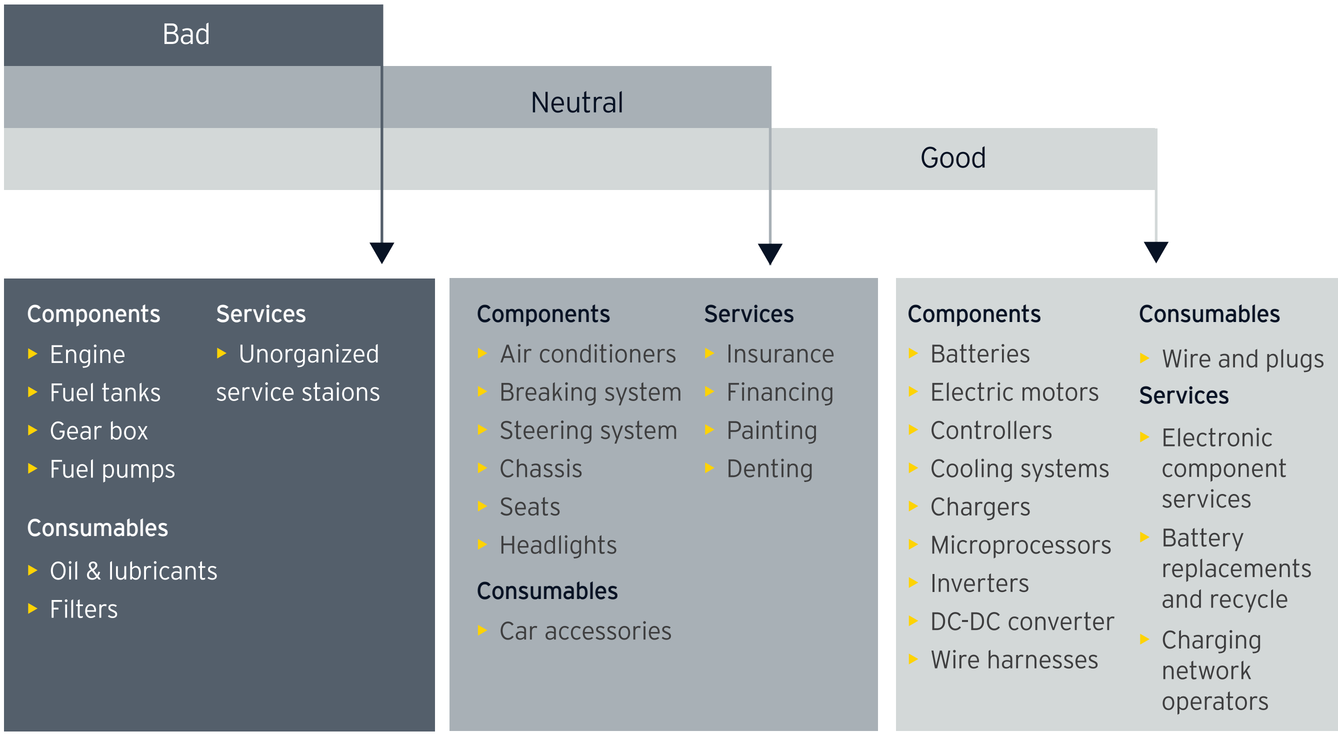
The design complexity in EV is less as compared to ICE vehicles because of the involvement of less moving parts. This may lead to the commoditization of the vehicle once the technology matures. In such a case, it is important for the existing players to increase their value proposition to differentiate their offerings in the market. These offerings may include owning dedicated charging stations and providing free charging, warranty, post-sales service and other relevant services.

The below-mentioned figure represents the impact of EV on the automotive supply chain, identifying the focus areas in planning investments for portfolio diversification and capacity building.

It is evident that the value added by the OEMs will shrink as EVs' market grows. To protect their interest, OEMs need to focus on in-house battery development and manufacturing to retain their share in the overall value chain.

The disruption in the supply chain may have implications on the logistics management as well. There may be a need to build more collaborative supply chains to develop inventory management of batteries, motors and power electronics.

Based on the readiness assessment study, it can be inferred that identifying the apt battery technology and logistics management would be the key to success. Accordingly, supply-side players need to form alliances across the value chains to increase product portfolios and reduce operational risks.



Some of the strategies that can be adopted by automobile manufacturers to stay relevant in the industry are highlighted below:

- Joint venture: for e.g., an automobile and battery manufacturer enter into a joint venture.
- Acquisition: for e.g., an automobile manufacturer acquires a battery manufacturer.
- Vertical integration: an automobile manufacturer develops an in-house R&D team and production line.
- Strategic suppliers: an automobile manufacturer continues to procure batteries from its strategic local and global players.

Demand-side

Demand for electric vehicles shall be driven by reduced total cost of ownership (TCO) and deployment of chargers at strategic locations in a city to reduce the range anxiety and grid augmentation planning so as to ensure a reliable power supply for charging batteries. Accordingly, city level models (in Delhi, Lucknow and Nagpur for assessing the impact on grid), business models (to assess the key considerations for reducing TCO) and city level implementation plan (for deploying chargers at strategic locations in a city) have been covered in the subsequent section: subsequent section:

Impact assessment on city grid

In order to assess the expected impact of EVs uptake on grids in cities, a comprehensive analytical model was developed. Existing city planning reports and data (mobility plan, RTO data and power distribution expansion plan), and local stakeholders' consultations including and not limited to DISCOM, transport and city officials were utilized.
The key findings for Delhi, Lucknow and Nagpur are mentioned below:

S. No.	Key outputs of city level model	Delhi	Lucknow	Nagpur
1	EVs mix as % of total stock (For 100% yearly new addition to become EVs by 2030)	37% (86 lakhs)	40% (19 lakhs)	40% (19 lakhs)
2	EVs' mix across segments in 2030	▸ Two-wheelers: 66% ▸ Three-wheelers: 1% ▸ Four-wheelers: 32% ▸ Buses: 0.1%	▸ Two-wheelers: 65% ▸ Three-wheelers: 5% ▸ Four-wheelers: 30% ▸ Buses: 0.2%	▸ Two-wheelers: 85% ▸ Three-wheelers: 2.8% ▸ Four-wheelers: 11.9% ▸ Buses: 0.3%
3	Cumulative LIB capacity in 2030 (GWh)	48.48 GWh ▸ Integrated LIBs: 88% ▸ Swap batteries: 12%	13.67 GWh ▸ Integrated LIBs: 70% ▸ Swap batteries: 30%	3.7 GWh ▸ Integrated LIBs: 70% ▸ Swap batteries: 30%
4	Total average connected EV charging load to grid (MVA)	▸ 2020: 346 ▸ 2030: 15,901 ▸ CAGR: 47%	▸ 2020: 224 ▸ 2030: 6,000 ▸ CAGR: 39%	▸ 2020: 44 ▸ 2030: 1,600 ▸ CAGR: 43.3%
5	Total peak demand of city including EVs (MVA)	▸ 2020: 7,844 ▸ 2030: 14,845 ▸ CAGR: 6.6%	▸ 2020: 587 ▸ 2030: 2,458 ▸ CAGR: 15%	▸ 2020: 536 ▸ 2030: 1,038 ▸ CAGR: 6.8%
6	% EV contribution to peak demand	▸ 2020: 1% ▸ 2030: 20%	▸ 2020: 11% ▸ 2030: 71%	▸ 2020: 2% ▸ 2030: 32%
7	Electricity consumption for EV charging (MUs/year)	▸ 2020: 176 ▸ 2030: 8169	▸ 2020: 120 ▸ 2030: 2,864	▸ 2020: 22 ▸ 2030: 798
8	EVs' contribution in electricity consumption (%)	▸ 2020: 0.5% ▸ 2030: 13%	▸ 2020: 0.4% ▸ 2030: 2%	▸ 2020: 1% ▸ 2030: 18%
9	Electricity consumption from EV charging across charging types (2030)	▸ Home charging: 49% ▸ Swapping: 25% ▸ Office/private: 13% ▸ Public charging: 13%	▸ Home charging: 44% ▸ Swapping: 28% ▸ Office/private: 16% ▸ Public charging: 12%	▸ Home charging: 39% ▸ Swapping: 31% ▸ Office/private: 20% ▸ Public charging: 9%
10	Total LIB charges in 2030	12,540 lakhs ▸ Home charging: 61% ▸ Office/private ▸ Public charging: 10% ▸ Bulk swap charging: 21%	3,703 Lakhs ▸ Home charging: 56% ▸ Office/private charging: 10% ▸ Public charging: 11% ▸ Bulk swap charging: 23%	1,434 lakhs ▸ Home charging: 61% ▸ Office/private charging: 8% ▸ Public charging: 9% ▸ Bulk swap charging: 22%

S. No.	Key outputs of city level model	Delhi	Lucknow	Nagpur
11	Estimated charging points by 2030	22.6 lakhs ▸ Slow chargers (Home): 93% ▸ Fast chargers: 2% ▸ Swapping: 5%	6.3 Lakhs ▸ Slow chargers (Home): 91% ▸ Fast chargers: 3% ▸ Swapping: 6%	2.6 lakhs ▸ Slow chargers (Home): 93% ▸ Fast chargers: 2% ▸ Swapping: 5%
12	EV/EVSE ratio (public charging)	17 (International benchmark:15)[11]	11.48 (International benchmark: 15)[11]	20 (International benchmark: 15)[11]

Viability assessment for setting up charging stations

Effective deployment of charging infrastructure based on a sustainable operating model is necessary for accelerating adoption of EVs. At present, low uptake of EVs results in lower asset utilization in terms of utilization hours of charging stations. Further, due to rapid technological transitions in battery and apprehension on standards of EVSE, the technology risk seems to be higher. Due to this, investors are skeptical of deploying such an infrastructure.

The models developed in this study are based on a detailed viability assessment study. The models are based on a scenario wherein the parking lot operating agency installs a 22kW fast DC charging station at its parking lot. The charging station has a single DC charging point and is used for charging vehicles with an average battery capacity of 18.55 kWh. It has been further assumed (on basis of existing electric cars available in the Indian market) that the vehicle would deliver a range of 130 km on a single full charge. Further, it has been assumed that the losses due to conversion and across other active and passive electrical components present in EVSE would be about 20%.

Accordingly, the following three cases have been considered:

- Case 1: Capital subsidy is provided
- Case 2: No capital subsidy is provided
- Case 3: Charging station operator gets into PPP mode

Key findings for each of the cases are mentioned below:

Key findings - with capital subsidy

- It is determined that the project is viable i.e., net present value (NPV) is greater than zero, when capital subsidy is more than 45%. Moreover, project is feasible if subsidy is greater than 45%, as NPV becomes greater than zero and equity IRR is 30.2%, which is greater than WACC.
- It is observed that higher utilization of EVSE results in lower retail per minute pricing that would be charged by the charging station operator. The retail pricing has been determined to be INR4 per minute of charging that the operator is likely to charge the EV user, considering the charging station shall be effectively utilized six hours a day and shall operate for 330 days in a year.
- The cost of operation on an electric car with a range of 130 km and a battery capacity of 18.55 kWh has been determined to be INR1.54 per km. Further, the cost of operations of equivalent diesel and CNG fuel-fired internal combustion engine (ICE) car was found to be INR4.20 and INR1.85 per km, respectively. If the tariffs charged by DISCOMs to the charging station operators exceeds INR8.5 per kWh, then it is observed that EVs will lose the advantage of lower operational costs.

[11] https://www.theicct.org/sites/default/files/publications/EV-charging-best-practices_ICCT-white-paper_04102017_vF.pdf

Key findings - without the capital subsidy

- It was determined that the project is viable, i.e., NPV is greater than zero when the mark-up on electricity is more than 3%. Moreover, the project is feasible if mark-up on electricity is greater than 3%, as NPV becomes greater than zero and equity IRR is, 14.5%, which is greater than WACC.
- The retail pricing has been determined to be INR4.13 per minute of charging that the operator will charge the EV user considering the utilization of charging station to be effective for six hours a day and would operate for 330 days in a year.
- The cost of operation on electric car with a range of 130 km and battery capacity of 18.55 kWh has been determined to be INR1.61 per km. Further, the cost of operations of equivalent diesel and CNG fuel-fired internal combustion engine (ICE) car was found to be INR4.20 and INR1.85 per km, respectively. If the tariffs charged by DISCOMs to charging station operators exceed INR9 per kWh, then it is observed that EVs will lose the advantage of lower operational costs.

Key findings – PPP models

- Land opportunity cost for municipal corporation, considering monthly rental of INR20,000 with an annual escalation of 10%, comes out to be INR18 lakhs. Even after a 10% revenue sharing arrangement with private entity, the public entity cannot recover this cost. As observed in mature markets, public entity has to look for additional revenue streams (like advertising and lease rental from restaurants) to increase its viability.
- Public entities with underutilized land (having a low opportunity cost) will be more suitable for this model. For e.g., distribution companies might utilize their land near existing substations for setting up charging stations which might also require a collaboration with the municipality to get clearances to allow vehicles to park and charge.
- Assuming no capital subsidy is provided, the charging station operator has to charge a minimum of 13% as the mark-up on cost of electricity tariff as retail price for ensuring project viability.

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Viability gap funding shall be crucial for reducing overall cost of operation and risks due to lower demand

City level implementation plan

Public charging infrastructure deployment faces a major challenge of land unavailability. Government and public-sector agencies are ideally placed to mitigate this risk through collaborations with private players. Market players, such as municipal corporations and transport utilities, shall be anchoring the deployment of infrastructure at city level. Accordingly, electric mobility is expected to be a city-led development, wherein various city-level stakeholders shall be collaborating to reduce risks and improve overall operational efficiency.

Thus, city level initiatives will hold the key for reducing risks of supply- and demand-side stakeholders to boost demand and the issue of range anxiety must be addressed through deployment of charging stations at strategic locations in a city. This is likely to be based on pre-assessments of land, availability of power, civil works for pedestal and foundations, installation of transformers, line, terminations and packaged substations constituting of distribution boards, isolators, protection devices and metering equipment. In addition, a phase wise city level deployment plan must be made. Deployment can begin with charger installation at existing fuel retail stations. Additionally, fast charging stations can be set up at the bus depots, workshops, etc. and swapping stations can be set up at the intermittent halts for intracity and intercity buses. Charging/swapping stations for HDVs shall be deployed at intermittent halts such as food joints on highways, transport nagars and places where they are parked.

> Pre-assessments might be carried out at city level for identifying strategic locations considering land availability and reliable source of power.

The following are the key assessments required for identifying strategic locations for charging stations:

Assessment of demographic aspects and consumer behaviour

One of the key assessments is that of demographic aspects. It is the demography of a city that reflects the acceptance of end users/customers for transitioning to electric mobility.

The following assessments need to be undertaken to determine the demographic aspects of a city.

- Literacy levels of residents and daily commuters
- Economic levels to understand the market for different types of electric vehicles
- Preference of the medium of transport for inter/intra-city commutation
- Preference of the medium of transport for first and last mile connectivity
- Commuter preference for ride-sharing services

Assessment of existing transportation system

To understand the availability of dominant mode of transport in a city, the entire available transport system needs to be studied. Such an assessment may help in preparing a transition plan for a city to shift to electric powertrains. The following assessments might be required to be done to achieve the intended objective of reducing vehicular emissions.

- GIS assessment and mapping
- Medium of transport for commuting within the city
- Identification of routes with highest commutation
- Mapping distances between the routes with highest commutation
- Route planning

Infrastructure assessment for electric buses

City-level implementation for electric buses needs to analyze the existing design of the transportation network and introduce suitable alterations to the existing routes and planning methodologies. Such alterations to route planning and scheduling of fleet services need to assess the following factors:

- Number of buses plying in and around the city
- Number of buses plying on routes having highest commutation
- Number of bus depots available in and around the city
- Assessment of route plan and schedule
- Average number of trips on routes of highest commutation
- Average distance between the depots
- Average number of buses parked in a depot
- Availability of space in depot for setting up charging stations for e-buses
- Availability of alternate spaces in the route
- IT and automation for metering, billing and data related to utilization and handling of electric buses

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Existing fuel stations, bus depots, metro stations and shopping complexes can be considered as initial locations for deployment of chargers

Assessment of operations of first and last mile commuting vehicles in a city

First and last mile connectivity are provided by three wheelers in India. India has witnessed a natural transition to electric powertrains by these service providers for whom the economics work even today owing to shorter trip lengths and lower upfront purchase costs. Charging of such vehicles has been mostly noticed to be unauthorized. It is important to assess the clusters in which such vehicle operates so as to plan their infrastructure and fulfil their requirements to support a sustainable growth.

- Number of rickshaws plying in the clusters of a city
- Number of rickshaws plying on routes of highest commutation
- Average distance commuted by a rickshaw in a day
- Average number of trips taken by an e-rickshaw in a day
- Availability of free space for parking and access to reliable power for charging
- Availability of alternate spaces in the route
- IT and automation for metering, billing and data related to utilization and handling of electric buses

Infrastructure assessment for public chargers

Assessment for deployment of public chargers for private fleet and individual private electric vehicle owners is essential to boost the transition to electric powertrains. The assessments for this category of vehicles (mostly car and commercial vehicle) may encompass forecasting exercises of vehicle stocks, EV penetration projections and possible locations of deployment of charging infrastructure in a city.

- Existing vehicle stock and growth trends
- Forecast vehicle stock and EV penetration
- Determine year-on-year (YOY) growth rates of electric vehicles in the city
- Determine the number and type of chargers/ number of battery swapping stations
- Number of parking lots in shopping malls, railway stations, office complexes, etc.
- Number of fuel retail stations (sharing of space for distribution/retail of battery) for installation of DC fast chargers or setting up battery swapping stations
- GIS assessment

Infrastructure assessment of power distribution infrastructure availability and resilience

Electric mobility can be sustainably implemented if both issues in transport and power sectors are judiciously taken care of. Assessment for availability of power distribution infrastructure and augmentation plan needs to be in place as part of city-level implementation plan as transition of vehicles to electric powertrains and augmentation of distribution infrastructure need to take place in tandem.

- Assessment of existing margins in distribution transformer levels
- Load flow analysis
- GIS assessment
- Access of reliable power
- Existing type of point of connection
- Applicable tariff structure
- Grid integration for vehicle to grid (V2G) implementation
- Renewable power purchase obligation

Facilitation

Electric mobility initiatives in India, initially, were led by the Ministry of Heavy Industries and Public Enterprises (MoHIPE) who launched National Electric Mobility Mission Plan (NEMMP) in 2013 and Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) in 2015. Over the years, identifying cross sectoral complex linkages of electric mobility and achieving a multi-stakeholder development NITI-Aayog was mandated to anchor and coordinate the Electric mobility efforts in India.

Government of India — **NITI Aayog**

Policy roadmap ↓ ↑ **Consultation**

Ministries

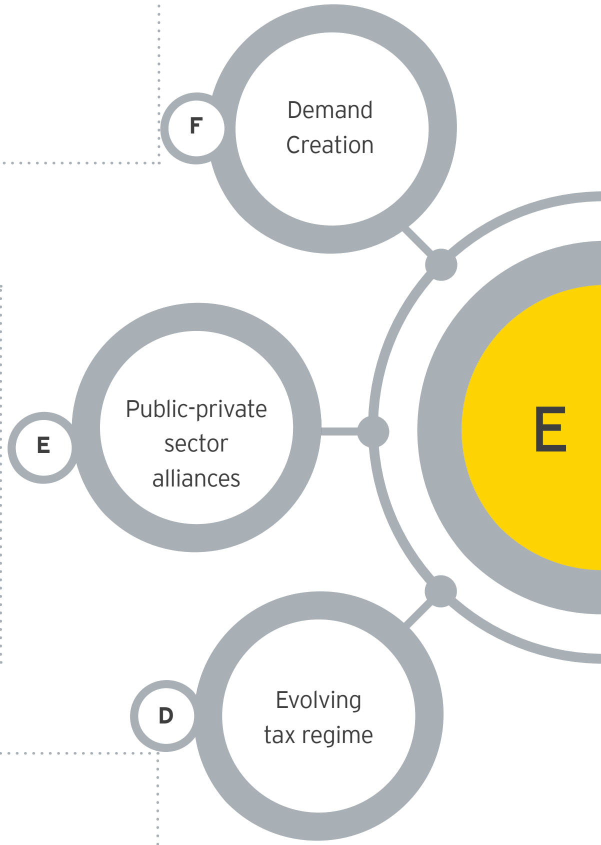
MoHIPE	MoRT&H	MoP	MoST	MoH&UA
Ministry of Heavy Industries and Public Enterprises)	(Ministry of Road Transport and Highways)	(Ministry of Power)	(Ministry of Science and Technology)	(Ministry of Housing and Urban Affairs)
• MoHIPE has been leading electric mobility initiatives in India since 2013. • MoHIPE launched the NEMMP and manages FAME scheme to disburse financial incentives.	• MoHIPE has been leading electric mobility initiatives in India since 2013. • MoHIPE launched the NEMMP and manages FAME scheme to disburse financial incentives.	• The MoP launched the National e-Mobility Programme by procuring EVs and EVSE through EESL. • The MoP released a notification declaring EV charging to be a service rather than sale of electricity. • The MoP declared guidelines for setting up charging infrastructure.	• The MoST has formed a "Technology Platform for Electric Mobility (TPEM)", funded primarily by the MoHIPE. • MoST will play a key role in forming electric mobility standardization roadmap for India.	• Initial EV development will be predominantly an urban scenario led by cities. • MoH&UA notified that residential and commercial complexes will have to allot 20% of their parking space for electric vehicle charging facilities • MoH&UA will play a key role in bringing together various city-wide stakeholders together to facilitate development.

Coordinated efforts resulted in six key facilitative initiatives, namely, FAME II, Urban facilitation, power sector facilitation, evolving tax regime, public private alliances and demand aggregation, which are attributed for the development of electric mobility in India.

Electric mobility

India has witnessed four demand aggregation models in the electric mobility sector –

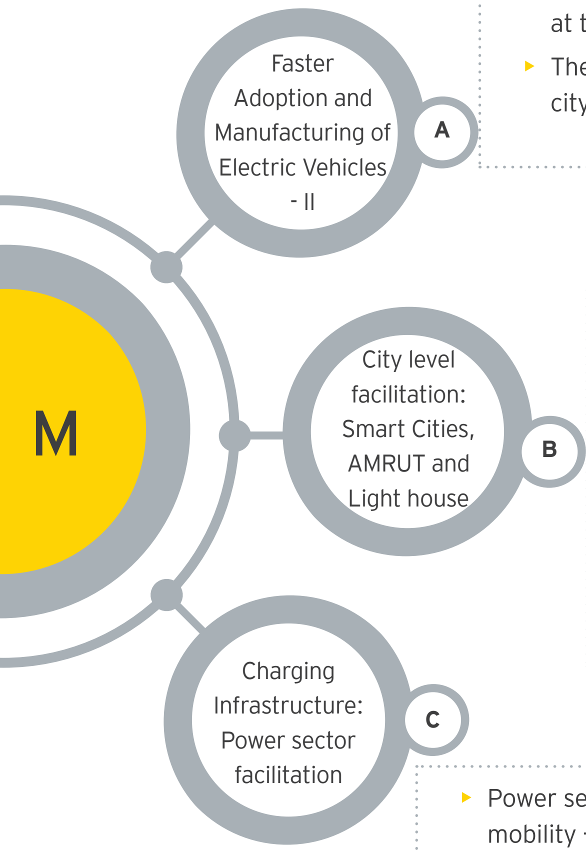
- EESL led demand aggregation
- PSU & city administrators led
- Private sector led
- City-led under FAME program
- Tariff categories, standards, business models etc.



- Tata Power and Mahindra collaborated with the Government of Maharashtra to deploy EVs and EVSE in the state.
- PGCIL collaborated with L&T Hyderabad Metro Rail (HMR) to set up charging stations in metro premises.
- FORTUM and IOCL collaborate to set up charging infrastructure in Hyderabad.
- Smart-e in collaboration with Kinetic green, DMRC,PhonePe, Rajasthan Electronics & Instruments Ltd (REIL) and Exicom is deploying e-mobility ecosystem in Delhi

Tax initiatives to promote fully electric vehicles:

- GST reduction on Fuel cell vehicles: 28% to 18%
- GST reduction on Li-ion battery: 28% to 12%
- Hybrid vehicles have been kept in the same category as luxury cars and will be taxed at the peak rate of 28% plus a cess of 15%



A

- The NEMMP targets were supported by fiscal incentives of 795 crores ($ 114 Mn) through FAME scheme.
- As a part of Government's investments for demand creation, incentives are provided to buyers, which can be availed upfront at the point of purchase.
- The scheme is expected to be renewed as FAME II focusing on city level public sector fleet electrification

B

- To facilitate city level developments three key programs Smart cities, AMRUT and Light house were launched. There are 100 smart cities, 500 AMRUT cities and 1 Light city (Pune) approved by the government.
- Smart cities and AMRUT focus on a holistic development and Light House initiative will focus on a 'Shared', 'Electric' and connected mobility developments in the city.
- Investment: 1 lakh crore ($14 Bn) for urban development

C

- Power sector entities have taken an active stance in electric mobility –
- Ministry of Power declared EV charging to be a service rather than sale of electricity, facilitating the private sector participation.
- MoP is drafting a policy on charging infrastructure covering technological, regulatory and implementation aspects
- Statutory bodies BEE, CEA, CERC, SERC are enabling the sector by exploring/forming safety provisions, tariff categories, standards, business models etc.

Policy level recommendations

Electric mobility proliferation will be a private sector-led development. However, policy and regulatory bodies and city/state governments need to act as facilitators to reduce the risks of private sector. To increase the uptake of electric mobility market in India, various policy and regulatory initiatives have already been taken. The section below highlights the policy level recommendations and key regulations instrumental for the uptake of electric mobility in India.

S. No.	Incentive	Vehicle segment	User	Responsible agency	Recommendations
Fiscal measures					
1	GST	All	All	Central and state	▸ The GST rate for EV may be brought down. ▸ If the above is not feasible then the state government may consider exempting SGST.
2	Road tax	All	All	Central and state	▸ The road tax should be fully exempted in EV for first few years. ▸ The above amendment in Motor Vehicle Act can act as an enabler.
3	Financing - interest rate	All	All	Central and RBI	▸ Setting up manufacturing units, charging stations and EV purchase(s) can be considered under priority sector lending.
4	Income Tax benefits	All	Institution corporates	Central	▸ The EV buyer can avail accelerated depreciation of 40% like solar. ▸ The EV charging stations can be promoted with solar or energy storage solutions to avail such benefits.
Non-fiscal measures					
5	Power tariff	All	All	State	The following tariff changes could be adopted by India: ▸ Relaxing additional fixed/demand charges coming from EVs for all connection categories. This could be time bound for first five years and upon evaluation, it can be extended further. ▸ For (not-for-profit purposes) home and office/work charging, allowing an option to move to three-phase connection with TOD tariff or continuing with same tariff category. ▸ For (profit purposes) commercial EV charging or EV leasing as a service (with some minimum number of chargers or kW load), allowing new separate meter under new EV tariff category. This tariff category to be kept competitive like Delhi order of fixed 5 and 5.5 INR/kWh for LT and HT connection. Keeping this tariff tied to the average cost of supply (ACoS) of DISCOMs and allowing the maximum loading of 10%-15% for AT&C losses, could be a good way for all states to lend support. ▸ Also allowing such businesses to mark up their charging services prices (including electricity) at market rates. ▸ Allowing such businesses to opt for an easy open access (if they meet minimum kW load requirements).

S. No.	Incentive	Vehicle segment	User	Responsible agency	Recommendations
Non-fiscal measures					
6	Toll charges	All	All	State	▸ This can be exempted for EV buyers till 2022-23.
7	Entry tax	PV and buses	Commercial	State	▸ The state entry taxes may be fully exempted.
8	Parking fees	All	All	State	▸ The parking fees may be exempted for all types of EVs.
9	Permits	3W and PV	Commercial	State	▸ The permit cost may be fully exempted.
10	2W/3W taxi	2W/3W	Commercial	Central and state	▸ Motor Vehicle Act may be amended to allow 2W and 3W as fleet/taxi businesses and corporate ownership.
11	Green plates	All	All	Central	▸ The green plates can be given to EV buyers. Some EVs (cars and buses) with green plates could be given access to dedicated lanes and parking areas.

Regulations for deployment of charging infrastructure

The landmark clarification from the MoP that operations of charging infrastructure is not resale of electricity and hence, beyond the purview of EA 2003[12] , has paved the way for participation of private players. Further, CEA has amended regulations to incorporate charging stations. Other than central level regulations supply code, metering regulations and EA 2003 clearly outlines the procedural requirements for deployment of charging infrastructure. The following table lists the various regulations applicable to set up charging infrastructure.

S.No.	Phase of EV charging infrastructure deployment	Regulatory framework				
		Regulation	Article	Centre/ state level	Verbatim	Description
1	Connection request	Supply code	Chapter 3	State	New and existing connections	Procedure to follow to raise a connection request for deploying a charging station.
2	Request processing and agreement on timelines	Distribution License Regulations[13]	Chapter 4	State	23. Obligation to supply on demand 23.1 Subject to the provisions of the Act, the distribution licensee shall, on the application of the owner or occupier of any premises within the area of license, give supply of electricity to such premises within one month of the receipt of such application or within such period as may be specified by the commission, if such supply requires extension of distribution mains or new substations.	The timelines for grant of approval for establishing the charging infrastructure is to be within a month if that does not require augmentation of grid infrastructure.
3	Right of way	Electricity Act, 2003[14]	PART VIII - Works of licensees	State (DISCOM is a state subject)	Section 67. (Provisions as to opening of streets, railways, etc.): Section 68. (Provisions relating to overhead lines): Section 69. (Notice to telegraph authority):	The act defines the provisions to obtain the right of way as per the sections 67, 68 and 69.
4	Other approvals	Supply code	2. & Annexures - Form A1	State	Application for power supply/ additional power supply A-1 Application Form (to be used for residential and other connections, except agriculture and industrial)	Relevant forms that an individual or entity needs to fill for placing a request for connection to distribution utility.

S.No.	Phase of EV charging infrastructure deployment	Regulatory framework				
		Regulation	Article	Centre/ state level	Verbatim	Description
5	Safety and standards and quality of hardware	CEA (2010 and later amended), supply code (state) and Electricity Rules 2005 and draft regulations of Distributed Generation Resources.[15] [16]	Supply Code - 9, 10 and 11	Centre and state	9. DISCOM specific supply mains and apparatus 10. Wiring on consumers' premises 11. Consumers' apparatus	As per the provisions of supply code, electricity rules and distributed generation resources regulations, the standards for connectivity of a charging station to distribution infrastructure needs to be ensured.
6	Installation implementation and cost of incurrence by DISCOM	Terms and conditions for determination of Wheeling Tariff and Retail Supply Tariff Regulations, 2011[17]	5.6	State	Return on Capital Employed (RoCE) shall be used to provide a return to the distribution licensee, and shall cover all financing costs, without providing separate allowances for interest on loans and interest on working capital.	As per the provisions of state-level conditions for determination of tariff which suggests methodology for calculation of return on capital employed (RoCE).
7	Tariff determination methodology	Draft amendments to National Tariff Policy 2016 [18]	8.3	Centre	(a) Tariff shall be less than or equal to the average cost of supply determined, based on AT&C loss level of 15% or actual, whichever is lower, and (b) there shall be single part tariff for this purpose in the initial three years	The proposed amendments to NTP, 2016 vide letter no. 23/2//2018-R&R specifies that tariff for charging station operations should not be two-part tariff but single part and the tariff should be average cost of supply of DISCOM with an assumption of 15% AT&C losses blended into it.

[12] https://powermin.nic.in/sites/default/files/webform/notices/Clarification_on_charging_infrastructure_for_Electric_Vehicles_with_reference_to_the_provisions_of_the_Electrcity_Act_2003.pdf (last accessed on 14 August 2018)
[13] http://tserc.gov.in/file_upload/uploads/Regulations/Draft/2016/DraftTSERC%20Distribution%20Regulation.pdf (last accessed on 07 August 2018)
[14] http://www.cercind.gov.in/Act-with-amendment.pdf (last accessed on 07 August 2018)
[15]http://www.cea.nic.in/reports/regulation/draft_tech_std_dgr_2018.pdf (last accessed 07 August 2018)
[16]http://www.cea.nic.in/reports/regulation/draft_safety_regulations_2018.pdf (last accessed 07 August 2018)
[17]http://www.derc.gov.in/regulations/dercregulations/Regulaations2011/Distribution.pdf (last accessed 07 Aug. 18)
[18]https://powermin.nic.in/sites/default/files/webform/notices/Proposed_amendments_in_Tariff_Policy_0.pdf (last accessed 07 Aug. 18)

S.No.	Phase of EV charging infrastructure deployment	Regulatory framework				
		Regulation	Article	Centre/ state level	Verbatim	Description
8	Tariff setting	Electricity Act (EA), 2003	U/S 86	State	a) Determine the tariff for generation, supply, transmission and wheeling of electricity, wholesale, bulk or retail, as the case may be, within the state.	State Electricity Regulatory Commission has been empowered by EA 2003 to determine tariff as per ARR filed.
9	Standard for metering	Installation and Operation of Meter Regulations, 2006	Part III	Center	The consumer meter may have the facilities to measure, record and display one or more of the following parameters depending upon the tariff requirement for the various categories of consumers.	Existing provisions as mentioned in the supply code with reference to metering regulations mentions the parameters to be measured for consumer meter.
10	Future EV charging infrastructure investments by DISCOM	EA 2003 and treatment of income from other business	U/S 51	Center and state	A distribution licensee may, with prior intimation to the appropriate commission, engage in any other business for optimum utilization of its assets: Provided that a proportion of the revenues derived from such business shall, as may be specified by the concerned state commission, be utilized for reducing its charges for wheeling.	With consent of SERC, the DISCOMs can invest in deployment of charging infrastructure and maintain books as per the regulations for non-tariff income specified by SERCs.
11	Retail pricing/tariff to EV users	Clarification on charging infrastructure for electric vehicles, dated 13 April 2018		Center	Charging of batteries of electric vehicles by charging station does not require any license under the provisions of the Electricity Act, 2003.	Clarification note of MoP specifies charging of EV is a service and does not require any license. This enables operator of charging infrastructure to charge innovative pricing to EV users such as INR/kWh, INR/km, INR/min, etc.
12	De-licensing ownership and operation of charging infrastructure				Charging of battery of an EV by a charging station does not involve sale/distribution of electricity.	Charging station operators do not require a license to operate.

S.No.	Phase of EV charging infrastructure deployment	Regulatory framework				
		Regulation	Article	Centre/ state level	Verbatim	Description
13	Technology adoption for Charging Infrastructure	Charging Infrastructure for Electric Vehicles - Guidelines and Standards - Regulation		Central and state	Create adequate charging infrastructure as per all the available charging technologies.	Specification of a charging station Fast ▸ CCS (min 50 kW) ▸ CHAdeMO (min 50 kW) ▸ Type-2 AC (min 22 kW) Slow/moderate ▸ Bharat DC-001 (min 15 kW) ▸ Bharat AC-001 (min 10 kW)
14	Deployment strategy for public charging infrastructure				To achieve a uniform distribution of accessible charging infrastructure.	▸ One charging station should be available in a grid of 3 km X 3 km. ▸ One charging station should be available at every 25 km on both sides of highway. ▸ One fast charging station at every 100km for long range EVs.
15	Real estate for charging infrastructure	Amendments to Model Building Bye-Laws, 2016	10.4	Central and state	Availability of affordable (for charging station operator) and accessible (EV owner) space plays a critical role in the viability of charging station operations.	▸ The total parking provisions in the premises of building for charging infrastructures shall be provided only for EVs. ▸ This would be 20% of all vehicle holding capacity (i.e., parking capacity) at the premise. ▸ Additionally, the building premise will have to have an additional power load, equivalent to the power required for all charging points (in a PCS) to be operated simultaneously.

1 Electric vehicle charging infrastructure: global landscape

In 2017, the total number of operational electric vehicle chargers crossed two million. As of December 2017, the world had six times the number of electric vehicles than the number of available public chargers. The number of publicly available chargers saw a 70% increase in 2017. There has been a rapid increase in the number of deployed fast chargers due to the rapid deployment in mature markets such as China. This rapid deployment of the electric vehicle chargers has been made possible due to various policy and regulatory level initiatives of the governments.

Market assessment study of the US, Germany, China, Japan and Finland has shown that apart from the subsidy support, various fiscal and non-fiscal incentives have played a defining role in improving business viability of setting up charging infrastructure. The table listed below gives a brief of key growth drivers in each of these countries.

Table 1: Key growth drivers in the countries studied

Country	Key growth drivers							
	EV Policy	Tax holidays	Unregulated tariff	Utility involvement in deployment	EV purchase incentives	Incentives for public charging infrastructure	Time of Use tariff	Indirect incentives (access to reserved lanes)
The USA	✔	✔	✔	✔	✔	✔	✔	✔
China	✔	✔	✕	✔	✔	✔	✔	✔
Japan	✔	✔	✕	✔	✔	✔	✔	✔
Germany	✔	✔	✔	✔	✔	✔	✔	✔
Finland	✕	✔	✔	✔	✕	✔	✔	✕

In addition to the fiscal and non-fiscal incentives, adoption of the standards for EV, EVSE and testing has been an important factor influencing the growth. Although, most of these markets (except China) have been technology agnostic. i.e., charging station operators choose the standards based on the market conditions. In addition, these operators are independent to adopt any revenue model.

e-mobility markets in these countries have been driven by utilities and network service providers. Utilities have launched various electric mobility programs specifying the number of chargers to be installed, total budget, eligible agencies for setting up charging infrastructure, minimum number of chargers per site and modes of pricing. Most of the utilities follow two modes of pricing, namely pass through pricing and custom pricing.

In pass through pricing, the charging point operator/host passes the Time of Use (TOU) tariff directly to the EV owner. The host has the option to include a rate added above the TOU rate being charged. The rate added represents the non-energy additional charges such as demand charges, meter charges, etc. Site hosts are required to revise the rate added, based on the historic EV charger utilization to ensure that the site hosts are not overcharging the customers. In custom pricing, the host creates a customized pricing structure. For e.g., a dollar per unit time rates, flat fees pricing, free charging, etc.

In addition, the prevalent business models in the studied countries have been utility centric. Role of the utilities vary based on the power market structure of the region. In California, a region having regulated market structure, utilities are responsible for deploying grid infrastructure and billing the consumers. Expenditure for installing the requisite infrastructure is recovered through the tariff (expenditure is accounted for in the tariff filings). However, in Germany, a region having unregulated power market, power retailers charge the charging point operators (CPOs) for supplying electricity. CPOs are free to choose the retailer for procuring power. For billing CPOs, a smart meter is installed at the point of connection of each charging station.

Network service providers (NSPs) have also played an important role in e-mobility ecosystem. These cloud service providers have been instrumental in addressing key concerns of EV owners by providing real-time information such as nearest stations, service charge and expected waiting time. They also provide services such as advanced booking of charging slots and payment options. In addition, NSPs also provide visibility to DISCOMs on real-time basis to enable them to implement demand response and Time of Use (TOU)/Time of Day (TOD) tariff regimes.

The sections below detail out the key developments which led to market development in the US, Germany, Japan, China and Finland. This includes assessment of power market structure, key growth drivers such as policy and regulatory level initiatives, technological developments and utility centric business models for setting up charging stations.

[19] International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018


1.1

United States of America

Various states in the United States of America have adopted different approaches for propagating EV chargers. California has emerged as one of the largest market for EVs in the country.

California

1.1.1. Power market in California

The electricity sector restructuring of the 1990s and early 2000s introduced competitive markets in the US electricity sector. The competitive market in the country boosts more than 3,000 electric utilities operating in the sector. More than 2000 utilities operate in power distribution whereas a fewer than 1,000 utilities are power generation based.

Based on the ownership structure, electric utilities in California can be grouped into five categories [20 21]:

- Publicly owned utilities (municipal utilities)
  - Owned by the local community and operated by local governments (e.g., cities and towns).
  - These utilities own the generation, transmission and distribution in their service territories.

These are private organizations owned by investors holding the company stocks.

- Investor-owned utilities (IOU)
  - These are private organizations owned by investors holding the company stocks.
- Electric service providers (ESP)
  - These are non-utility entities that offers "direct access" electric service to customers located within the service territory of an investor-owned utility.
- Community choice aggregators (CCA):
  - CCA are local, not-for-profit agencies operating as an alternative to the investor owned utilities.
  - In this model, local entities aggregate the electricity demand within their local jurisdiction and choose power generation source on the behalf of consumers.
- Rural electric cooperatives (REC)

These are not-for-profit organizations, owned and controlled by the people who use their services.

Regulatory framework

California has established the following three governing institutions to regulate and manage their energy sector:

- California Energy Commission: regulates the state's primary energy policy and planning.
- California Public Utilities Commission (CPUC): regulates investor-owned public utilities, which includes -
  - Pacific Gas and Electric (PG&E)
  - San Diego Gas and Electric (SDG&E)
  - Southern California Edison (SCE)
  - Southern California Gas Company (SoCalGas)

Note: PG&E, SDG&E and SCE serve approximately three quarters of California's electricity demand.

- California Independent System Operator (CAISO)
  - CAISO is an independent, not-for-profit, public benefit corporation.
  - They are responsible for operating high voltage and long-distance electric transmission lines that make up 80% of California's electricity system.
  - They are also responsible for facilitating California's wholesale electric power markets

[20] List of utilities in California: http://www.energy.ca.gov/almanac/electricity_data/utilities.html#service
[21] National Renewable Energy Laboratory (NREL) - https://www.nrel.gov/docs/fy17osti/67106.pdf

1.1.2. Policy roadmap for electric mobility in California

California has been a trendsetter in the US in environmental reforms. The Government of California has set a target for 5 million zero emission vehicles (ZEVs) on the roads by 2030 and 250,000 electric vehicle charging stations by 2025. Towards that aim, California is constantly pushing for green mobility through various policy reforms, some of the key policies are [22]:

Table 2: Electric mobility policy roadmap in California

S. No.	Policy/Initiative	Timeline	Description
1	Electric Vehicle Supply Equipment (EVSE) Policies for multi-unit dwellings	2011 Updated - 2012	Encourages installation or use of EVSE in a homeowner's designated parking space or in a common area.
2	Zero Emission Vehicle (ZEV) Promotion Plan	2012 Updated - 2018	Encourages all state agencies of California to support and facilitate rapid commercialization of ZEVs in California. The targets include: ▸ By 2020, the state will have established adequate infrastructure to support one million ZEVs. ▸ By 2025, there will be 1.5 million ZEVs on the road in California and clean as well as efficient vehicles will displace 1.5 billion gallons of petroleum fuels annually. ▸ By 2025, there will be 200 hydrogen fueling stations and 250,000 plug-in electric vehicle (PEV) chargers, including 10,000 direct current fast chargers, in California. ▸ By 2030, there will be 5 million ZEVs on the road in California. ▸ By 2050, greenhouse gas emissions from the transportation sector will be 80% less than 1990 levels State agencies must also work with their stakeholders to accomplish the following: ▸ Update the ZEV action plan, with a focus on low income and disadvantaged communities. ▸ Recommend actions to increase the deployment of ZEV infrastructure through the Low Carbon Fuel Standard. ▸ Support and recommend policies that will facilitate the installation of PEV infrastructure in homes and businesses. ▸ Ensure PEV charging and hydrogen fueling are affordable and accessible to all drivers. The ZEV Promotion plan additionally directs the state fleet to increase the number of ZEVs in the fleet through gradual vehicle replacement. By 2020, ZEVs should make up at least 25% of the fleet's light-duty vehicles. Vehicles with special performance requirements necessary for public safety and welfare are exempt from this requirement.
3	State Agency Electric Vehicle Supply Equipment (EVSE) Installation	2012	Encourages California's state agencies to actively identify and pursue opportunities to install EVSE and accommodate future EVSE demand. Locations recommended are state employee parking facilities and in new existing agency buildings.

[22] The Alternative Fuels Data Center (AFDC), Department of Energy (USA) - https://www.afdc.'energy.gov/laws/all?state=CA

S. No.	Policy/Initiative	Timeline	Description
4	Electric Vehicle Supply Equipment (EVSE) Open Access Requirements	2013	EVSE service providers may not charge a subscription fee or require membership for use of their public charging stations. Operators must disclose: ▸ actual charges for using public EVSE at the point of sale ▸ allow at least two options for payment ▸ disclose the EVSE geographic location ▸ schedule of fees
5	The California Building Standards Commission: Mandatory Electric Vehicle Supply Equipment (EVSE) Building Standards	2013	Establishes building standards for EVSE installation in parking spaces at multi-family dwellings and non-residential developments.
6	Zero Emission Vehicle (ZEV) Deployment Support	2013	California signed a multi-state MoU on electric mobility collaborations. Each state committed to: ▸ Deploy at least 3.3 million ZEVs and adequate fueling infrastructure within the signatory states by 2025. ▸ Support ZEV commercialization through consistent state-wide building codes and standards for installing EVSE, streamline the metering options for homes equipped with EVSE, provide opportunities to reduce vehicle operating costs, increase electric system efficiency through time-of-use electricity rates and net metering for electric vehicles, and integrate ZEVs with renewable energy initiatives. ▸ Establish ZEV purchase targets for governmental agency fleets, explore opportunities for coordinated vehicle and fueling station equipment procurement, work to provide public access to government fleet fueling stations, and include commitments to use ZEVs in state contracts with auto dealers and car rental companies, wherever appropriate. ▸ Evaluate the need for, and effectiveness of, monetary incentives to reduce the upfront purchase price of ZEVs as well as non-monetary incentives, such as high occupancy vehicle lane access, reduced tolls and preferential parking and pursue these incentives as appropriate. ▸ Work to develop uniform standards to promote ZEV consumer acceptance and awareness, industry compliance and economies of scale, including adoption of universal signage, common methods of payment and interoperability of EVSE networks, and reciprocity among states for non-monetary ZEV incentives. ▸ Cooperate with vehicle manufacturers, electricity and hydrogen providers, the fueling infrastructure industry, corporate fleet owners, financial institutions, and others to encourage ZEV market growth. ▸ Share researches and develop a coordinated education and outreach campaign to highlight the benefits of ZEVs, including collaboration with related national and regional initiatives.

S. No.	Policy/Initiative	Timeline	Description
7	Establishment of a Zero Emission Medium- and Heavy-Duty Vehicle Program	2014-2020	US$12 million-US$20 million in funding annually through 2020, for zero and near-zero emission heavy-duty vehicles, including vocational trucks, short- and long-haul trucks, buses and eligible off-road vehicles and equipment.
8	Zero Emission Vehicle (ZEV) Initiative	2014	Establishes a goal of 1 million ZEVs in California by 2023.
9	Electric Vehicle Supply Equipment (EVSE) Policies for Residential and Commercial Renters	2014	Encourages installation of EVSE in residential locations.
10	Plug-In Electric Vehicle (PEV) Charging Electricity Exemption	2014	Electricity used to charge PEVs at a state-owned parking facility is exempt from California law, prohibiting gifting public money or items of value.
11	State Agency Low Carbon Fuel Use Requirement	2015	At least 3% of the aggregate amount of bulk transportation fuel purchased by the state government must be from very low carbon transportation fuel sources. From 2018, the percentage will increase by 1% annually until 2024. Such policies are to promote the uptake of low carbon mobility like electric vehicles.
12	Freight Efficiency Action Plan	2015	Various public- sector entities of California implemented the California Sustainable Freight Action Plan, which establishes targets to improve freight efficiency and transition to zero emission technologies. The plan identifies state policies, programs and investments to achieve the following targets: ▸ Improvement of freight system efficiency by 25% by 2030. ▸ Deployment over 100,000 zero emission freight vehicles and associated equipment, maximizing the number of vehicles powered by renewable energy, by 2030.
13	Electric Vehicle Supply Equipment (EVSE) Local Permitting Policies	2015	A city or county must adopt an ordinance that creates an expedited, streamlined permitting process for EVSE.
14	Zero-Emission Vehicle (ZEV) Fee	2017	From 2020, zero-emission vehicle (ZEV) owners must pay an annual road improvement fee of US$100 upon vehicle registration or registration renewal for ZEVs' model year 2020 and later.
15	Volkswagen Group of America's (VW) Zero Emission Vehicle (ZEV) Investment Plan	2017	As required by the October 2016's 2.0-Liter Partial Consent Decree, VW must invest $800 million over ten years to support the increased adoption of ZEV technology in California.

S. No.	Policy/Initiative	Timeline	Description
16	Plug-in Electric Vehicle (PEV) Parking Space Regulation	2017	Establishes specific parking spots for EV users. It also levies traffic violation penalties to users violating the rule.
17	Support for Zero Emission and Autonomous Vehicle Infrastructure	2017	Cities and counties are encouraged to fund advanced transportation technologies and communication systems, including, zero emission vehicle fueling infrastructure and infrastructure-to-vehicle communications for autonomous vehicles.
18	Electric Vehicle Supply Equipment (EVSE) Signage Authorization on Highways	2017	EVSE facilities located at roadside businesses are eligible to be included on state highway exit information signs.

1.1.3. Incentives for EV uptake

The Government of California, through their various fiscal and non-fiscal incentives, has reinforced their support for the development of electric mobility sector. Innovative schemes like specific lanes, toll tax waiver, insurance discounts, etc. have been brought to action to popularize EVs in the state.

Table 3: State incentives [22]

State incentives		
S. No.	Title	Description
1.	Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Insurance Discount	Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Insurance Discount Farmer insurance scheme provides a discount of up to 10% on all major insurance coverage for HEV and EV owners.
2	Alternative Fuel Vehicle (AFV) Parking Incentive Programs - 2012	This program encourages Department of General Services (DGS) and California Department of Transportation (DOT) to implement AFV parking incentive programs in public parking facilities
3	The South Coast Air Quality Management District (SCAQMD) Air Quality Investment Program (AQIP) Employer Invested Emissions Reduction Funding - South Coast	This is an employer investment fund to meet employers' emissions reduction targets. The revenues collected are used to fund electric vehicle projects.
4	Low Emissions School Bus Grants- 2011	Encouragement incentives to replace older school buses with EVs.
5	High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) Lane Exemption-2006 (Updated-2017)	Allots "Clean Air Vehicle" sticker for EVs which can be used to access HOV lanes. EVs are also eligible for tax rebates in HOT lanes.

[23]The Alternative Fuels Data Center (AFDC), Department of Energy (USA) - https://www.afdc.'energy.gov/laws/all?state=CA; EY analysis

State incentives		
S. No.	Title	Description
6	Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Grants	The Motor Vehicle Registration Fee Program provides funding for purchasing electric vehicles and developing charging infrastructure.
7	REMOVE II program - Low Emission Vehicle Incentives and Technical Training - San Joaquin Valley	Provides incentives to educate personnel on the mechanics, operation safety, maintenance of AFVs, fueling stations and tools involved in the implementation of alternative fuel technologies.
8	Technology Advancement Funding - South Coast	Funding for research, development, demonstration and deployment projects that are expected to help accelerate the commercialization of advanced low emission transportation technologies.
9	Alternative Fuel and Vehicle Incentives 2007 (Updated- 2012)	Financial incentives for businesses, vehicle and technology manufacturers, workforce training partners, fleet owners, consumers, and academic institutions with the goal of developing and deploying alternative and renewable fuels and advanced transportation technologies. Funded projects include: ▸ Commercial alternative fuel vehicles' (AFVs) demonstrations ▸ Deployment ▸ Alternative and renewable fuel production ▸ Research and development of alternative and renewable fuels ▸ innovative technologies ▸ AFV manufacturing ▸ Workforce training ▸ Public education, outreach and promotion.
10	Hybrid Electric Vehicle (HEV) and Zero Emission Vehicle (ZEV) Purchase Vouchers 2010 (Updated- 2016)	California Air Resources Board provides vouchers in the range of US$2,500 to US$117,000 to eligible fleets to reduce the incremental cost of qualified medium- and heavy-duty HEVs and ZEVs at the time of purchase.
11	Plug-In Hybrid and Zero Emission Light-Duty Vehicle Rebates 2010 (Updated- 2017)	The Clean Vehicle Rebate Project (CVRP) offers rebates for the purchase or lease of electric vehicles.
12	Advanced Transportation Tax Exclusion-2015	The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) provides sales and use tax exclusion for the qualified manufacturers of advanced transportation products, components, or systems that reduce pollution, use energy and promote economic development.
13	Alternative Fuel Vehicle (AFV) Incentives - San Joaquin Valley	Public Benefit Grant Program, which provides funding to cities, counties, special districts (such as water districts and irrigation districts), and public educational institutions for the purchase of electric vehicles. The maximum grant amount allowed per vehicle is US$20,000, with a limit of US$100,000 per agency per year.

State incentives		
S. No.	Title	Description
14	Alternative Fuel and Advanced Vehicle Rebate - San Joaquin Valley	The San Joaquin Valley Air Pollution Control District (SJVAPCD) administers "The Drive Clean! Rebate Program", which provides rebates for the purchase or lease of electric vehicles. The program offers rebates of up to US$3,000
15	Hybrid and Zero Emission Truck and Bus Vouchers - San Joaquin Valley	The San Joaquin Valley Air Pollution Control District (SJVAPCD) contributed funds to the California Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) for eligible vehicles used in the eight-county San Joaquin Valley Air Basin. Vouchers range from US$12,000 to US$30,000, depending on the vehicle. These vouchers are provided in addition to California Air Resources Board voucher amounts.
16	Residential Electric Vehicle Supply Equipment (EVSE) Financing Program-2014	Property-Assessed Clean Energy (PACE) financing allows property owners to borrow funds to pay for energy improvements, including purchasing and installing EVSE. Financing limits are 15% of the first US$700,000 of the property value and 10% of the remaining property value.
17	Plug-In Hybrid and Zero Emission Light-Duty Public Fleet Vehicle Fleet Rebates-2014 (Updated- 2016)	The Public Fleet Pilot Project (PFPP) offers rebates to eligible state and local public entities for the purchase of qualified light-duty fleet vehicles located in disadvantaged communities. The rebates are for up to US$5,250 for plug-in hybrid electric vehicles, US$10,000 for battery electric vehicles.
18	Voluntary Vehicle Retirement Incentives - San Joaquin Valley and South Coast-2015	The San Joaquin Valley Air Pollution Control District and the South Coast Air Quality Management District administer the Enhanced Fleet Modernization Program (EFMP) Pilot Retire and Replace program, and provides incentives to replace a vehicle eligible for retirement with a more fuel-efficient vehicle like electric vehicles.
19	Electric Vehicle Supply Equipment (EVSE) Loan and Rebate Program- 2015	The Electric Vehicle Charging Station Financing Program (Program), a part of the California Capital Access Program (CalCAP), provides loans for design, development, purchase, and installation of EVSE at small business locations in California. The program may provide up to 100% coverage to lenders on certain loan defaults. Lenders must apply to the California Pollution Control Financing Authority (CPCFA) to participate and enrol each qualified EVSE loan through CalCAP. Small businesses are eligible for a rebate of 50% of the loan loss reserve amount after the small businesses repay the loan in full or meet monthly payment deadlines over a 48-month period.
20	Electric Vehicle Supply Equipment (EVSE) Incentives - San Joaquin Valley-2015	The San Joaquin Valley Air Pollution Control District (SJVAPCD) administers the Charge Up! Program, which provides funding for public agencies and businesses for the purchase and installation of new, publicly accessible EVSE. A single-port Level 2 station is eligible for up to US$5,000 per unit, and a dual port Level 2 station may receive up to US$6,000 per unit. There is an annual funding cap of US$50,000 per applicant.
21	Electric Vehicle Supply Equipment (EVSE) Pilot Programs- 2017	The California Public Utilities Commission (PUC) will provide funding for pilot utility programs to install EVSE at school facilities, other educational institutions and state parks or beaches.

State incentives		
S. No.	Title	Description
22	Electric Vehicle Supply Equipment (EVSE) Rebate - South Coast and MSRC- 2018	The South Coast Air Quality Management District (SCAQMD) and the Mobile Source Air Pollution Reduction Review Committee's (MSRC) Residential Electric Vehicle (EV) Charging Incentive Pilot Program offers rebates of up to US$250 towards the purchase of a qualified residential Level 2 EVSE. Additional rebates of up to US$250 are available for low-income residents.

Also, various utilities and private organizations have come up with novel incentives to further boost the demand. Listed below are some of the utility and private incentives [24]:

Table 4: Utility/Private incentives

Utility/Private incentives		
S. No.	Title	Description
1	Plug-In Electric Vehicle (PEV) Charging Rate Reduction - LADWP	The Los Angeles Department of Water and Power (LADWP) offers a US$0.025 per kilowatt-hour discount for electricity used to charge PEVs during off-peak times. Residential customers who install a separate time-of-use meter panel will also receive a US$250 credit.
2	Electric Vehicle Supply Equipment (EVSE) Rebate - LADWP	The Los Angeles Department of Water and Power (LADWP) provides rebates to commercial and residential customers toward the purchase of Level 2 EVSE. Commercial customers can receive up to US$4,000 for each charger and residential customers can receive US$500.
3	Plug-In Electric Vehicle (PEV) Charging Rate Reduction – SCE	Southern California Edison (SCE) offers a discounted rate to customers for electricity used to charge PEVs. Two rate schedules are available for PEV charging during on- and off-peak hours, the Residential Time-of-Use Plan and the Electric Vehicle Plan.
4	Plug-In Electric Vehicle (PEV) Rebate - SCE	Southern California Edison (SCE) provides rebates of US$450 to residential customers who purchase or lease an eligible new or pre-owned PEV.
5	Clean Vehicle Electricity and Natural Gas Rate Reduction - PG&E	Pacific Gas & Electric (PG&E) offers discounted residential time-of-use rates for electricity used for plug-in electric vehicle charging.
6	Plug-In Electric Vehicle (PEV) Rebate - PG&E	Pacific Gas and Electric (PG&E) provides rebates of US$500 to residential customers who purchase or lease an eligible PEV.
7	Plug-In Electric Vehicle (PEV) and Natural Gas Infrastructure Charging Rate Reduction - SDG&E	San Diego Gas & Electric (SDG&E) offers lower rates to customers for electricity used to charge PEVs.

[24] The Alternative Fuels Data Center (AFDC), Department of Energy (USA) - https://www.afdc.energy.gov/laws/state_summary?state=CA&search_button=Go

Utility/Private incentives		
S. No.	Title	Description
8	Plug-In Electric Vehicle (PEV) and Natural Gas Infrastructure Charging Rate Reduction - SDG&E	San Diego Gas & Electric (SDG&E) offers lower rates to customers for electricity used to charge PEVs.
9	Electric Vehicle Supply Equipment (EVSE) and Charging Incentives - Sonoma Clean Power	Qualified customers are eligible to receive a free EVSE with communication software "JuiceNet" enabled.
10	Electric Vehicle Supply Equipment and Charging Incentives - SMUD	Sacramento Municipal Utility District (SMUD) offers residential customers a US$599 rebate or a free Level 2 (240 volt) plug-in electric vehicle (PEV) charger.
11	Electric Vehicle Supply Equipment (EVSE) Rebate - Burbank Water and Power (BWP)	BWP provides rebates to commercial and residential customers towards the purchase of Level 2 EVSE. Commercial customers rebate - US$2,000 for each charger and up to four rebates per fiscal year. Residential customers rebate - US$500 and will be allotted BWP's time-of-use electricity rate.

1.1.4. Role of utilities

Till 2014, California Public Utilities Commission (CPUC) prohibited the utility ownership of electric vehicle service equipment (EVSE), with an exception for charging infrastructure for utilities' own fleet or vehicles. CPUC acknowledged certain benefits of utility ownership of the charging infrastructure, but mentioned that the benefits were speculative and did not outweigh the competitive limitation that may result from utility EVSE ownership. CPUC mentioned to revisit the prohibition if the utilities provided an evidence of any underserved markets or market failure which may have occurred due to the prohibition.

In a proceeding consisting of various parties of the power and transport sector, unanimous comments in the favor of utility ownership of EVSE were received by the CPUC, post which CPUC endorsed an expanded role for utility activity in developing and supporting EV charging infrastructure. However, CPUC declined to define the extent of involvement of the utility and decided to evaluate the utility proposals on case-specific basis [25] .

In response to removal of the prohibition, the three investor owned electric utilities (IOUs) of California namely, Southern California Edison (SCE), San Diego Gas & Electric (SDG&E) and Pacific Gas & Electric Company (PG&E) developed proposals for their individual EVSE deployment pilot programs for CPUC's approval. The CPUC-approved pilot programs of the three utilities are as follows:

- SCE – charge Ready
- PG&E – EV Charge Network
- SDG&E – Power Your Drive

[25] California Public Utilities Commission (CPUC) - R.13-11-007 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M143/K682/143682372.PDF

Table 5: Summary of the electric mobility programs by the California utilities[26]

Summary of the programs	SCE – Charge Ready	PG&E – EV Charge Network	SDG&E – Power Your Drive
Number of chargers to be deployed under the program	1,500	7,500	3,500
Budget	US$22 million	US$130 million	US$45 million
Eligibility	Public, MUDs and workplaces	MUDs and workplaces	MUDs and workplaces
Disadvantaged communities	10% or greater are reserved for the disadvantaged communities	15% or greater are reserved for the disadvantaged communities	10% or greater are reserved for the disadvantaged communities
Minimum number of chargers per site	10	10	10 at workplaces and 5 at MUDs
Ownership of charger	Host	Host or utility	Utility
Cost to host	Charger costs, charger installation costs, operations, maintenance and network costs	Charger costs, charger installation costs, operations, maintenance and network costs	No costs other than participation fees.
Pricing	Pass through pricing or custom pricing	Pass through pricing or custom pricing	Pass through pricing or custom pricing (free only)

South California Edison (SCE) - Charge Ready [27]

Charge Ready is an EV charging infrastructure deployment program run by the SCE with an aim of increasing the deployment of 1,500 level 1 and level 2 EV chargers in its service territory. As part of this pilot program, the SCE provides the requisite grid infrastructure at an SCE consumers' premises (also known as the site host) for installing the EVSE. Under the program, the consumer holds the responsibility for procuring, owning and maintaining the charging infrastructure in accordance with the program rules and regulations.

Any existing non-residential SCE consumer interested in deploying the charging infrastructure at their premises; and the sites that offers/consists long dwell-time parking spaces such as office spaces, fleet parking, cinema halls, stadiums are eligible for the program. However, single family homes are ineligible. Each consumer is required to deploy at least 10 chargers.

The process for enrolling into the program is as follows:

- **Enrolment:** the participant is required to enrol themselves on the Charge Ready website. The consumer is required to provide the SCE account details, tax registration details, approval of property owner(s), name of the authority for issuing building permits, proposed charging station's location and the site plan.
- **Agreement:** site assessment will be conducted by SCE to assess the feasibility of deploying charging stations. Post the review, SCE will develop a proposal mentioning the number of proposed charging stations at the site. Post deliberations between the site host and SCE, an agreement will be signed for the deployment of the chargers. Necessary approvals from the site owner (if the property is leased) are required. The property owner is also required to provide an easement to SCE for accessing the property for carrying out the construction process.

[26]EY analysis
[27]South California Edison (SCE) - https://www.sce.com/wps/wcm/connect/2938d47c-ab4a-4457-a162-7d7c927c1090/ChargeReadyProgramParticipationPackage.pdf?MOD=AJPERES

- **Planning and construction:** the site host is expected to share a certification of purchase to SCE confirming the purchase of the chargers from a list of SCE empaneled charger manufacturers. SCE according to its design and installation standards will locate, design and install the required grid infrastructure including the required distribution infrastructure (including any new transformers, services and meters) and customer premises distribution infrastructure (including any new panels, step-down transformers, conduits, wires, connectors and any other hardware installed by SCE). SCE is responsible for all the costs associated with the deployed distribution infrastructure. The chargers will then be installed by the charger manufacturers' contractors. Consumers are also required to subscribe to an EV charging network provider and share the charging data with SCE.
- **Note:** All charging stations are installed on a new and dedicated circuit deployed by SCE with its own panel, meter and service separate from any existing panel, meter or service.
- **Final assessment:** a post-installation site assessment will be conducted to confirm equipment installation and the operability of the charging site with the approved plans. Any applicable rebates are issued to the host post the final assessment.

Note: Under the Charge Ready program, all consumers are eligible for a rebate on the full (100%), partial (0% or 25% or 50%) on the base cost of the charging stations installed. The value of rebate is dependent on the consumer category and the location.

Demand Response program: customers installing level 2 chargers are mandated to participate in at least one EV charging related demand response programs when they are introduced. These customers are also required to contract a qualified EV charging network provider to access usage related data and to obtain demand response (DR) services. The service provider and the consumer are required to provide SCE with information related to the (not limited to) duration of each charge, rate, cost and load. The data is received directly from the network provider.

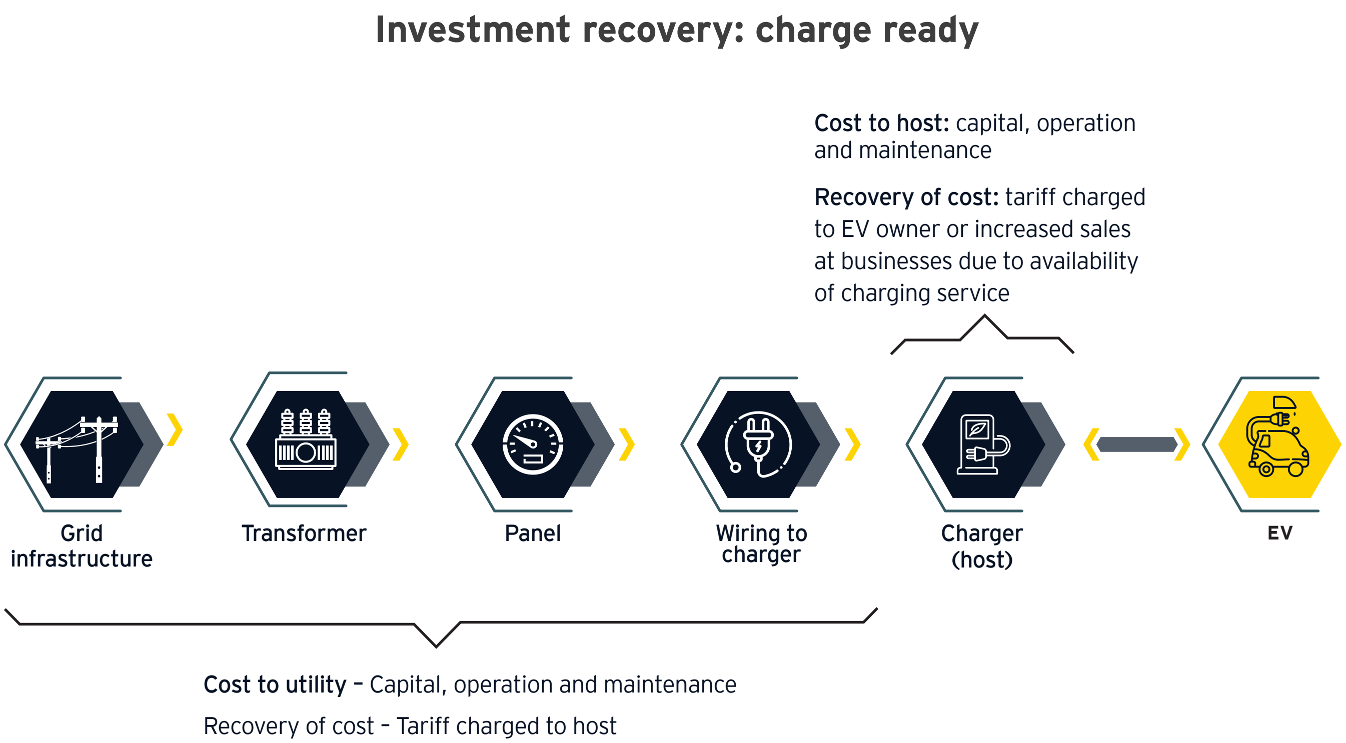
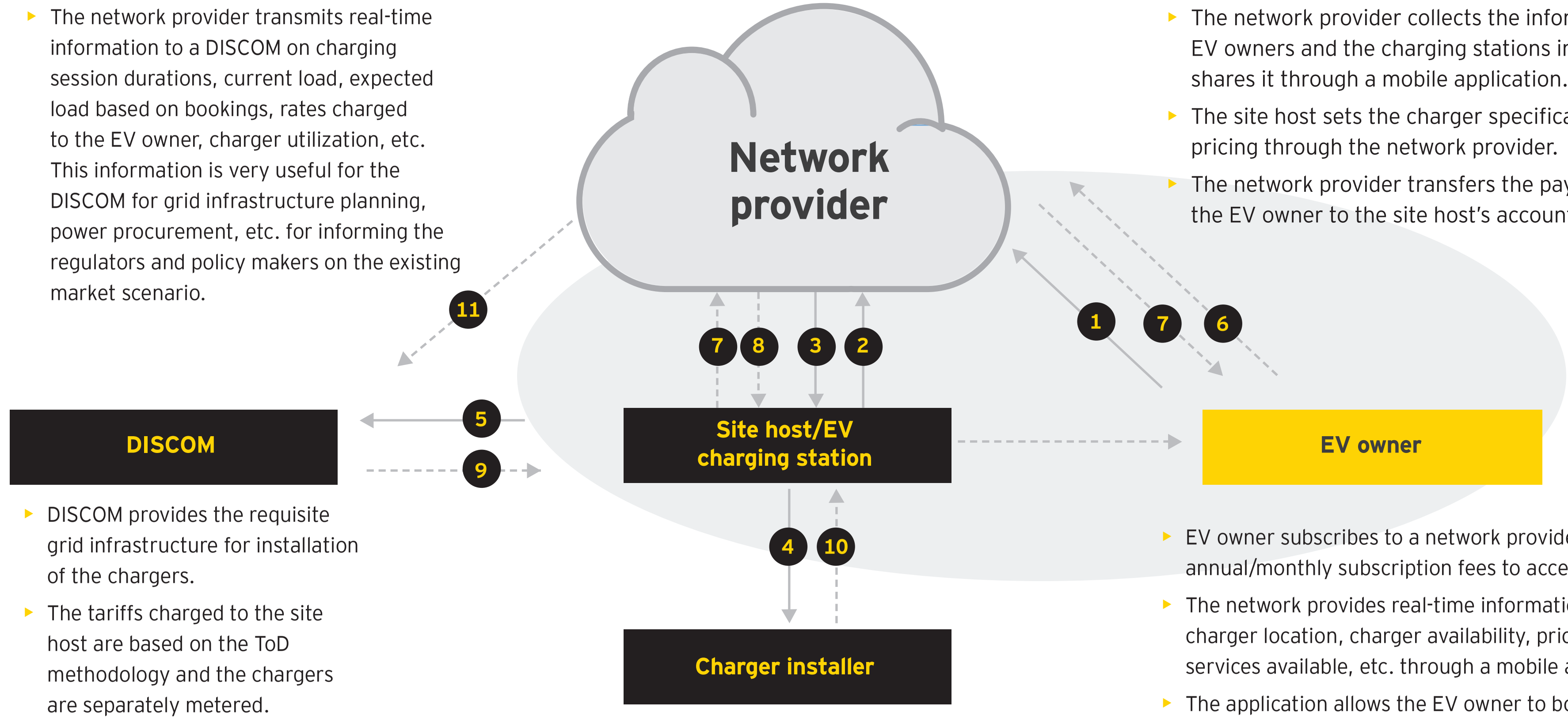


Figure 1: Investment recovery mechanism for Charge Ready[28]

[28] EY analysis

EV charging ecosystem



- The network provider transmits real-time information to a DISCOM on charging session durations, current load, expected load based on bookings, rates charged to the EV owner, charger utilization, etc. This information is very useful for the DISCOM for grid infrastructure planning, power procurement, etc. for informing the regulators and policy makers on the existing market scenario.

- The network provider collects the information from the EV owners and the charging stations in real-time and shares it through a mobile application.
- The site host sets the charger specifications and the pricing through the network provider.
- The network provider transfers the payments made by the EV owner to the site host's account.

- DISCOM provides the requisite grid infrastructure for installation of the chargers.
- The tariffs charged to the site host are based on the ToD methodology and the chargers are separately metered.

- EV owner subscribes to a network provider and pays an annual/monthly subscription fees to access the network.
- The network provides real-time information on the nearest charger location, charger availability, pricing, other services available, etc. through a mobile application.
- The application allows the EV owner to book a charging session in advance at a charging station available in the selected time slot.
- Payments for the charging session are made over the network through credit card/e-wallet, etc.
- Payment for the charging session is made to the network provider.

- The charger installer, usually a partner with the network provider, installs the chargers at the premises of the site host.
- The installer charges the site host for the capital cost of the chargers, installation cost and the periodic maintenance cost.

Transfer of funds
Sale of product/service
Network ecosystem

Figure 2: EV charging ecosystem

Pricing: EV charging is identified as a separate consumer category while defining the applicable tariffs. Time-of-use tariffs apply for EV charging under the SCE distribution circle. The tariff has been defined under three different rate options:

1. **Rate plan 1** (EV load: 0 - 20 kW): TOU tariff design with two separate rate schedules:
    - Rate schedule 1: does not incorporate demand charges but has higher energy charges than rate schedule 2.
    - Rate schedule 2: incorporates demand charges and has lower energy charges than rate schedule 1.
2. **Rate plan 2** (EV load: 20 - 500 kW): TOU tariff design incorporating demand charges
3. **Rate plan 3** (EV load: exceeding 500 kW): TOU tariff design incorporating demand charges

Tariffs under each rate plan have been defined as per the following format:

Table 6: Rate plan structure for SCE Charge Ready[29]

Rate plans	Summer	Winter
On-peak rates (noon to 6 PM on weekdays except holidays) 22	-	-
Mid-peak (8 AM to noon and 6 PM to 11 PM on weekdays except holidays)	-	-
Off-peak (All other hours)	-	-
Customer charge	-	-
Facilities related demand charge	-	-

Business models

Under all the mentioned business models, the following stakeholders play the following roles:

- **Utility:** under the Charge Ready program, SCE deploys the requisite distribution infrastructure and the customer premises distribution infrastructure. Expenditure for installing the requisite infrastructure is recovered through the tariff (expenditure is accounted for in the tariff filings). SCE charges the metered consumer (SCE consumer) based on the TOU tariff charged per kWh.
- **Site host/participant/metered consumer:** under the Charge Ready program, the SCE consumers procure the EV chargers and are responsible for the procurement costs, operation costs and the maintenance costs of the charging infrastructure. The SCE consumers, with deployed charging infrastructure, receive a rebate ranging from 0% - 100% for the charging infrastructure procured.
- **Charging network provider:** the network provider is paid a subscription fee/usage fee by the SCE consumer (charging infrastructure owner) and the end consumer utilizing the installed charging infrastructure.

The business models (BM) are as follows:

- **BM 1 –** Site host provides free public charging: the host, a commercial entity, plans to benefit by retaining and attracting more customers at their business (café, restaurant, retail store, etc.) by offering free charging to the EV owner and thereby paying for the electricity consumed.
- **BM 2 –** Site host charging at the utility rates: the host plans to benefit by retaining and attracting more customers at their business (café, restaurant, retail store, etc.) by offering charging at the utility rates. The EV owner utilizing the installed charging infrastructure pays for the electricity consumed per kWh (at the utility rate) through the charging network provider.
- **BM 3 –** Site host provides free charging but charges for parking: the host plans to benefit by retaining and attracting more customers at their business (café, restaurant, retail store, etc.) by offering free charging. The EV owner is charged for parking the vehicle at the host's premises. The pricing for the parking is fixed by the host and is usually set as US$ per unit time. The payment for utilizing the charging station is made to the network provider which transfers the payment to the host. The cost for the electricity used is borne by the host.
- **BM 4 –** Existing SCE consumer provides charging at utility rates and also charges for parking: the consumer, a commercial entity, plans to benefit by retaining and attracting more customers at their business (café, restaurant, retail store, etc.) by offering charging at the utility rates in addition to parking charges. The pricing for the parking is fixed by the SCE consumer and is usually set as US$ per unit time. The payment for parking the vehicle and the electricity used is made to the network provider which transfers the payment to the SCE consumer.

Pacific Gas & Electric (PG&E) – EV Charge Network

In 2016, CPUC approved the three-year EV Charge Network program to install 7,500 electric vehicle chargers at multi-unit dwellings and workplaces lying within the PG&E service territory. Existing PG&E non-residential

[29]EY analysis

customers having more than 10 available parking spaces are eligible under the program. The program covers level 2 chargers only.

PG&E will be responsible for the payment, maintenance and coordination of the construction of the infrastructure from the transformer to the parking space which is estimated to be around 60% to 80% of the project cost.

The eligible customers under the program have two ownership options for the chargers:

- Customer-owned chargers: available to all program participants.
- PG&E-owned chargers: available to program participants residing in multi-unit dwellings and disadvantaged communities.

Table 7: Ownership models in PG&E[30]

Ownership models	Customer-owned chargers	PG&E-owned chargers
Eligibility	All program participants are eligible.	Multi-unit dwellings and workplaces in disadvantaged communities.
Costs	Complete installation costs of the chargers and all costs post installation are borne by the host. Host may be eligible for some rebate.	Participants pay a one-time participation fees.
Charger	A participant selects from a full list of approved vendors.	A participant selects from a limited list of approved vendors.

Table 8: Ownership models cost break-up in PG&E[31]

Ownership models cost break-up	Customer-owned chargers	PG&E-owned chargers
Infrastructure till the parking space (or grid infrastructure)	All program participants are eligible.	Multi-unit dwellings and workplaces in disadvantaged communities.
Charger installation	Responsibility of the participant.	No cost borne by the participant. Costs borne by PG&E.
Charger costs	Costs borne by the participant.	No cost borne by the participant. Participant to pay a one-time participation fees.
Ongoing costs	Costs borne by the participant.	No cost borne by the participant. Costs borne by PG&E.

The process for applying to the EV Charge Network program is as follows:

- Application: existing PG&E customers with greater than 10 available parking spaces and those who are willing to host chargers at their premises are required to submit an application at the PG&E website.
- Approval: PG&E conducts a site visit and determines the eligibility of the site for the program.
- Design and contracting: once approved, PG&E will create a preliminary site design/layout for installation and share it with applicant/site host. The applicant will select the ownership model for procurement and procures the requisite chargers and other equipment based on the shared design. The selection will be done from a list of PG&E-empaneled EV chargers and network providers. Post selection of the ownership model and the chargers, PG&E will provide the site host with an implementation schedule and plan.
- Final approval: once the site host approves the design, PG&E and the site host sign:
  - Contract for 10 years
  - An easement agreement to provide access to PG&E over the property of the host
  - Participation agreement

[30] EY analysis
[31] EY analysis

- Construction: PG&E manages the site construction with the host. PG&E and its contractors design and construct the EV service connection and EV supply infrastructure in compliance with the terms mentioned in the contract. The site host and its contractors install the EV charging infrastructure in compliance with the terms of the contract.
- Activation: once the construction is complete, the charging station receives electricity and PG&E conducts an inspection to assess if the installation complies with the quality and safety standards before confirming project completion and issuing any rebate, if applicable. Based on the ownership model selected by the host, PG&E issues rebates, if applicable, to the site host or collects the participation fees.

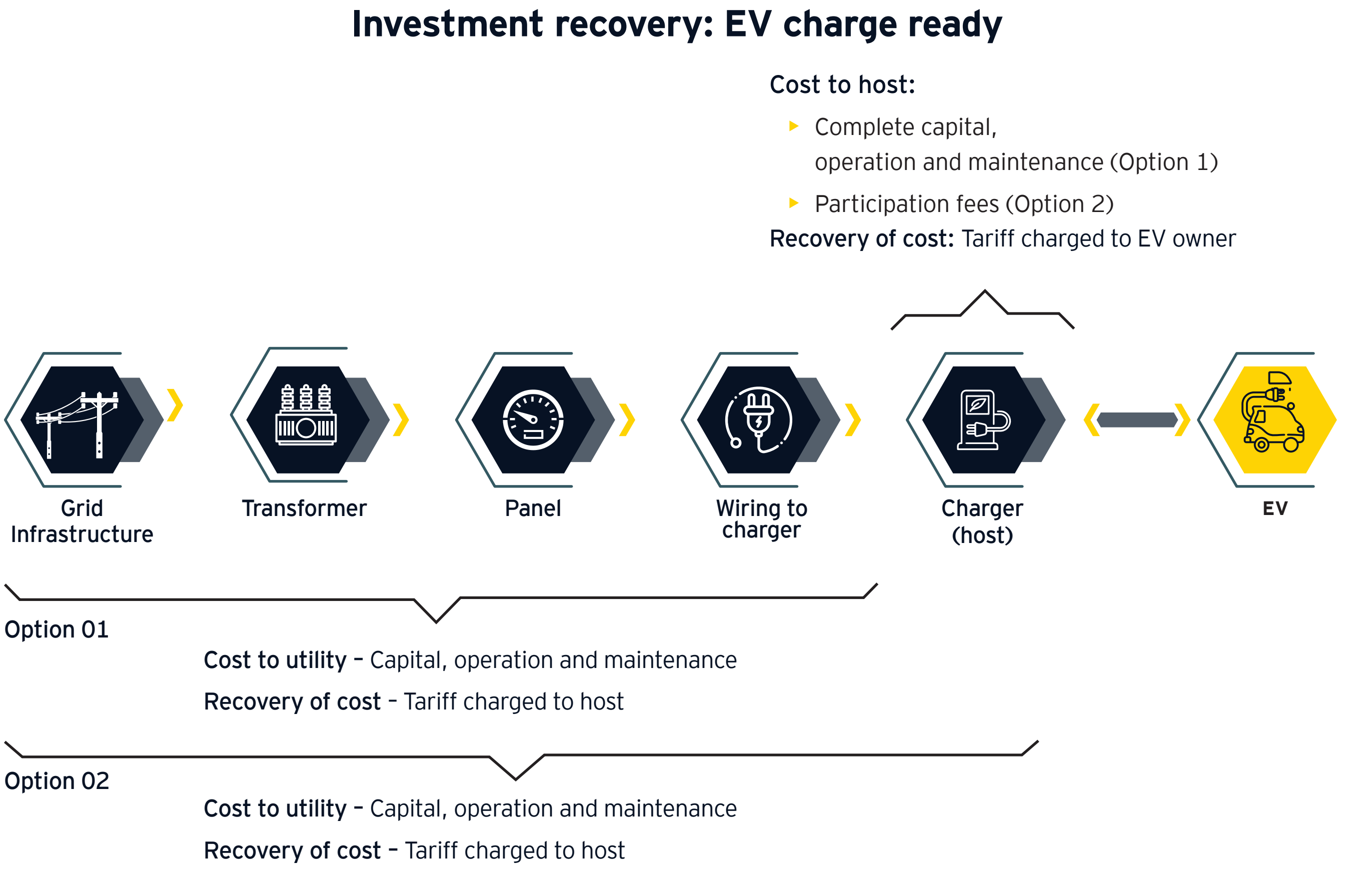


Figure3: Investment recovery mechanism for Charge Ready[32]

Pricing: the EV chargers deployed at the site are dedicatedly metered and are charged under a commercial rate plan for the EV chargers, irrespective of the rate plan of the site facility. Two rate plans are available for consumers within the PG&E distribution area:

Table 9: Rate plans in PG&E [33]

Rate plans	A6 (small general time-of-use service)	A10 (small general time-of-use service) (medium general demand-metered service)
Eligibility	The power consumption by the site host at any time might be less than 75 kW. Any host with the maximum demand greater than 75 kW for three consecutive months will be automatically shifted to the A10 rate plan	The power consumption by the site host at one time can be greater than 75 kW.
Energy rates	Higher energy rates (US$/kWh) compared to A10 and no demand chargers	Lower energy rates (US$/kWh) compared to A6 and demand chargers are applicable as well.
Demand charge	Not applicable	Applicable

[33]EY analysis

Two pricing options apply in the program:

- Pass-through pricing
- Custom pricing

Table 10: Pricing options in PG&E [34]

Pricing options	Pass-through pricing	Custom pricing
Pricing for host	Time-of-use (TOU) pricing structure, accounted through a dedicated meter. The power consumption by the site host at one time can be greater than 75 kW.	
Pricing for EV owner	The host passes on the TOU rate (US$/kWh) directly to the EV owner. The host has the option to include a rate added above the US$/kWh rate being charged. The rate adder should represent the non-energy additional charges such as demand charges, meter charges, etc. converted into US$/kWh. Site hosts are required to revise the rate adder based on the historic EV charger utilization to ensure that the site hosts are not overcharging the customers. The visibility provided by the network provider to the utility in terms of utilization of the chargers, prices charged to the EV owners, charging sessions booked in-advance, etc. will be very useful for the PG&E to check any inflation in rate adder by the host.	The host creates a customized pricing structure. For e.g. US$ per unit time rates, flat fees pricing, free charging, etc.
Pricing implementation	The host sets the pricing structure through the network provider.	The host sets the pricing structure through the network provider and submits a load management plan to PG&E.

Load management plan: it is mandatory to provide a load management plan to PG&E in case of selection of custom pricing model by the site host. PG&E will provide load management plan guidelines to the site hosts. All load management plans must be acceptable to PG&E. EVSE site used patterns will be monitored, and in addition, site host-determined prices or fees to use the EVSE will be tracked. This data will be used to inform CPUC policy.

Through the load management plan, site hosts will be required to shift the amount of EV charging from their sites on certain occasions called "events". This is done to support the grid. Site hosts may be asked to increase/decrease the EV charging at their sites during certain events such as during increased solar generation/increased demand from the grid respectively. The site hosts are notified in advance of the event.

The site hosts can deploy the following load management strategies:

- Communicating to employees or residents through an e-mail and texts to encourage them to partake in the event.
- Modifying the prices for charging.
- Requiring advance charging schedules on the event days

Business models

Unlike SCE's Charge Ready program which caters to Multi-Dwelling Units (MUD), workplace and public chargers, PG&E's EV Charge Network caters to just MUDs and workplaces. The business models in EV charge network will be similar as in case of Charge Ready.

San Diego Gas & Electric (SDG&E) – Power Your Drive

The Power Your Drive program is very similar to the EV charging programs run by SCE and PG&E. The program is targeting at installing 3,500 charging stations in the MUDs and office spaces across its service area. All the chargers deployed under the program are for private charging and public chargers are not covered under the program.

As opposed to the programs run by SCE and PG&E,

[34] EY analysis

SDG&E's Power Your Drive program is responsible for owning, operating and maintaining the installed chargers. The program is open to existing SDG&E consumers who have dedicated parking spaces (minimum five for MUDs and 10 for businesses). The eligible property owners have to apply to the program through the SDG&E website and complete a similar evaluation process as in the case of SCE and PG&E.

All costs are borne by the program in case the participant lies in a disadvantaged community, while for participants not belonging to disadvantaged communities, one-time participation fee is applicable.

All other costs including capital, installation, operation (excluding energy costs), maintenance, etc. are borne by SDG&E.

Only two pricing options are available under the program:

- Energy costs are borne by the EV user. The cost of charging is added onto the SDG&E electricity bill of the EV user.
- Energy costs are borne by the site host. The charging service is provided free of cost to the EV user.

All other characteristics of the program are similar to the SCE and PG&E's programs.

Investment recovery: Power Your Drive

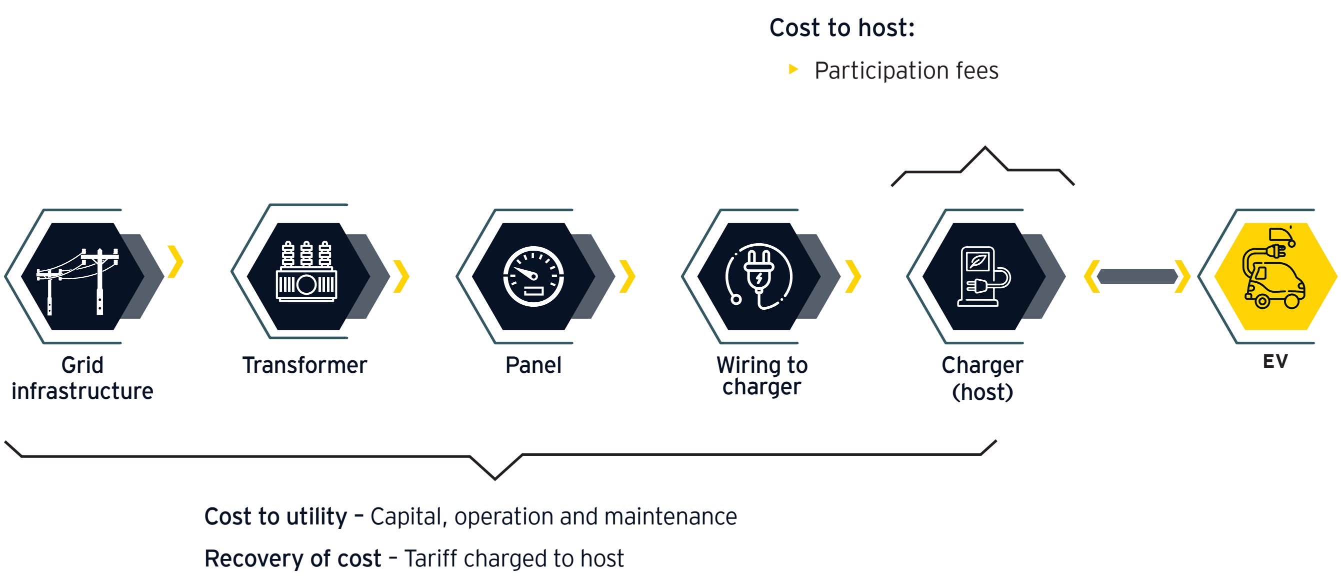


Figure 4: Investment recovery scheme for Power Your Drive[35]

Apart from the utility-driven pilot programs on electric vehicle charging infrastructure in California, the Clean Energy and Pollution Reduction Act was passed which sets the targets for California to undertake vehicular electrification activities.

1.1.5. Standards adopted in the US

Standards related to safety specifications, testing methods and communication interface can be referred from annexure Table 76: Standards adopted in USA[36]

1.1.6. Technological growth drivers

The Silicon Valley has been at the forefront of innovations. Startups like Tesla Motors have innovated and disrupted the sector with their cutting-edge automobile and energy solutions. Global organizations like GM, Ford and Renault too are following the lead and coming up their EV projects.

[35]EY analysis

Types of chargers

The chargers used for EV charging are broadly categorized by the level, current and power. A brief description of the power levels, type of connectors and the charging options is given in the table below[37] .

Table 11: Types of EV charging adopted in California [38]

	Conventional plugs	Slow chargers		Fast chargers		
Level	Level 1	Level 2		Level 3		
Current	AC	AC		AC, tri-phase	DC	
Power	<= 3.7 kW	> 3.7 kW and <= 22 kW	<= 22 kW	> 22 kW and <= 43.5 kW	Currently < 200 kW	
	Type B; SAE J1772 Type 1	SAE J1772 Type 1	Tesla	(Under development) SAE J3068	CCS Combo 1 (SAE J1772 and IEC 62196-3)	Tesla and CHAdeMO (IEC 62196-3 Type 4)

Batteries

With the uptake of EVs, Li-ion battery chemistry has emerged as the primary energy source. Newer chemistries like solid state and metal-air are also being explored by some EV manufacturers.

Panasonic, the battery manufacturing giant, has collaborated with Tesla motors to establish a Li-ion battery "Giga-Factory" with a planned annual battery production capacity of 35 gigawatt-hours (GWh).

Artificial Intelligence (AI)

The rise of EVs has sparked a series of developments in AI to realize a fully autonomous (Level 5) vehicle that will be able to drive itself and will no longer need a driver. There have been various examples where Tesla, which is partial autonomous, has avoided on-road accidents while driving, the car had already computed the possibilities of an accident by analyzing the driving patterns of the other vehicles on the road and avoided the accident. Companies like Tesla, Google, Apple, Microsoft and Uber are already extensively working on it and are now in the stage of achieving Level 4 autonomy (wherein, a driver is not needed to drive but the car is mostly confined to a specific geographical area).

1.1.7. Appendix: Senate Bill 350 (SB 350) - Clean Energy and Pollution Reduction Act

SB 350 came into power on 7 October 2015 and had set ambitious targets for California to achieve energy efficiency, renewable energy deployment and vehicular electrification. The bill mandates California to:

- Increase the renewable energy procurement goal from 33% in 2020 to 50% in 2030.
- Double the savings through energy efficiency measures in electricity and natural gas end uses.
- Transform California Independent System Operator (CAISO)
- Undertake vehicular electrification activities

To ensure that the goals are met, the publicly owned utilities (POUs) in California with an average load greater than 700 GWh (from 2013-2016) will be required to develop and submit Integrated Resource Plans (IRPs) by 1 January 2019. Based on the historic load data, 16 POUs are required to submit the IRPs. The IRPs will be electricity grid planning documents which will provide an insight into the proposed roadmap of the utility for achieving the goals mandated by SB 350. The POUs are mandated to mention the resource requirements, policy goals as well as physical and operational constraints during implementation.

The bill requires the POUs to consider transportation electrification in their IRP. Proceedings were held by the California Energy Commission and the POUs need to understand and explore the capabilities and the barriers faced by the POUs in terms of:

- Transportation electrification planning
- Funding charging infrastructure and the required utility system up gradation
- The impact of the EVs on grid operation, management, etc. [39]

[36] American National Standards Institute (ANSI) -https://www.ansi.org/standards_activities/standards_boards_panels/evsp/overview
[37] International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[38] International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

1.2

Germany

Germany has a prominent footprint in automobile developments and has been a hub of major research and developments in the sector. The German government's push towards the adoption of cleaner technologies has given a substantial push to the adoption of electric mobility in the country.

In order to tap in numerous benefits of EV market uptake, the Federal Ministry of Germany has been proactive in the policy and regulatory front. The EV sector presents opportunities for cross sector collaboration and requires a dedicated body for designing long-term strategy. The Federal Ministry of Economics and Technology (BMWi), in February 2010, set up a dedicated Electric Mobility coordination office with the Federal Ministry of Transport, Building and Urban Development (BMVBS) in the guise of the Joint Agency for Electric Mobility (GGEMO). The agency has been specially created to bundle and coordinate the Federal Government's electric mobility tasks.

Further, the National Electric Mobility Platform was created by the Federal Government which constituted of seven working groups of 20 members responsible for directing and shaping the roadmap for EV proliferation. GGEMO supports both the Federal Government and the National Electric Mobility Platform to implement and further develop the National Electric Mobility Development Plan.

1.2.1. Power market in Germany

The energy sector in Germany is governed by a number of acts and ordinances which are subject to constant modifications and amendments. The main legislation is the Energy Industry Act (Energiewirtschaftsgesetz (EnWG)). As per this legislation, electricity grid has to be operated through "unbundled" entities and grid operators cannot be involved in power production or retail activities as in a vertically integrated entity. Accordingly, the market consists of independent transmission system operators (TSOs), distribution system operators (DSOs) and retailers. TSOs are subject to either full ownership unbundling or must ensure that the grid operation is independent of both electricity production and supply.

Unbundled market has had both positive and negative implications for EVs' growth in Germany. Segregation of content and wire business has resulted in innovative business models for charging infrastructure. Further, competition in retail supply has been a key factor for determining market driven pricing structures which are acceptable to most of the EV owners. However, large number of markets players, including DSOs and retailers, have resulted in challenges in regulatory planning and designing large scale programs for EV proliferation.

Regulatory framework

The regulatory framework governing EV market in Germany comprises of the following ministries and agencies:

- Federal Ministry for Economic Affairs and Energy (BMWi)
- Federal Ministry for Education and Research (BMBF)
- Federal Ministry of Transport and Digital Infrastructure (BMVI)
- Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)
- Joint Agency for Electric Mobility (GGEMO)
- National Electric Mobility Platform

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1.2.2. Policy roadmap for electric-mobility in Germany

Germany has set the goal of becoming the leading market for electric mobility by 2020 as part of its long-term zero emission mobility vision. As per its National Electric Mobility Development Plan, Germany plans to have one million EVs on road by 2020. Other targets set by the federal government include:

- Target of achieving 40% reduction in CO2 emission levels, accounting to 34 million ton by 2020.
- Achieving battery density by volume level of 280 to 300 Wh/L by 2025 as part of technical development of third and fourth generation batteries.

Table 12: Policy roadmap [40]

S. No.	Policy/Initiative	Timeline	Description
1	Integrated Energy and Climate Programme (2007)	2007	In 2007, the German Federal Government declared the promotion of electric vehicles as a major building block in its Integrated Energy and Climate Programme to achieve climate protection goals.
2	Lithium-Ion Battery 2015 – BMBF Innovation Alliance (2007)	2007	A consortium of companies including BASF, BOSCH, EVONIK, LiTec and Volkswagen made a commitment to invest EUR360 million in lithium-ion battery research in the coming years, a figure which will be matched by EUR60 million BMBF funding. Battery research in Germany extends across the entire battery production value chain: starting at the identification of new materials to the development of individual components, and cell and battery production.
3	National Strategy Conference Electric	2007	This was followed by talks with the industry, research and policy stakeholders at the National Strategy Conference Electric Mobility in November 2008, which, in turn, paved the way forward for the creation of the National Electromobility Development Plan. The four government departments responsible at this time (Federal Ministry of Economics and Technology; Federal Ministry of Transport, Building and Urban Development; Federal Ministry of Education and Research; and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) gave their support to a comprehensive package of support measures.
4	Economic Stimulus Package Ii (2009)	2009	The Umweltprämie ("environmental premium" but more commonly known as the "scrapping bonus") was introduced in January 2009 to help promote demand for new vehicles as part of the Konjunkturpaket II ("Economic Stimulus Package II") to counter global recession.
5	National Electromobility Development Plan (2009)	2009	The Economic Stimulus Package II also sets out a number of progress milestones on the route to Germany establishing itself as the lead market for Electric Mobility. These activities will be further developed and implemented within the framework of the National Electric Mobility Development Plan. As well as this, existing government promotion instruments were adjusted to include Electric Mobility as part of their subsidy and support remit.

[40] EY analysis

S. No.	Policy/Initiative	Timeline	Description
6	Joint Agency for Electric Mobility – GGEMO (2010)	2010	The Joint Agency for Electric Mobility (GGEMO) was set up by the Federal Ministry of Economics and Technology (BMWi) in February 2010 to coordinate all Federal Government's Electric Mobility activities. The agency supports both the Federal Government and the National Electric Mobility Platform to implement and further develop the National Electromobility Development Plan.
7	National Electric Mobility Platform (2010)	2010	In May 2010, the German Federal Government constituted the National Electric Mobility Platform (NPE), consisting of representatives from politics, industry, science, local authorities and consumers. The platform's seven working groups direct and shape the roadmap for the realization of the objectives laid out in the National Electromobility Development Plan.
8	Government Program Electromobility (2011)		In May 2011, the Federal Ministry of Economics and Technology (BMWi) and the Federal Ministry of Transport, Building and Urban Development (BMVBS) adopted a far-reaching R&D support program in response to the findings of the second report of the National Platform for Electric Mobility. Ministry-supported R&D measures were flagged by regional showcase and technical flagship projects for the creation of increased synergies within the electric mobility sector.
9	Electric Mobility Act (2014)	2014	Formally approved by the Federal Cabinet in September 2014, the new act providing preferential treatment to electric vehicles became effective in 2015 for a period of 15 years (June 2030). According to the new law, vehicles approved in Germany will be identifiable by special number plates entitling them to preferential treatment.

Impact of Electric Mobility Act

EV market has shown a significant growth in Germany since 2011. By the end of 2017, the number of electric cars in Germany rose 29% to 77,153, up from just 4,000 in 2011. Further, Germany now has 7,407 charging points, which is 27 % higher than in 2016[41]. This growth has been primarily driven by policy level clarity and a favourable investment climate.

The Electric Mobility Law, passed in 2014, was quite significant as it provided further impetus to the country's electric mobility revolution. By putting the appropriate policy measures and R&D funding to implement the necessary changes in place, the German Federal Government has tried to ensure that Germany plays a decisive role in electric mobility.

[41]Cleantechnica - https://cleantechnica.com/2017/04/17/germany-increased-electric-car-charging-points-27-2016.

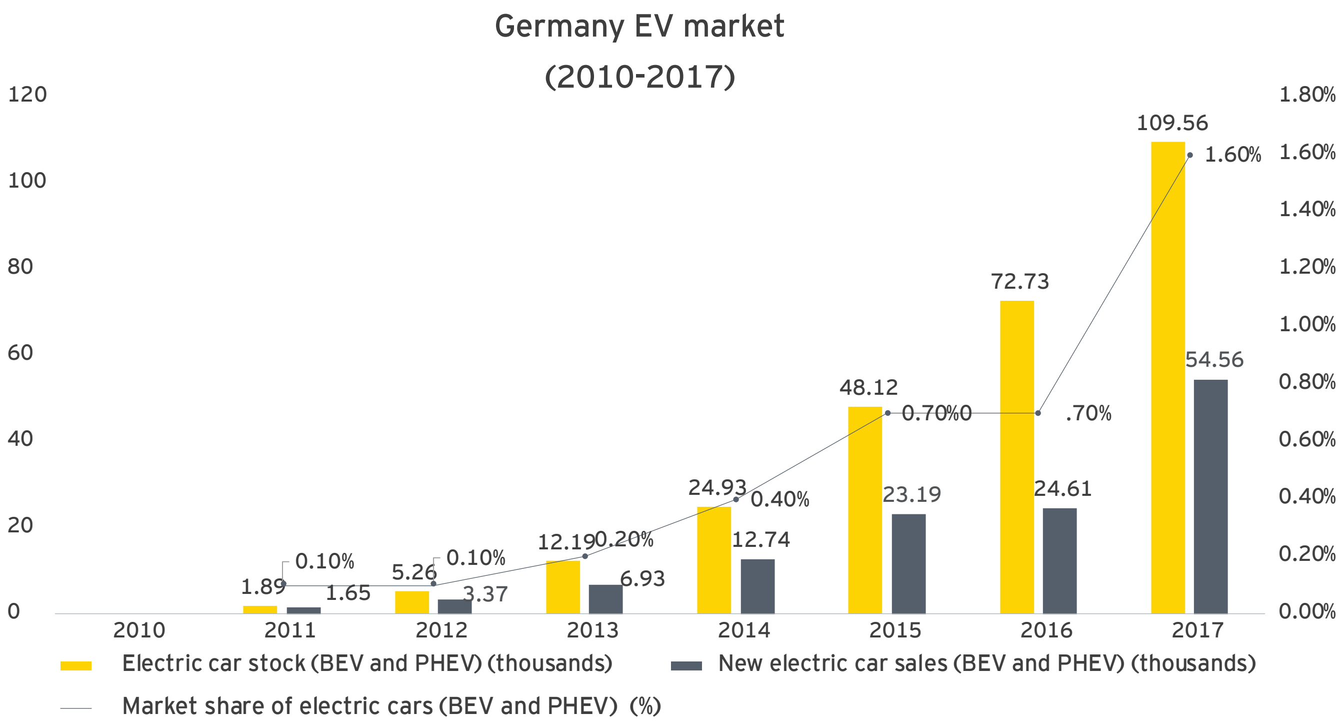


Figure 5: EV growth trajectory from 2010 to 2017 in Germany[42]

The above-mentioned graph[43] highlights the growth trajectory for different types of EVs. Accordingly, from 2013 to 2015, the market share and overall sales of EVs experienced a spike primarily attributed to the electric mobility act. In addition, a similar trend was observed for publicly accessible slow and fast chargers.

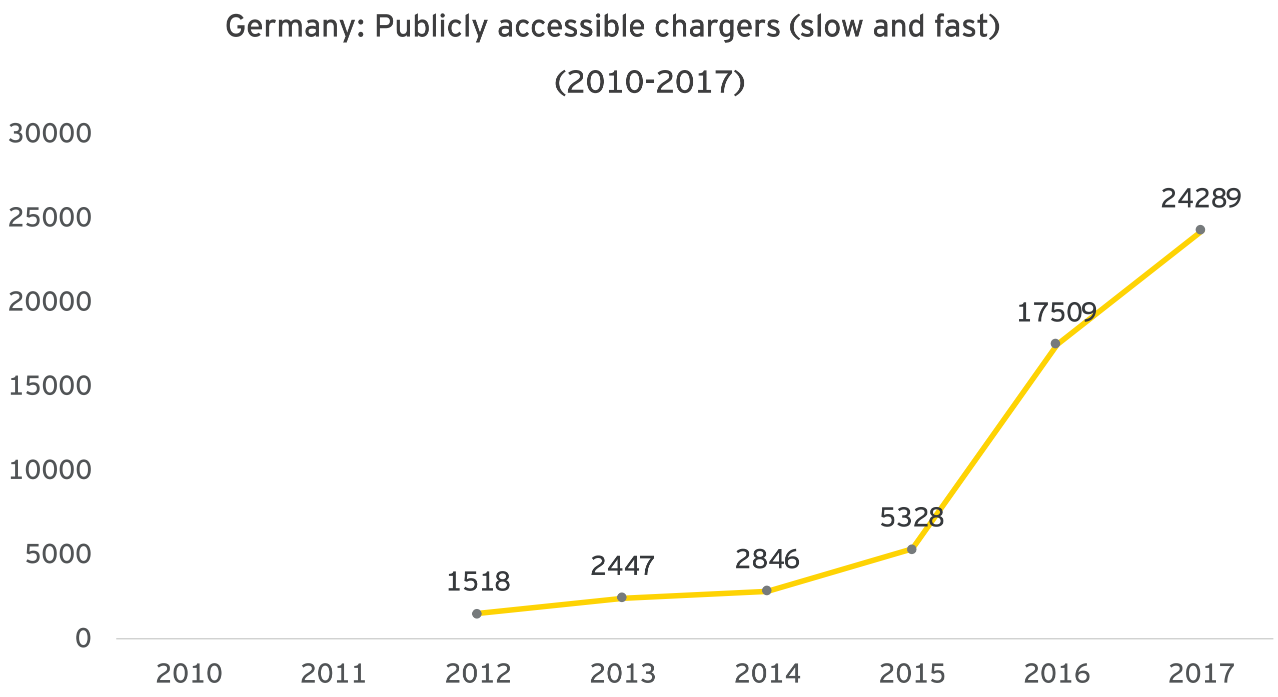


Figure 6: Rise in publicly accessible charger stock from 2010 to 2017 in Germany[44]

[42]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[43]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[44]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

1.2.3. Incentives for EVs' uptake in Germany

EV market growth in Germany has been further fueled by various fiscal and non-fiscal incentives. Key incentives are mentioned below:

- **Motor Vehicle Tax Exemption: EVs registered between 1 January 2016 and 31 December 2016 have been exempted from motor vehicle tax for five years.**
- **Company Car Taxation: Annual Tax Act was passed in 2013 regulating private use of commercial vehicles. This was done to ensure that electric and hybrid vehicle owners are not subjected to an income tax advantage and to make EVs more competitive.**
- **Road traffic measures such as:**
  - Special parking places for electric vehicles
  - Suspension of restricted entry access for electric vehicles
  - Authorized use of bus lanes for electric vehicles
  - Special traffic lanes for electric vehicles
- **Emissions and Environment Law Measures:** In accordance with the ordinances to Federal emissions control act, zero emission vehicles are issued blue stickers which get special privileges in traffic and public places.

Other measures such as low interest kFW bank credit, interchangeable vehicle license plates and public procurement plan.

1.2.4. Standards adopted in Germany

Structure of standardization landscape

Apart from the international bodies, such as ISO and IEC, European and national organizations have played a crucial role in setting up the standards related to safety, performance and testing methods. The figure below shows the relationship between the various standard setting organizations and their regulatory bodies.

Table 13: Standardization bodies[45]

	Standardization			
	General	Electro technology	Tele communications	Regulation
International standardization	ISO	IEC	ITU	UN
European standardization	CEN	CENELEC	ETSI	EU
National standardization (Germany)	DIN	DKE VDE DIN	DKE VDE DIN	National legislation

[45] EY analysis

Prevalent standards in German EV market[46]

Key standards prevalent in German electric mobility can be referred from Annexure Table 77: Standards adopted in Germany

1.2.5. Key technological enablers for EV proliferation

Types of chargers

Brief information about different type of chargers currently deployed in Germany is mentioned in the following table[47] .

Table 14: Types of EV charging standards adopted in Germany[48]

	Conventional plugs	Slow chargers		Fast chargers		
Level	Level 1	Level 2		Level 3		
Current	AC	AC		AC, tri-phase	DC	
Power	<= 3.7 kW	> 3.7 kW and <= 22 kW	<= 22 kW	> 22 kW and <= 43.5 kW	Currently < 200 kW	
Germany	Type C/F/G	IEC 62196-2 Type 2 Tesla	IEC 62196-2 Type 2	CCS Combo 2 (IEC 62196-3) 62196-3)	CCS Combo 2 (IEC 62196-3) 62196-3)	Tesla and CHAdeMO (IEC 62196-3 Type 4)

Apart from the standard developed by IEC, several mass-produced vehicles are equipped with connecting devices enabling the use of CHAdeMO chargers. In addition, Tesla has been using its own standard to support all levels and modes of charging through the same connector type.

Communication

The currently preferred solution for the physical layer for a communication interface between the charging station and the vehicle is the home plug greenphy which is a power line communication system. This is a downwardly compatible communication system and can be used with standardized plugs and sockets. Furthermore, IP and XML based technologies, in particular, are being used for the higher layers and it is widely assumed that the charging infrastructure will act as a gateway.

In terms of energy management, integration of private charging stations into automation systems of building is being considered. ISO/ IEC 14534 -3 "Information Technology – Home Electric Systems (HES)" is a current standard that provides guidelines for application in both residential and non-residential buildings. In addition, IEC 618450 -420, "Communication Networks and Systems for Power Utility Automation - Basic Communication Structure for Distributed Energy Resources Logical Nodes", is considered.

[46]German Institute for standardization (DIN) - https://www.din.de/blob/235254/a0d14b63b9685859b1c0c297827e50f8/roadmap-en-2020-data.pdf.
[47]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[48]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

Payment options

- **Scenario A:** it is now possible to charge cars at public charging stations without entering into a contract with a supplier. Charging is authorized via smartphone app. Alternatively, this also works using a smart charging lead or via "Smart Charging" (ISO 15118). With smart charging, the charging station communicates with the charging control device of the electric vehicle. The drivers locate the charging point in the app and start the process by tapping "Charge vehicle". To pay, they select PayPal or credit card and then enter the desired charging time in minutes. The app displays the total price for the charging process. Charging commences after tapping "Pay and start charging".
- **Scenario B:** the customers enter into a contract with a supplier of electricity for electric vehicles, for e.g., with the local municipal utility. These are usually the members of a payment system network such as "Inter-charge". In this way, drivers can charge their cars at all charging stations that are also a part of the network. The drivers are identified via their access cards or smartphone app at the station and start the charging process. Alternatively, they can be identified through Smart Charging (ISO 15118) which governs the automated, secure exchange of information between the vehicle and the charging infrastructure based on digital certificates. The customers are billed by their electricity supplier.

Battery

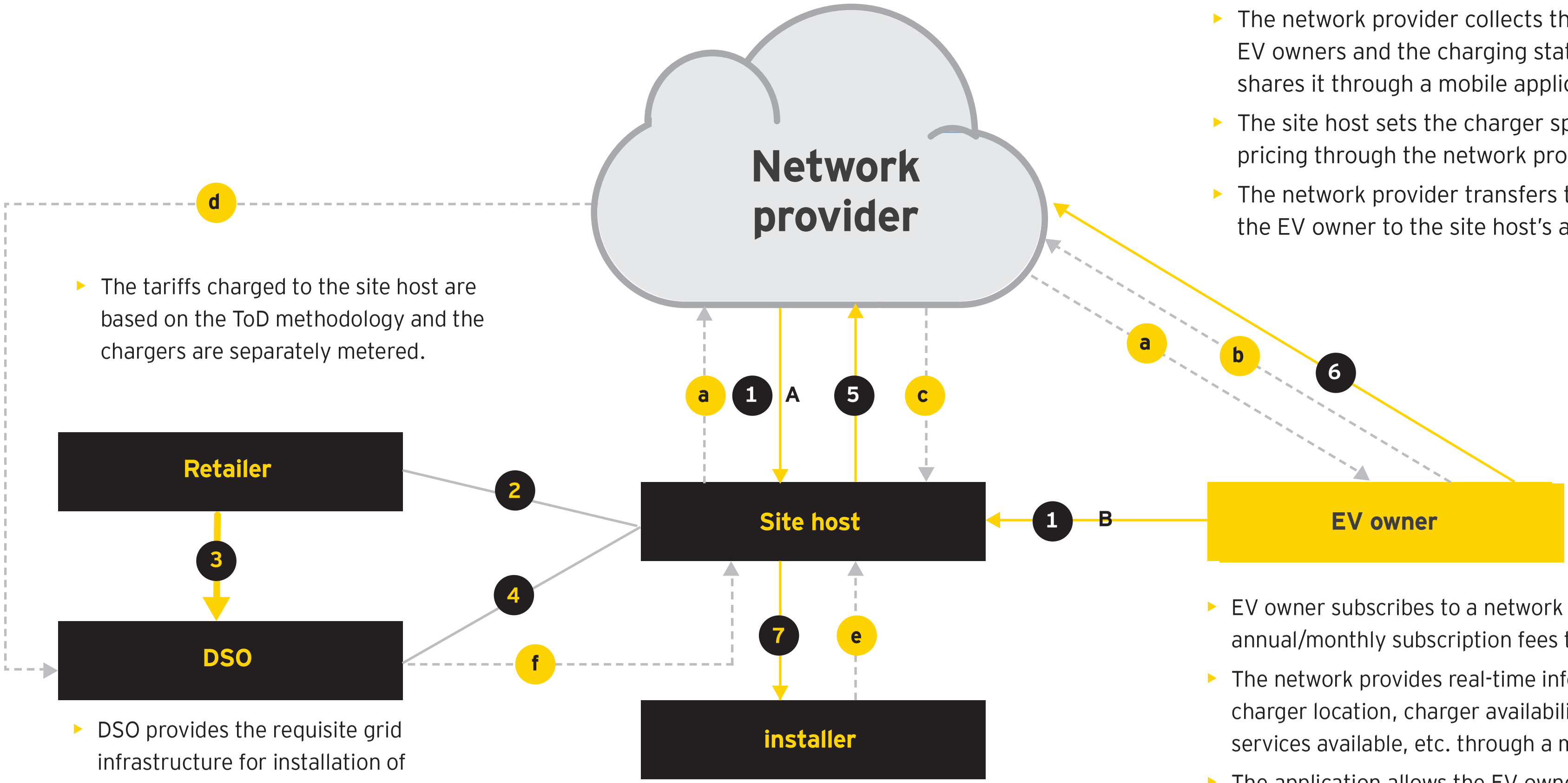
At present, the automotive industry almost exclusively uses nickel-metal hydride (NiMH) batteries for high performance applications (hybrid). Lithium-ion batteries, however, have an energy density several times higher than NiMH batteries at the system level. As such, lithium-ion battery technology is widely recognized as being the battery technology with the best long-term prospects thanks to its low weight, high-energy density and long durability. For that reason, the industry is committed to evolving lithium-ion technology in order to create a number of electric vehicle mobility strategies (e.g., BEV, REEV) to increase the driving distance in all the electric modes.

The amount of energy stored requires that electric vehicle cells and batteries satisfy strict safety requirements. There are already a number of cells, batteries and vehicles in the market which use lithium-ion technology for hybrid applications.

Tremendous growth prospects exist in the lithium-ion market as battery manufacturers and suppliers strive to provide cheap, reliable and safe battery solutions with increased energy density which make hybrid and electric vehicles a genuinely feasible consumer option. Germany has intensive R&D focus to evolve lithium-ion technology and develop post-lithium-ion technologies. Accordingly, R&D funding of around EUR500 million has been made avail¬able for batteries, whole system energy management, training and further educational activities. Battery research in Germany extends across the entire battery production value chain: starting at the identification of new materials to the development of individual components as well as cell and battery production.

1.2.6. EV charging ecosystem in Germany

Utilities have been at the forefront of evolution of electric mobility ecosystem in Germany. Based on the business models, utilities play diverse roles which include acting as system operators, providing installation and maintenance services to the host as well as acting as network service providers. Various business models, currently deployed in Germany, are detailed out in the section below.



- The network provider collects the information from the EV owners and the charging stations in real-time and shares it through a mobile application.
- The site host sets the charger specifications and the pricing through the network provider.
- The network provider transfers the payments made by the EV owner to the site host's account.

- The tariffs charged to the site host are based on the ToD methodology and the chargers are separately metered.

- DSO provides the requisite grid infrastructure for installation of the chargers.

- The charger installer, usually a partner with the network provider, installs the chargers at the premises of the site host.
- The installer charges the site host for the capital cost of the chargers, installation cost and the periodic maintenance cost.
- The installation and maintenance activities can be also provide by subsidiaries of DSOs.

- EV owner subscribes to a network provider and pays an annual/monthly subscription fees to access the network.
- The network provides real-time information on the nearest charger location, charger availability, pricing, other services available, etc. through a mobile application.
- The application allows the EV owner to book a charging session in advance at a charging station available in the selected time slot.
- Payments for the charging session are made over the network through credit card/e-wallet, etc.
- Payment for the charging session is made to the network provider.
- Payment can also be made directly to the host based on the contractual arrangement.

Legend	
Cash Flow	Service
1. **a. Fees charged by the host for the charging session.** **b. Fees directly charged by site host from EV owner**	a. Transmission of data on nearby charger availability, charger types, pricing, available time slots for booking charging sessions, available payment option, other services available at the station etc.
2. Electricity supply contract with retailer of choice/ Tariff payment for energy consumed	b. Transmission of real-time location, vehicle type, battery capacity, charging preference, time slot for charging session and payment information
3. Retailer signs an electricity transport contract with the DSO.	c. Visibility to the network-subscribed EV owners of the charging station
4. The direct relation between DSO and charging point operator is only for connection.	d. Real-time , expected loads information to the DISCOM on charging session durations., current loads on based bookings, rates charged to the EV owners, charger utilization etc.
5. Subscription fee for utilising the network	e. Installation and maintenance of chargers,
6. Subscription fee for utilising the network + fees charged by the host for the charging session.	f. Responsible for providing requisite grid infrastructure.
7. Capital cost for charger + One-time installation cost + periodic maintenance cost	

Figure 7: EV charging ecosystem in Germany

Cash flow   Services

Business models

In accordance with the ecosystem mentioned above, roles played by the key stakeholders are mentioned below:

- **Utilities:** utilities play varied roles as per the business models. Acting as DSOs, utilities are mainly responsible for setting up requisite grid infrastructure. However, DSOs, through their subsidiaries, also act as independent network service providers. In addition, these subsidiaries also provide installation and maintenance services. Accordingly, charging point operators are charged on an yearly/monthly subscription basis.
- **Power retailer:** as per the market structure of Germany, power retailer has to charge the charging point operators (CPOs) for supplying electricity. However, CPOs are free to choose the retailer for procuring power. For billing CPOs, a smart meter is installed at the point of connection of each charging station.
- **Charging point operator:** charging point operator is responsible for procuring requisite equipment. In most of the cases, maintenance services are outsourced to a third-party. As the market is unregulated, the output tariff (tariff charged to EV owners) is market driven. EV owners are charged as "pay per kWh" in accordance with TOU tariff design.
- **Charging network provider:** the network provider is paid a subscription fee/usage fee by the charging point operator and the end consumer utilizing the installed charging infrastructure.

The business models (BMs) are as follows:

- **BM1:** Charging point operator provides free public charging: in this case, CPO is a commercial entity (restaurant/retail store owner). The EV owners are offered free charging at their premises. Accordingly, the CPO derives benefits through increased customer attraction at the site.
- **BM2:** CPO charges EV owners at market driven tariff: EV owners are charged as per their usage (per kWh) in accordance with the TOU regime. Payments are done either through a direct transaction between EV owners and CPO or through the network service providers.


1.3

Finland

1.3.1. Power market in Finland

Similar to Germany, the power market in Finland is also liberalized and is dominated by TSO and DSOs. Finnish electricity wholesale market is part of North European electricity market. Finland, Denmark, Sweden, Estonia, Norway, Lithuania and Latvia have integrated their wholesale electricity markets. Additionally, the Finnish market has been gradually liberalized and opened for competition. Accordingly, consumers have been able to choose their preferred electricity supplier since 1998.

Regulatory framework

The regulatory framework governing EV market in Finland comprises of following ministries and agencies:

- Finnish Energy Authority which is the main authority regulating the Finnish electricity sector.
- Ministry of Employment and Economy which is responsible for preparing legislations affecting the electricity sector.
- Centre for Economic Development, Transport and Environment which supervises the relevant environment permits and designs electric mobility legislations for Finland.
- Finnish Competition and Consumer Authority which supervises competition law issues arising in the electricity sector.

1.3.2. Policy roadmap for Electric Mobility in Finland

Finland, being a prominent member of the EU, is committed to the EU's environment targets and Kyoto Protocol. As per the directives, GHG emission should be reduced to the level of 1990 and renewable energy mix should increase to 38% by 2020. As transport causes 20% of Finland's GHG emissions, government has set dual goals of reducing GHG emissions from traffic and transport by 15% and to increase the energy efficiency of the transport sector by 9% from 2005 to 2020. The government has also developed a vision for 2050 in which the direct specific emission of cars are supposed to reach 80g-90g CO2 per km by 2030, 50-60g CO2 per km by 2040 and 20-30g CO2 per km by 2050[49] .

Finland has aimed to achieve these targets through technological innovations in vehicles and increasing the use of biofuels. Although the initial focus was majorly on biofuels for meeting the emission reduction targets, Finland has started to explore the opportunities for EV adoption in the last couple of years. The government has set an EV deployment target of **2,50,000 by 2030[50].** Furthermore, Finland government has supported EVI's "EV30@30" campaign which sets a collective aspirational goal to reach 30% market share for EV by 2030. For facilitating increased usage of EVs, Finnish government has further set a target of 25,000 charging points by 2030[51].

Although the growth was slow in the initial phase, EV market has picked up since 2015. The number of EVs grew by a CAGR of 99.87%[52] from 2015 to 2017.

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[48]Nordic Energy Research; KTH Royal Institute of Technology https://www.sintef.no/globalassets/project/norstrat/d4.2---policy-and-institutional-review-electric-vehicles.pdf.
[49]International Energy Agency (IEA) - IEA NordicEVoutlook 2018.
[50,7, 8] International Energy Agency (IEA) - IEA NordicEVoutlook 2018.

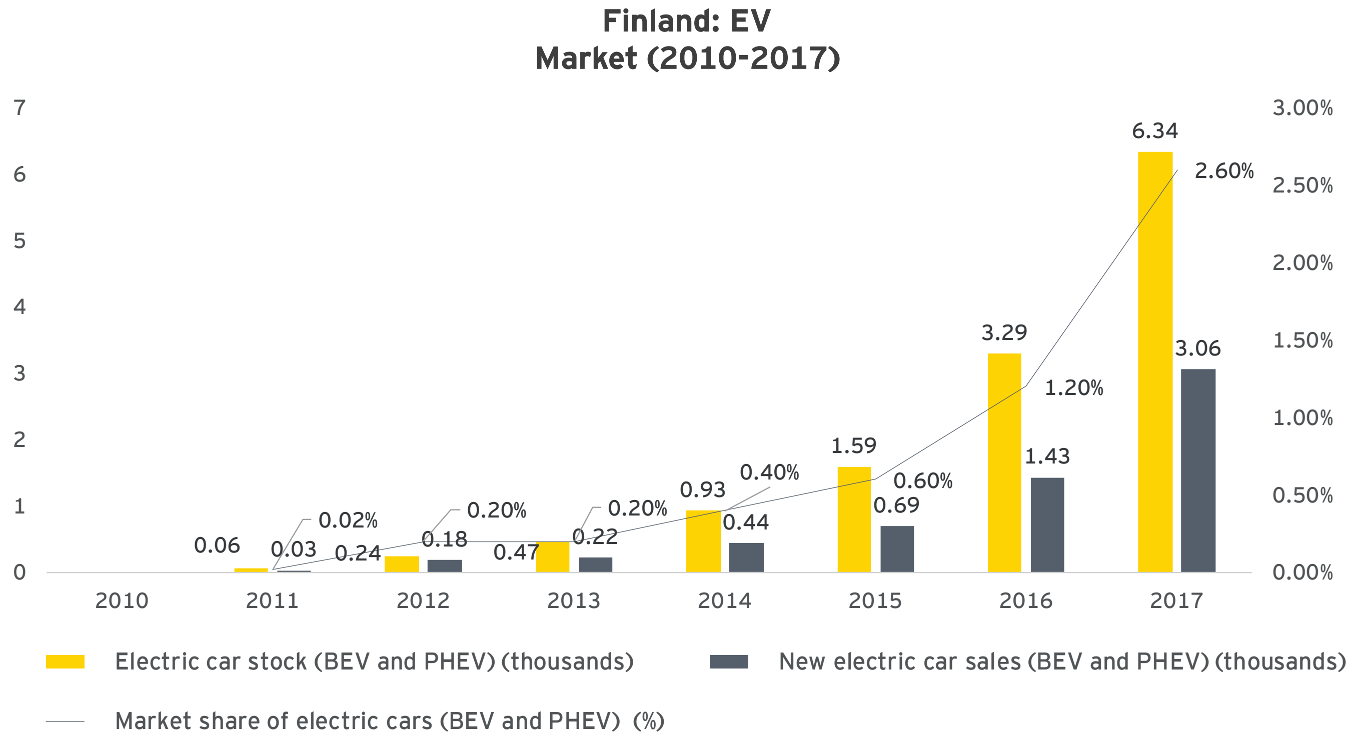


Figure 8: Growth trend of EVs in Finland from 2010 to 2017[53]

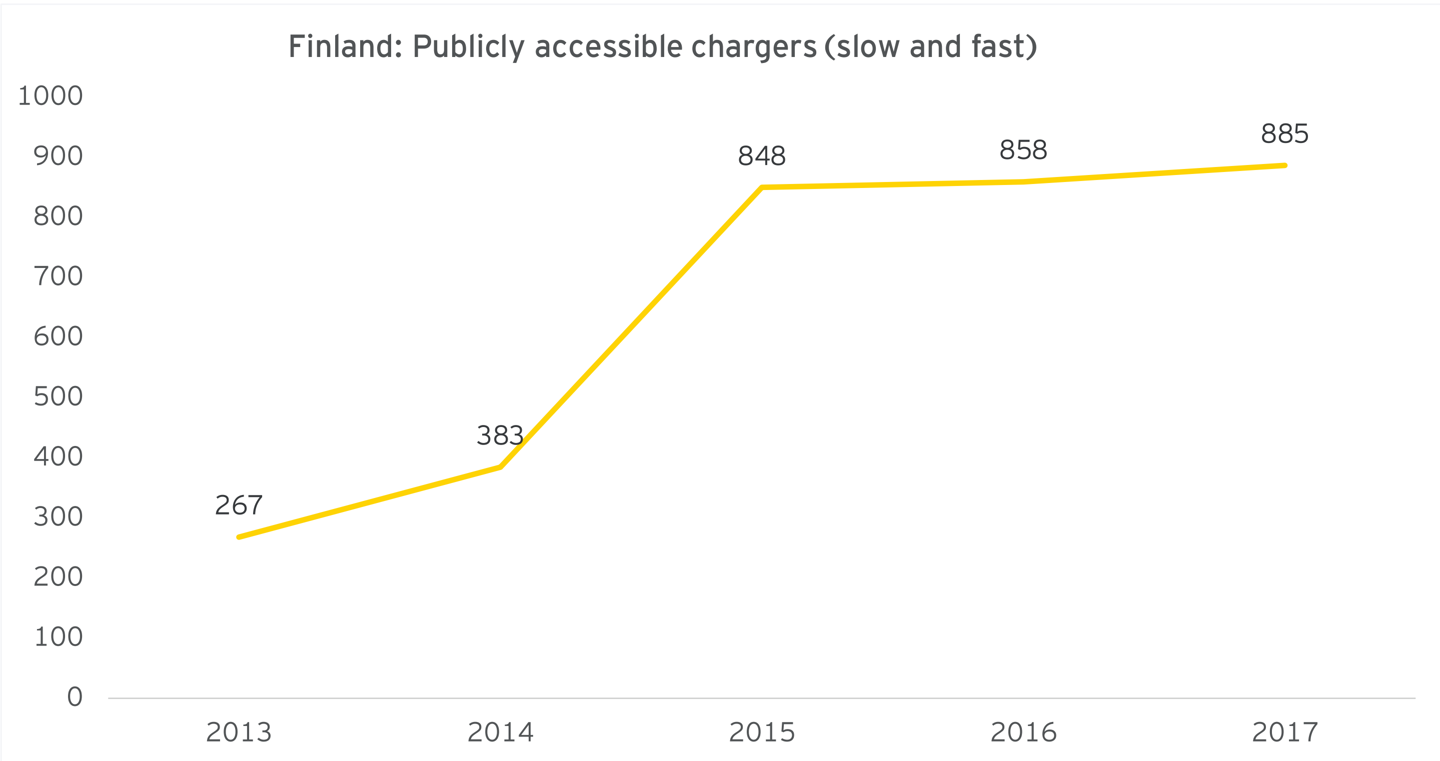


Figure 9: Finland publicly accessible chargers (slow and fast) 2013-2017[54]

[53]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[54]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

The steep rise in the number of EVs can be attributed to following policy level initiatives:

- Finland government has provided direct financial support for EVSE deployment. The electric vehicle systems programme (2011- 2015), set up by the Ministry of Employment and Economy, allocated Euro10 million in 2012 to support EV procurement and to give a necessary push to investments in charging infrastructure.
- The government had also launched a subsidy scheme of Euro4.8 million in 2017 for public charging stations. As per the scheme, subsidy will be provided to public smart charging stations in order to boost the implementation of fast chargers. The subsidy rate is 30% for normal chargers and 35% for fast chargers and the budget is equally split between the two. Further, only the installations with open payment system will be eligible for funding[55] .
- The Finland government launched "The Finnish Transport Services Act" act in 2017. It establishes common rules for all mobility service providers. As per the act, all public and private transport service providers will be required to give unbiased access to essential data such as routes, time tables, prices and other related information. This shall result in a proficient data driven approach for setting up charging stations factoring in key parameters such as strategic location and type of charger.

Other incentives for EV adoption in Finland

Other incentives for EV market proliferation include[56] :

- From 2018, an acquisition discount of EUR2,000 will be given for cars priced below EUR50,000 at the time of leasing or sale.
- Registration tax rate for zero emission vehicles will decline from 4.4% in 2016 to 2.7% in 2019.

Overview of the policy level incentives in Finland as compared to those in other Nordic countries is mentioned below:

Table 15: Comparative analysis of EV policy schemes in Nordic countries[57]

Country	EV purchase incentives				EV use and circulation incentives		Waivers on access restrictions			
	Registration tax/sale rebates	Registration tax (excl. VAT) exemption	VAT exemption	TAX credits	Circulation tax rebates	Circulation tax exemption	Waivers on fees (e.g. tolls, parking, ferries)	Tax credits (company cars)	Access to bus lanes	Free/dedicated parking
Denmark	National policy				National policy		Local policy			
Finland	National policy				National policy					
Iceland		National policy	National policy			National policy				
Norway	National policy	National policy	National policy		National policy		National policy		Local policy	Local policy
Sweden	National policy			National policy	National policy		Local policy	National policy		

Legend: National policy | Local policy | No policy

[55]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[56]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[57]EY analysis

As evident from the table, major incentives have been around rebates in registration taxes. Other popular measures such as access to bus lanes, dedicated parking and modification of building codes have not been adopted in Finland till now.

1.3.3. Standards adopted in Finland

The standards adopted in Finland, along those countries of Nordic region, are in line with European standards. Also, international IEC standards are also applicable for Finland. A brief overview of standards applicable in Finland are mentioned below:

- **IEC 62196-1 (general requirements), IEC 62196-2 (AC charging, level 2) and IEC 62196-3 (AC and DC charging, level 3):** standards regarding plugs, sockets/outlets, vehicle connectors and vehicle inlets for the conductive charging of electric vehicles (level 2 and level 3 chargers).
- **Combined charging system for connectors:** for AC charging, IEC 61851-1 and 61851-22 standards are applicable. In addition, IEC 61851-1 and 61851-23 are applicable for DC charging.
- Tesla connector and CHAdeMO standards are also followed.
- The communication interface between the electric vehicle and the charging point is based on the international standard ISO/IEC 15118.

All the IEC and ISO standards followed in Germany are applicable for Finland as well. For details refer, Table 77: Standards adopted in Germany

1.3.4. Key technological enablers for EV proliferation in Finland:

Chargers

Different types of chargers are classified as per the power levels into level 1, level 2 and level 3 chargers. A brief description of the power levels, type of connectors and the charging options is given in the table below[58]

Table 16: Types of EV charging adopted in Finland[59]

	Current	Level	Power	mode	Connector type
Devices installed in households, the primary purpose of which is not to recharge electric vehicles	AC	Level -1	≤ 3.7 KW	Mode1-2	Type C
Slow EV chargers (private or public)	AC	Level -2	≥ 3.7 KW and ≤ 22 KW	Mode2-3	IEC 62196 type 2 (7-22 KW); Commando (7-22KW)
Fast EV chargers (publicly available)	Ac tri-phased	Level -2	>22KW and ≤ 43.5KW	Mode-3	IEC 62196-2 type 2
	DC	Level -3	>22KW and ≤ 150KW	Mode-4	CCS combo 2 connector (IEC 62196-3 type 2) 50kW CHAdeMO (IEC 62196-3 type 4)(50KW) Tesla (120KW)
Ultra-fast/high power EV chargers (intended for public use but not yet deployed)	DC	Level -3	>150KW and ≤ 350KW	Mode-4	CCS Combo 2 (IEC 62196-3) (150-350KW) and CHAdeMO(150-350KW)
Note: KW= Kilowatt; AC=Alternate Current; DC=Direct Current; CCS=Combined charging system; CHAdeMO=Charge de Move; IEC 62196-2 type 2 and 62196-3(CCS Combo 2) connectors are mandated by the EU 2014/94 directive [60].					

[58]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[59]EY analysis

Communication and payment options

Various standards for EV to EVSE and EVSE to grid level communication along with the payment options are similar to those adopted in Germany. For further details, refer Table 77: Standards adopted in Germany.

Batteries

Batteries are primarily based on Lithium-Ion technology. Almost all electric vehicle manufacturers have partnerships with battery suppliers and are looking to promote the development of battery pack technology.

1.3.5. EV ecosystem in Finland

The EV ecosystem for Finland is similar to that of Germany primarily due to similar market structure. The major operators in the field of EV charging stations are Fortum charge and drive, and the network of charging locations developed and managed by Virtapiste, also known as Liikennevirta Oy. Virtapiste operates in Finland as both an infrastructure developer and network manager for companies like Helen. Additionally, it handles payment systems for electric vehicle charging and provides an application interface to facilitate payments and customer services.

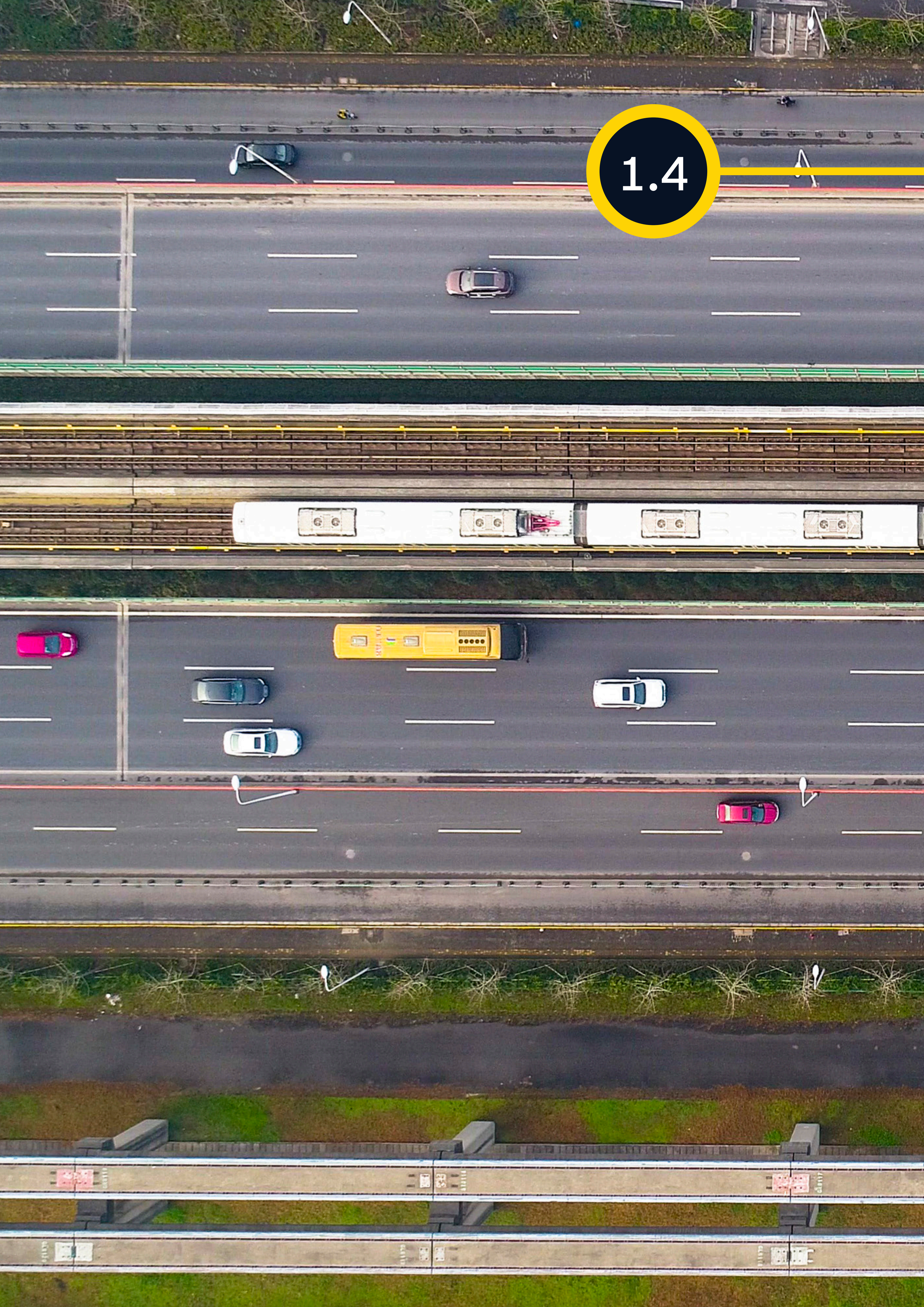
Business models

In accordance with the ecosystem mentioned above, roles played by the key stakeholders are mentioned below:

- **Utilities:** utilities play varied roles as per the business models. Acting as DSOs, utilities are mainly responsible for setting up requisite grid infrastructure. However, DSOs, through their subsidiaries, also act as independent network service providers. In addition, these subsidiaries also provide installation and maintenance services. Accordingly, charging point operators are charged on a yearly/monthly subscription basis.
- **Power retailer:** as per the market structure of Finland, power retailer has to charge the charging point operators (CPOs) for supplying electricity. However, CPOs are free to choose the retailer for procuring power. For billing CPOs, a smart meter is installed at point of connection of each charging station.
- **Charging point operator:** charging point operator is responsible for procuring requisite equipment. In most of the cases, maintenance services are outsourced to a third-party. As the market is unregulated, the output tariff (tariff charged to EV owners) is market driven. However, in this case, CPOs charge EV owners as per different pricing methods such as pay per kWh and pay per hour.
- **Charging network provider:** the network provider is paid a subscription fee/usage fee by the charging point operator and the end consumer utilizing the installed charging infrastructure.

Various business models adopted in Finland are mentioned below:

- **BM1:** Charging point operator provides free public charging: In this case, CPO is a commercial entity (restaurant/retail store owner). The EV owners are offered free charging at their premises. Accordingly, the CPO benefits through increased customer attraction at the site.
- **BM2:** CPO charges EV owners at market driven tariff: EV owners are charged as per their usage (per kWh) in accordance with the time-of-use regime. Payment is done either through a direct transaction between EV owner and CPO or through the network service providers.
- **BM3:** CPO charges EV owners for parking: EV owners are charged on pay per hour basis for parking.


1.4

Japan

1.4.1. Power market in Japan

The electricity sector in Japan was gradually fully liberalized following the 2011 occurred, Great East Japan Earthquake and the accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Plants.

Japan, before the Fukushima meltdown, relied on nuclear power for 25% of its electricity generation. However, the country's entire nuclear power capacity (42GW in total), was gradually shut down in the aftermath of the Fukushima Daiichi nuclear accident and came to a complete halt in 2013 , .

Since the Fukushima accident, Japan's energy security remains at a risk. Japan's dominant reliance on fossil fuel imports (coal, gas and oil) for 82% of its electricity generation has contributed to a reversal in its trade balance from the 30 years of trade surplus to a deficit that reached US$116 billion in 2014. Seven years after the incident, its challenges are delineated by sluggish economic growth, a shrinking population and declining electricity demand, down 11.5% from its 2010 peak[61] [62]

Regulatory framework

The regulatory framework governing EV market in Japan comprises of following ministries and agencies:

- METI - The Ministry of Economy, Trade and Industry
- MLIT - The Ministry of Land, Infrastructure, Transport and Tourism
- NEDO - New Energy and Industrial Technology Development Organization
- MEXT - Ministry of Education, Culture, Sports, Science and Technology
- JARI – Japan Automotive Research Institute
- JEWA – Japan Electric Wiring Devices and Equipment Industries Association
- JSAE – Society of Automotive Engineers of Japan
- JAMA – Japan Automotive Manufacturers Association
- Next Generation Vehicle Promotion Center

[61] IEA - https://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesJapan2016.pdf
[62] Institute for Energy Economics and Financial Analysis - http://ieefa.org/wp-content/uploads/2017/03/Japan_-Greater-Energy-Security-Through-Renewables-_March-2017.pdf

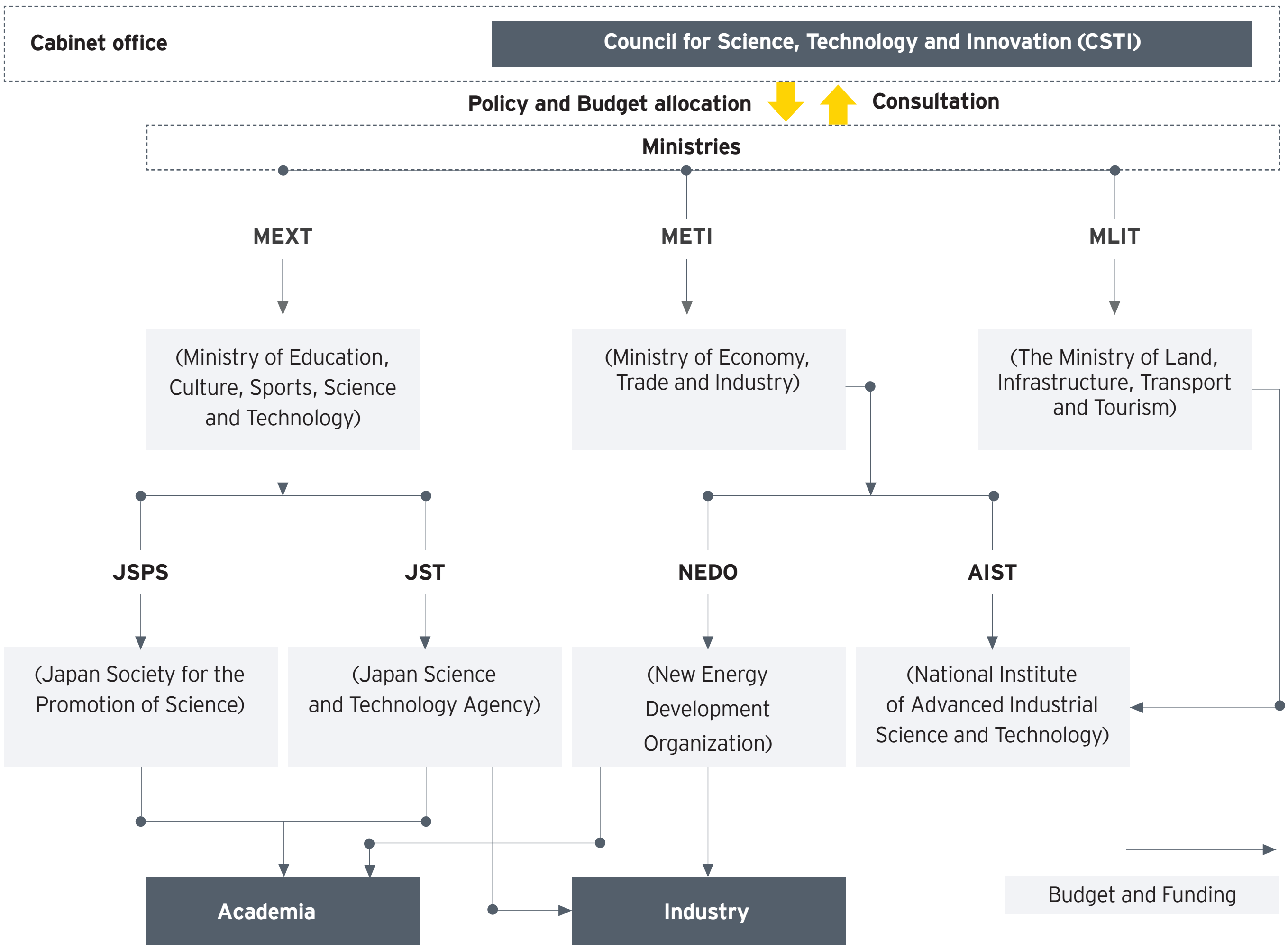


Figure 10: Regulatory framework in Japan[63]

1.4.2. Electric mobility growth trends

In 2017, Japan boosts an EVSE (quick charging points) to EV (electric vehicles) ratio of 0.039. The country's quick charging points have already crossed the 5,000 mark and are at 5,990 public quick-charge stations. Non-residential slow charger points are at 17,260 which is just 1% of Japan's two million slow charger target. In 2016, Japan's electric car charging points crossed the number of petrol stations in the country. Japanese car manufacturer, Nissan, reported that the number of charging points including domestic chargers surged past 40,000 compared to 35,000 petrol stations[64].

63The Ministry of Economy, Trade and Industry (METI)
64World Economic Forum (WEF) - https://www.weforum.org/agenda/2016/05/japan-now-has-more-electric-charging-points-than-petrol-stations/

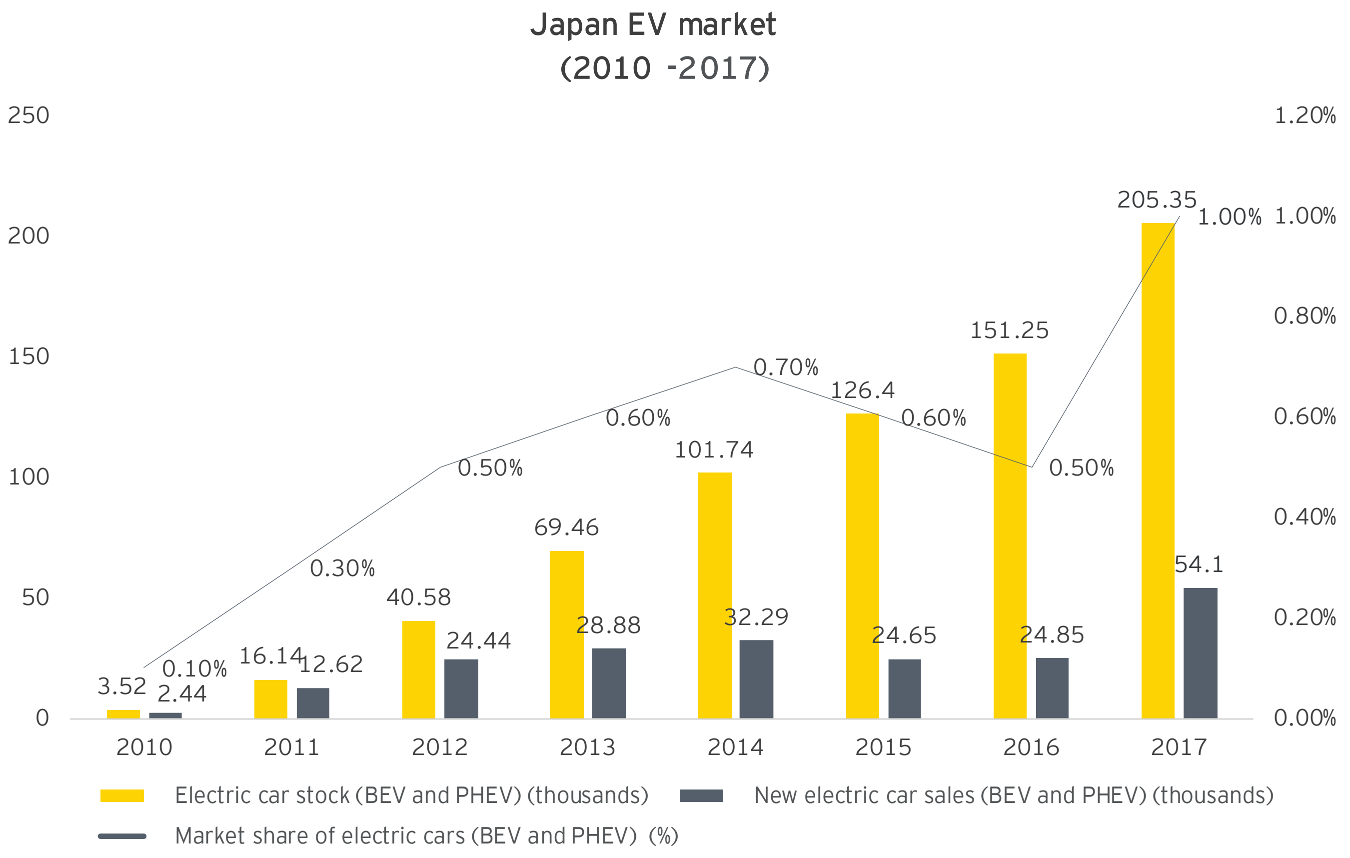


Figure 11: Japan EV market (2010-2017)[65]

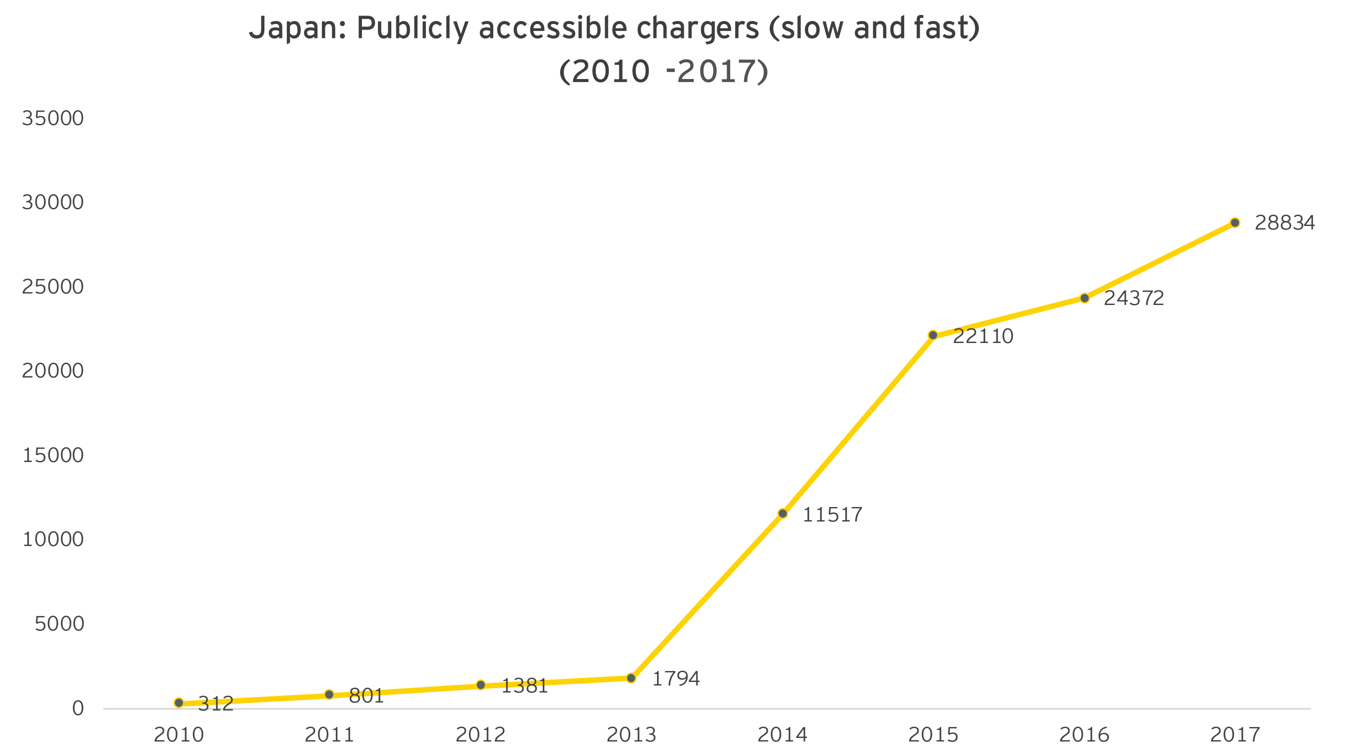


Figure 12: Japan publicly accessible chargers (slow and fast) 2010-2017[66]

[65]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[66]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

1.4.3. Policy roadmap for Electric Mobility in Japan

Policy framework has been extensively developed and evolved over the years to support and achieve the target set by the government. The "Roadmap for EVs and PHVs toward the dissemination of electric vehicles and plug-in hybrid vehicles" set an aim to capture 50% to 70% of next-generation vehicles to total new car sales by 2030. The Government of Japan established its support as a facilitator in the development process supplying both R&D support and artificially creating niche markets, and easing the way for targeted technologies by means of legislation and standards[67 68], .

Projections v/s Target

Diffusion Projection (with Private sector effort)	2020	2030
Conventional vehicles	80% or more	80% or more
Next Gen Vehicles	Less than 20%	30%-40%
Hybrid vehicles	10%-15%	20%-30%
EV/plug-in hybrid vehicles	5%-10%	10%-20%
Fuel cell vehicles	Miniscule	1%
Clean diesel vehicles	Miniscule	-5%

Diffusion Target (Government Targets)	2020	2030
Conventional vehicles	50%-80%	30%-50%
Next Gen vehicles	20%-50%	50%-70%
Hybrid vehicles	20%-30%	30%-40%
EV/plug-in hybrid vehicles	15%-20%	20%-30%
Fuel Cell vehicles	-1%	-3%
Clean diesel vehicles	-5%	5%-10%

Figure 13: Projections and targets representation of electric mobility in Japan[69]

[67] https://policy.asiapacificenergy.org/sites/default/files/Japan%20Revitalization%20Strategy.pdf
[68] http://www.meti.go.jp/english/press/2016/0323_01.html
[69] The Ministry of Economy, Trade and Industry (METI)

Timeliness of electric mobility policies as observed in Japan[70].

Table 17: Electric mobility policy roadmap in Japan[70]

S. No.	Policy/Initiative	Timeline	Description
1	Strategic Energy Plan (SEP)	2014	The Japanese government implemented the fourth Strategic Energy Plan (SEP). These policies identified the promotion of next-generation vehicles as a way to reduce Japan's consumption of fossil fuels, promote a low-carbon transportation sector and strengthen Japan's energy security.
2	Japan Revitalization Strategy (JRS	2015 (rev.)	Under the Strategic Market Creation Plan of Japan Revitalization Strategy (JRS), on a theme of realizing clean and economical energy supply and demand, the Government of Japan's Ministry of Economy, Trade and Industry (METI) aims to capture 50% to 70% of next-generation vehicles to total new car sales by 2030.
3	Next-Generation Vehicle Plan	Drafted in 2010 and updated after JRS, 2015	"Next-Generation Vehicle Plan" set forth six plans to achieve the electric vehicle diffusion projections for 2020 and 2030, of which the infrastructure roadmap for the deployment of Electric Mobility infrastructure sets a target to achieve 2 million normal chargers and 5,000 quick chargers by 2020.
4	Next-Generation Vehicle Charging Infrastructure Deployment Promotion Project (NGV-CIDPP)	2013	▸ METI launched a large scale project named "Next Generation Vehicle Charging Infrastructure Deployment Promotion Project" using 100 billion JPY of supplementary budget for fiscal year 2012, followed by utilizing the 30 billion JPY from the FY 2014 Supplementary Budget[71] . ▸ The objective is the strategic and quick deployment of charging infrastructure. This project has encouraged municipalities and expressway operating organizations nationwide to issue charger deployment plans, which were made public in April 2013. ▸ This ground-breaking project subsidizes: ▸ the cost of chargers ▸ 2/3 of the installation costs for the municipalities and organizations who intend to install public chargers based on their published charger deployment plan, which shall accelerate the deployment of charging infrastructure along the principal routes nationwide[72].
5	Extension support by Tokyo prefecture to NGV-CIDPP	2018	▸ Tokyo government, in order to cover the remaining cost of charging infrastructure after the national subsidy, has announced plans to include one billion Yen in the fiscal 2018 budget.

[70]EY analysis
[71]The Ministry of Economy, Trade and Industry (METI) - http://www.meti.go.jp/english/press/2015/0312_02.html
[72]CHAdeMo - https://www.chademo.com/wp/wp-content/uploads/2014/05/FY2013ActivitiesReport_EN1.pdf

	Overall plan	Batteries	Rare metals	Infrastructure	Systems	International standards
Target	next-gen. vehicle development and production	Secure battery R&D and technology	Secure rare metals and build resource recycling systems	Install 2 million normal chargers & 5,000 quick chargers	Vehicles with systems (smart grid, etc.)	Strategic international standardization
Action Plan	▸ Set diffusion targets (for 2020/2030) ▸ Next-generation vehicles account for up to 50% in 2020 ▸ Advanced eco-friendly vehicles (next-generation vehicles + eco-friendly conventional vehicles) account for up to 80% in 2020 ▸ Diversify fuels ▸ Higher-value-added parts ▸ Promote the siting of low carbon industries	▸ Improve performance of lithium-ion batteries ▸ Develop post-lithium-ion batteries ▸ Achieve economies of mass production by promoting EVs ▸ Create an environment for secondary use of batteries	▸ (Upstream) ▸ Strategically secure rare metals ▸ (Middle course) ▸ Develop batteries and motors free of rare metals ▸ (Downstream) ▸ Establish battery recycling systems	▸ Build infrastructure intensively and systematically during the market preparation phase ▸ Mainly in EV/PHV towns ▸ Pave the way for full-scale diffusion ▸ Compile EV/PHV town best practice handbook ▸ Collaborate with the private sector (CHAdeMO Association)	▸ Create new business models in EV/PHV towns. ▸ Verify systems through the Next-Generation Energy and Social System Demonstration program. ▸ Promote international standardization and business development based on the verification results	▸ Establish international standards for battery performance and safety evaluation methods. ▸ Establish international standards for charging connectors/systems. ▸ Enhance public-private organization for standardization. ▸ Develop human resources for standardization
		Battery R&D Target (set in 2006)	Resource Strategy Roadmap	Infrastructure Development Roadmap	International Standardization Roadmap	

Figure 14: Six plans outlined for the Next-Generation Vehicle Plan[71]

[73]The Ministry of Economy, Trade and Industry (METI)

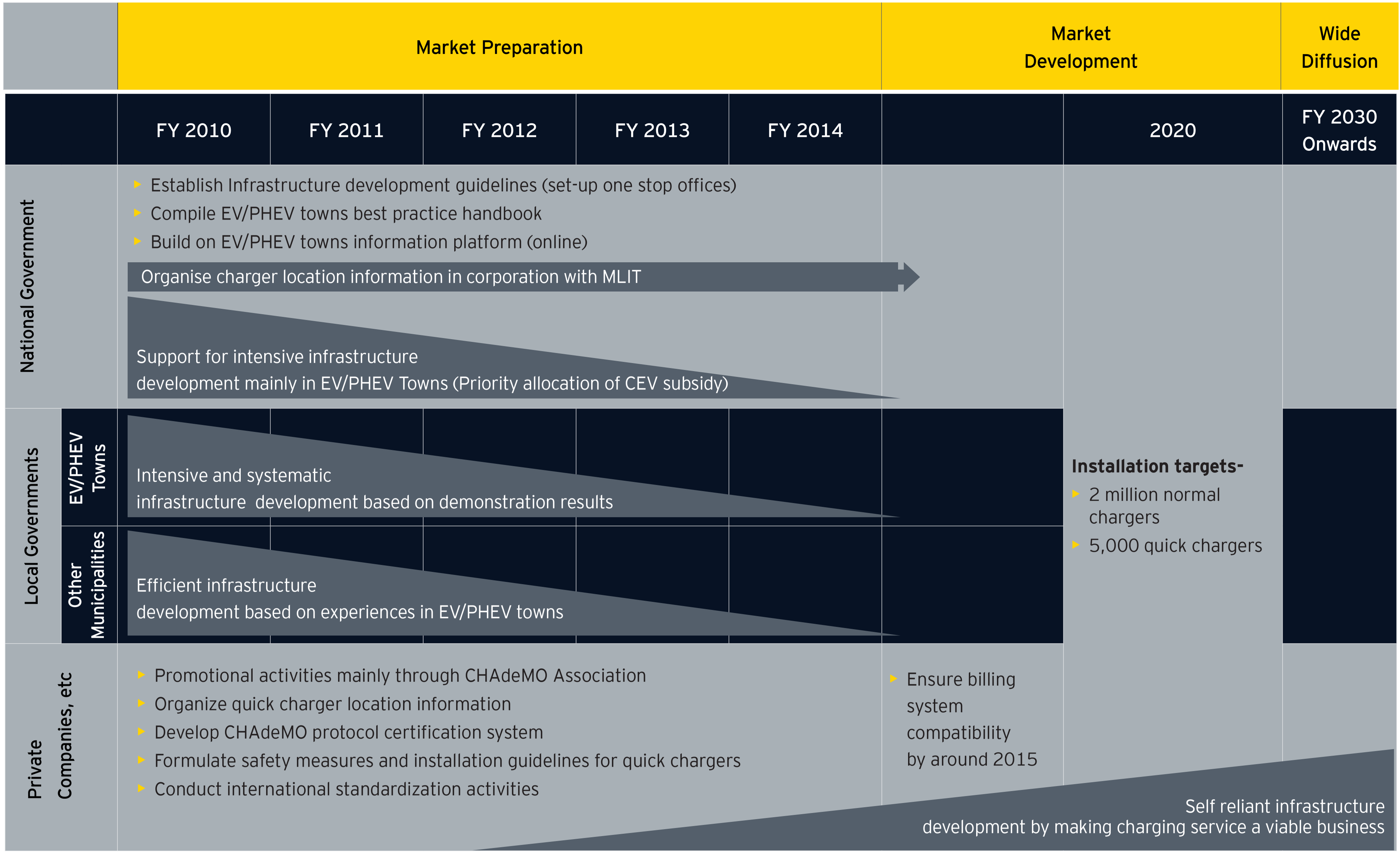


Figure 15: Japan's roadmap and targets for the development of charging infrastructure[74]

[74]The Ministry of Economy, Trade and Industry (METI)

Promotion project to develop charging infrastructure for next-generation vehicles

Budget amount

- 100.5 billion JPY - FY2012 Supplementary Budget
- 30 billion JPY - FY 2014 Supplementary Budget

Eligibility and subsidy rate

Purchasing and installation of chargers will be subsidized under the following categories:

Table 18: Subsidy rates under four categories[75]

Category	Outline	Covered	Subsidy rate
1	Subsidy is given to the charging infrastructure development plans by local governments for public chargers	Purchase and installation cost of chargers	2/3
2	Installation of public chargers not based on the local government plans	Purchase and installation cost of chargers	1/2
3	Installation of chargers in MUDs and parking areas	Purchase and installation cost of chargers	
4	Others	Charger purchase cost	

PHV, PHEV and EV charging infrastructure assistance project

Automakers Toyota Motor Corporation, Nissan Motor Co., Ltd., Honda Motor Co., Ltd., and Mitsubishi Motors Corporation announced a joint project to support the developments of EV charging infrastructure by providing additional subsidies to cover the remaining costs from government subsidies.

Table 19: Incentive structure for EVSE in Japan[76]

Category	Standard chargers	Quick chargers
Installation costs	One third of charger purchase cost	One third of charger purchase cost
	One third of charger installation cost	One third of charger installation cost
		Start-up inspection expense
Maintenance Costs (8 years)	Communication fees, maintenance contract and insurance	Communication fees, maintenance contract and insurance
		Demand charge (Low voltage only)
Electricity costs	Energy charge	Energy charge

[75]Next-generation vehicles (NGV); EY analysis
[76]CHAdeMO; EY analysis

Entities associated with "Charging Infrastructure for Next-generation Vehicle"

1. Nippon Charge Service (NCS)

Participating companies of "PHV, PHEV and EV Charging Infrastructure Assistance Project" along with additional funding and support from Development Bank of Japan Inc., Tokyo Electric Power Company, Inc., and Chubu Electric Power Co., Inc. formed a new entity Nippon Charge Service, LLC in 2014. The new company compensated for the installation cost, which was not fully covered by the government subsidies. NCS provided car owners with a universally-accepted charging card which enabled them to use all the chargers in NCS charging station network.

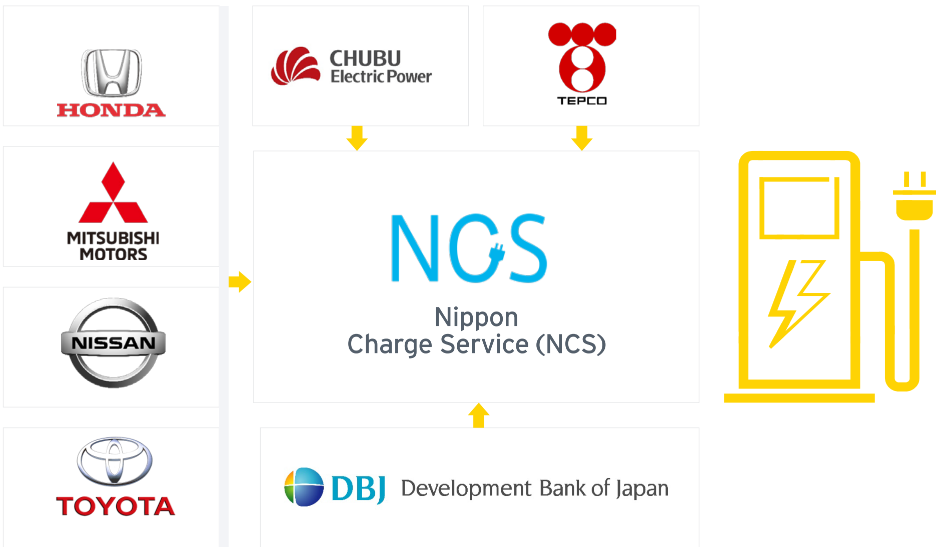


Figure 16: Founding organizations of NCS[77]

Figure 17: NCS charger labeling for quick and normal charger

[77]Nippon Charge Service (NCS)
[78]https://www.theicct.org/sites/default/files/publications/EV-charging-best-practices_ICCT-white-paper_04102017_vF.pdf

2. Charging Network Development Service (CHAdeMO Charge)

Tokyo Electric Power Company (TEPCO), an electric utility in Japan initiated the formation of "CHAdeMO Association" for the dissemination of charging infrastructure to promote the adoption of EVs in Japan.

CHAdeMO's members are spread across the value chain and include:

- Automobile manufacturers
- Electric power companies
- Charger manufacturers
- Charging service operators
- Local governments/prefecture

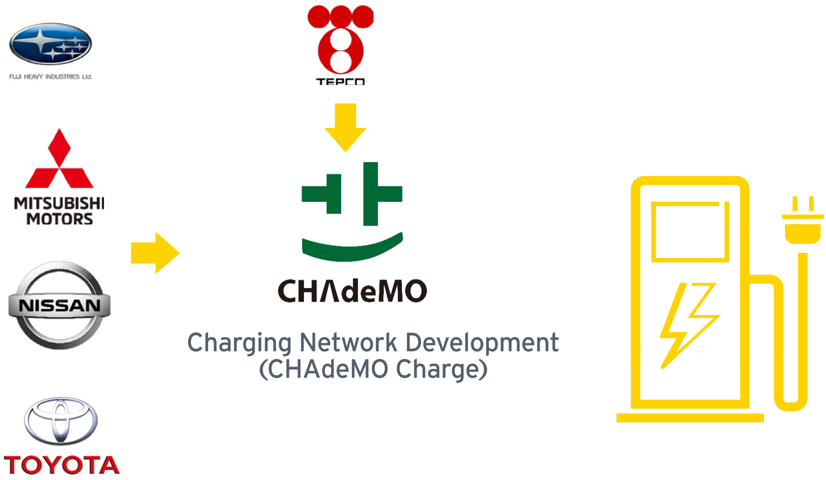


Figure 18: Founding organizations of CHAdeMO[79]

Note: 1. Both the entities, Nippon Charge Service, LLC, and Charging Network Development Service (CHAdeMO Charge) were merged around 2014[80].

CHAdeMO

CHAdeMO primarily operates as an e-mobility collaboration platform around CHAdeMO DC charging protocol. They are supported by 350 members, out of which 50 are charger manufacturers complying with CHAdeMO protocol. CHAdeMO performs three primary functions:

- Develop the protocol: adapting the protocol as per the market and the member requests.
- Certify EV chargers: CHAdeMO performs certification and testing of chargers to ensure they are compatible with the infrastructure and the EVs.
- Promotion of fast chargers: CHAdeMO actively promotes the adoption of fast chargers by disseminating their benefits and data through various communication channels.

CHAdeMO protocol

CHAdeMO defines a DC charging protocol (under the same name CHAdeMO) enabling power levels from 6kW to 200kW. 350 kW-400kW of power is under preparation. It was the first global fast charging protocol for electric vehicles and boosts more than 10,000 points, globally. CHAdeMO, in 2014, was published as an IEC and EN standard. In 2016, it was published as an IEEE standard.

- **Safety:** CHAdeMO mandates strict guidelines in designing chargers for electrical safety in any operating conditions.
- **Future-proof:** CHAdeMO is smart grid-ready through its bi-directional charging capability.
- **Ease of application:** CHAdeMO works on Controller Area Network (CAN) communication which is an on-board communication network for all EVs. Hence, its integration with the rest of the cars is easy and reliable.
- **Uniformity:** CHAdeMO connector is identical across the globe and is a stand-alone plug that can be with or without an AC connector.

[79] CHAdeMO - https://www.chademo.com/wp/wp-content/uploads/2015/05/FY2014ActivityReport.pdf
[80] https://www.chademo.com/wp/wp-content/uploads/2015/05/FY2014ActivityReport.pdf

1.4.4. Key technological enablers for EV proliferation in Japan

Standards

Electric vehicle charging standardization in Japan is regulated by Japan Automotive Research Institute (JARI), New Energy and Development Organization (NEDO) that acts as a governing body and coordinates with METI[81] . The key standards in Japan can referred from annexure Table 78: Standards adopted in Japan

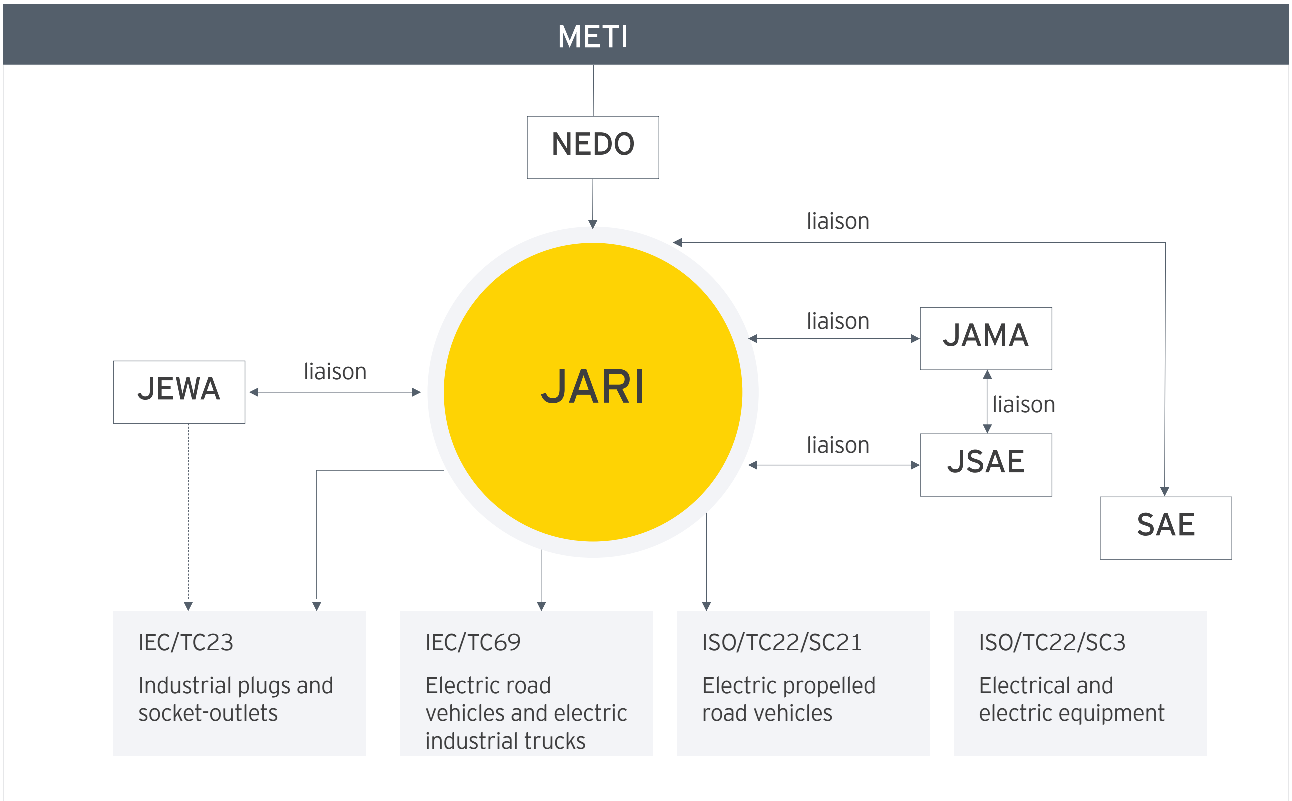


Figure 19: Standardization regulatory framework in Japan[82]

Types of chargers

CA brief information about different type of chargers, currently deployed in Japan, is mentioned in the following table [83]

Table 20: Types of EV charging adopted in Japan[82]

	Conventional plugs	Slow chargers		Fast chargers		
Level	Level 1	Level 2		Level 3		
Current	AC	AC		AC, tri-phase	DC	
Power	<= 3.7 kW	> 3.7 kW and <= 22 kW	<= 22 kW	> 22 kW and <= 43.5 kW	Currently < 200 kW	
Japan	Type B	SAE J1772 Type 1	Tesla		Accepts all IEC 62196-3 standards	Tesla and CHAdeMO (IEC 62196-3 Type 4)

[81]Ministry of Economy, Trade and Industry (METI) http://www.a3ps.at/site/sites/default/files/conferences/2011_eco-mobility2011/2011_Eco-Mobility_01_04_Miura.pdf
[82]Ministry of Economy, Trade and Industry (METI) http://www.a3ps.at/site/sites/default/files/conferences/2011_eco-mobility2011/2011_Eco-Mobility_01_04_Miura.pdf
[83]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[84]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

1.4.5. EV ecosystem in Japan

The major operators in the field of EV charging stations is Nippon Charge Network, which manages the installation and promote other charger installers to join the network. Also, they manage payment systems for electric vehicle charging and smart user cards based on the type of the charger used.

Utilities have been involved the development of EV charging infrastructure in Japan. CHAdeMO, as an alliance, was initiated by TEPCO, Inc. to promote common standard for the country. CHAdeMO protocol is based on a TEPCO's patented high-voltage (up to 500 V DC) high-current (125 A) fast charging via a Japan Automobile Research Institute (JARI) DC fast-charge connector. The connector is specified by the Japan Electric Vehicle Standard (JEVS) G105-1993 from the JARI.

Business models

In accordance with the ecosystem mentioned above, the roles played by the key stakeholders are mentioned below:

- **Utilities:** utilities play varied roles as per the business models. Acting as DSOs, utilities are mainly responsible for setting up requisite grid infrastructure. CHAdeMO, as an alliance, was initiated by TEPCO, Inc. to promote a common standard for the country.
- **Power retailer:** as per the market structure of Japan, power retailer has to charge the charging point operators (CPOs) for supplying electricity. However, CPOs are free to choose the retailer for procuring power. For billing CPOs, a smart meter is installed at the point of connection of each charging station.
- **Charging point operator:** charging point operator is responsible for procuring requisite equipment. In most of the cases, maintenance services are outsourced to a third-party. As the market is unregulated, the output tariff (tariff charged to EV owners) is market driven. However, in this case, CPOs charge EV owners as per different pricing methods such as pay per kWh and pay per hour.
- **Charging network provider:** the network provider is paid a subscription fee/usage fee by the charging point operator and the end consumer utilizing the installed charging infrastructure.

Various business models adopted in Japan are mentioned below:

- **BM1: Charging point operator provides free public charging:** CPO is a commercial entity (restaurant/retail store owner). The EV owners are offered free charging at their premises. Accordingly, the CPO benefits through increased customer attraction at the site.
- **BM2: Pay per click model:** Utilities collaborate with shopping malls, restaurants or gas stations to instal fast chargers in their premises. They can receive a fixed sum of money from the owner of the premises, each time the charger is used by the customers.
- **BM3: Subscription model:** Utilities can own and operate charging infrastructure in this model. They can charge a subscription fee from customers for using their charging facility. The subscription fee may include free charging.


1.5

People's Republic of China (PRC)

1.5.1. Power market in China

The power sector in People's Republic of China, hereafter China, is undergoing a power sector transition from being a vertically integrated, state-owned monopoly to an unbundled and market-oriented sector. The government's vision is to restructure electric sector as [85]:

- Generation - fully competitive in large regional markets
- Transmission and distribution: regulated monopoly services
- Retail service: fully competitive such that customers will be able to choose among providers and products

The State Council issued "Decree No. 9: Several Guiding Principles of Furthering the Reform of the Electricity Market", 2015 which forms the governing principles for the liberalization of the wholesale and retail electricity market, leaving the transmission in control of the government.

In the overall energy front, to meet its growing energy demand, China has shifted its focus to renewables and electricity, drastically scaling down the consumption of fossil fuels by two-thirds (at present) to less than 40% in 2040[86] . Focus is not only on phasing out fossils from generation but also from the consumption sectors like transport. This strategy towards a greener energy mix has given light to initiatives targeted at improving the energy security and reducing the pollution levels of the country.

As the level of economic and social development in China continues to increase, the car ownership continues to climb. Vigorously developing new energy vehicles can accelerate fuel substitution and reduce automobile exhaust emissions, which is of a great significance in ensuring energy security, promoting energy conservation and emission reduction, preventing and controlling atmospheric pollution, and promoting China's transition from a major automobile country to a powerful automobile country. Further, the shift towards new energy vehicles is also seen as a strategic move to upgrade China's indigenous automotive industry and to enable it to become a dominant leader in the new energy vehicle value chain.

Regulatory framework

- The Ministry for Industry and Information Technology (MIIT)
- Ministry of Science and Technology (MOST)
- Energy Bureau
- Standardization Administration of China (SAC)
- National Development and Reform Commission (NDRC)
- Ministry of Finance of the People's Republic of China (MoF)
- State-owned Assets Supervision and Administration Commission (SASAC)
- China Automotive Technology and Research Center (CATARC)
- National Energy Administration (NEA)

China's Electric Mobility initiatives are government-driven, where the policy guidelines are directly issued by the highest authority, i.e., the 'State Council' that follows a top down approach and is supported by multiple ministries and agencies.

[61]IEA - https://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesJapan2016.pdf
[62]Institute for Energy Economics and Financial Analysis - http://ieefa.org/wp-content/uploads/2017/03/Japan_-Greater-Energy-Security-Through-Renewables-_March-2017.pdf

1.5.2. Policy roadmap for Electric Mobility in China

The central government weights great importance on promoting the construction of charging infrastructure to speed up the promotion and application of electric vehicles. To improve the installation speed of new EV charging stations, the government has been actively reforming the state electric power sector by breaking electricity distribution monopolies over sales and gradually opening the electric power market to the public.

The number of charging poles in China range from approximately 300k-350k units, which included 50k public ports and 49k specialized ports. The primary growth in charging infrastructure is dominant in major cities like Beijing, Shanghai, Guangdong and Shenzhen due to a strong policy support. The public EV chargers saw a growth from 50k units in FY15 to ~150k units by the end of FY16[87] .

Table 21: City wide public charging ports by FY17[88]

City	Public charging ports (January FY17)
Beijing	22.5 k
Guangdong	22 k
Shanghai	17 k
Jiangsu	

EV:EVSE - 1:1

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[87]NOMURA - https://publishing.dealogic.com/nomura/China_EV_battery_Recharging_for_a_sequential_recovery.pdf
[88]NOMURA - https://publishing.dealogic.com/nomura/China_EV_battery_Recharging_for_a_sequential_recovery.pdf
[89]IEA - https://webstore.iea.org/global-ev-outlook-2018
[90]http://www.chinadaily.com.cn/a/201801/11/WS5a5759d9a3102c394518e9e1.html

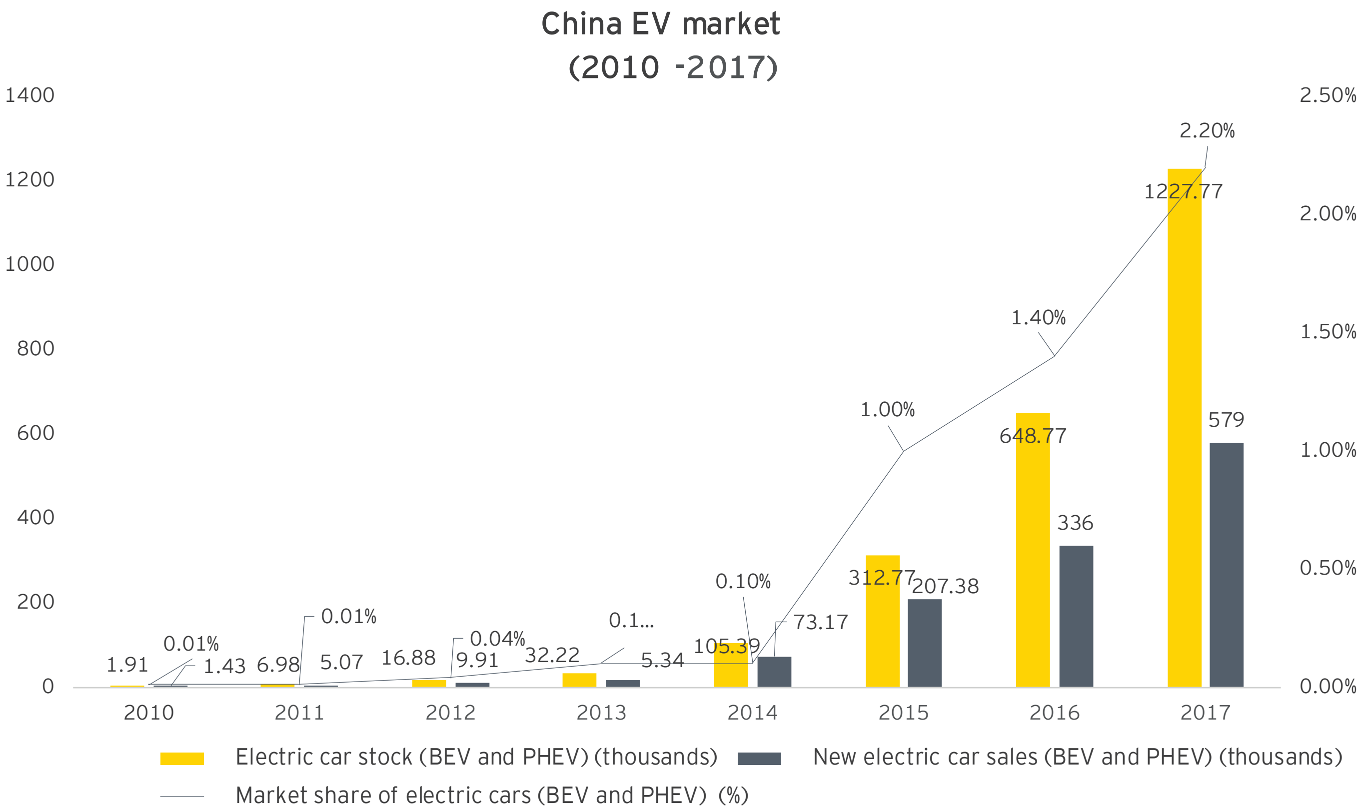


Figure 20: China EV market (2010-2017[91]

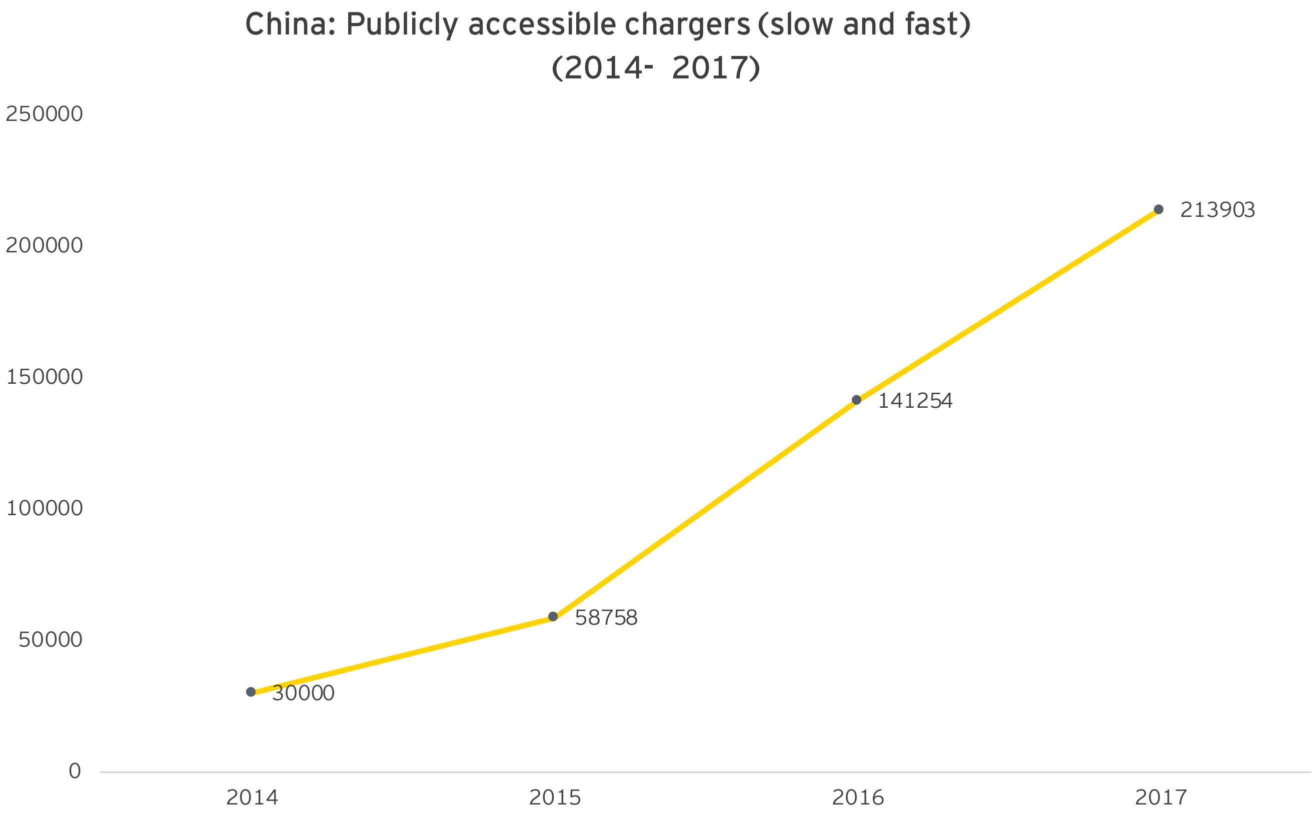


Figure 21: China publicly accessible chargers (slow and fast) 2010-2017[92]

[91]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[92]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018
[93]Oak Ridge National Laboratory (ORNL) - https://info.ornl.gov/sites/publications/files/Pub72210.pdf
[94]Fraunhofer - https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccp/innovation-systems-policy-analysis/2012/discussionpaper_30_2012.pdf
[95]Harvard University - https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/RPP_2015_07_Howell.pdf

The Government of China issues its new energy vehicle policies directly through the State Council , and is based on four pillars of development , namely[95,] namely:

- Technological upgrading
- Energy security
- Local pollution reduction
- Carbon emissions

Table 22: Policy roadmap[96]

S. No.	Policy/initiative	Timeline	Description
1	Tenth Five-Year Plan	(2001-2005)	Promotes R&D of new energy vehicle
2	Auto Industry Development Policy	2004	This policy identifies hybrid vehicles as a priority and encourage electric vehicles' development.
3	China Medium and Long-Term Science and Technology	(2006-2020)	This policy too was focused on and identifies hybrid vehicles as a priority and encourages alternate fuel development.
4	Eleventh Five-Year Plan on Energy-Saving and New Energy Vehicle Project	2006	This policy promotes the PEV industrialization.
5	Rules on the Production Admission Administration of New Energy Automobiles	2007	Targets manufacturing and sales
6	Auto Industry Restructuring and Revitalization Plan	2009	The State Council of China has set a target to achieve nation-wide 500,000 NEVs by the end of 2011, which will be 5% of new car sales by 2011.
7	Directory of Recommended Types of Energy Saving and New Energy Vehicle Demonstration Projects for Promotion Application	2009	This directive led to the formation of strategy for NEVs by major automakers in China.
8	Admittance Management Rules for New Energy Auto Manufacturing Companies and Products	2009	This policy defines "new energy vehicles" - the vehicles based on non-fossil fuel or newer forms of propulsions will be considered as an NEV.
9	Ten Cities, One Thousand Vehicles Program By 2011, the total model cities were increased to 25.	2009	The Government of China (MoST, MoF, MIIT and NDRC) initiated demonstration projects with a plan to diffuse 1,000 vehicles to be introduced every year for a period of three years in 10 selected cities.
10	State-owned Enterprise Electrical Vehicle Industry Alliance (SEVIA)	2010	This is an alliance of Chinese state-owned companies under the State-owned Assets Supervision and Administration Commission (SASAC). SEVIA plans to invest CNY 93.34 billion for the uptake and development of the NEVs.

[96]EY analysis

S. No.	Policy/initiative	Timeline	Description
11	Development of New Energy Vehicle Industry	2011-2015	Drafted by MIIT to form the roadmap of NEV diffusion until 2020.
12	Development Plan for Fuel-efficient and New Energy Vehicles	2011-2020	It is an industrial plan supporting the development of NEV value chain. The government invested 100 billion CNY with a target to have highest NEV sales in he world. ▸ 50 billion: energy saving and new energy vehicle industry fund utilized for technology R&D support and industrialization. ▸ 30 billion: pilot and demonstration projects ▸ 20 billion: promotion of energy saving vehicles. Reserve: ▸ 10 billion: support for core automotive industry ▸ 5 billion: pilot urban infrastructure projects
		Phase I – 2011-2015	▸ Develop Chinese owned intellectual property (IP) for NEV value chain components. ▸ 1 million mark out of 500,000 should be achieved by 2015 (include number of HEVs) ▸ Upper limit of 5.6 liters per 100 km mileage is set for the newly launched cars.
		Phase II – 2016-2020	▸ Major emphasis on EV and HEV. ▸ Market volume should be 5 million vehicles. ▸ Upper limit of mileage is increased to 4.5 liters per 100km.
		National teams	▸ National teams were formed comprising of leading enterprises. ▸ National teams will build pilot bases for the NEV industry and will integrate them with demonstration projects. ▸ Pilot bases should achieve a mark of 90% by 2020.
		Battery plan	▸ Hangzhou, Shenzhen and Tianjin will be established as the base locations to set up lithium-ion battery industries. ▸ Two-three enterprises with sales of over 20 billion-watt hours will be set up
13	Exemption of Vehicle Purchase Tax on New Energy Vehicles	2014	▸ Tax incentives for PEV purchasing.
14	Notice of Subsidy for Charging Infrastructure Constructions	2014	▸ Charging infrastructure development subsidies.
15	Financial Support Policies on the Promotion and Application of New Energy Vehicles (2016-2020)	2015	▸ The incentives provided in this scheme are gradually being withdrawn since 2016.

S. No.	Policy/initiative	Timeline	Description
15	Financial Support Policies on the Promotion and Application of New Energy Vehicles (2016-2020)	2015	The incentives provided in this scheme are gradually being withdrawn since 2016.
16	Made in China 2025	2015	Guidelines for the development of NEV value chain.
17	Provisions on the Administration of Newly Established Pure Electric Passenger Vehicle Enterprises	2015	Small scale manufacturers were motivated to become NEV manufacturers.
18	Provisions on the Administration of Newly Established Pure Electric Passenger Vehicle Enterprises	2015	Small scale manufacturers were motivated to become NEV manufacturers.
19	Guiding Opinions on Accelerating the Construction of Electric Vehicle Charging Infrastructure	2015	Construction and planning of charging infrastructure.
20	New Vehicle Charging National Standards	2015	Development of national standards was done.

Pilot models in "The Ten Cities, One Thousand Vehicles Program"

This pilot program saw cities developing and working on various deployment and implementation models[97]

1. Beijing: State leadership model

- The capital city's EV deployment was dependent on government support and policies. Primary focus was to build a strong EV industrial base which will cater to China's strategy to reinvent and dominate the automobile market.
- Yanqing government (a district in Beijing) set up a joint venture with BAIC Foton to deploy EV taxis. The capital investment was shared 50-50 and the Yanqing government provided the charging facility and operating personnel and BAIC Foton provided the taxis.

2. Shanghai: Platform-led business innovation model

- Shanghai was established as an EV pilot demonstration city with a focus on international cooperation.
- Shanghai has adopted a rental model borrowed from Bremen, Germany, wherein consumers can lease an EV with a membership card.
- Goals of the model were:

  i. Testing and piloting the EV development model

  ii. Test innovations in vehicle performance

  iii. Route design

  iv. Charging facility distribution

  v. Provide a site for auto manufacturer R&D collaboration

3. Shenzhen: Cooperative commercialization model

- Shenzhen had the advantage of well established electric grid and battery companies.
- The utility China Southern Power Grid with state-owned enterprises, Potevio New Energy and Shenzhen government, initiated a financial leasing model which can be looked as a commercial way to popularize the EVs
- Potevio's leasing model reduces the capital expenditures by separating the cost of the battery.
- Battery ownership is retained by Potevio (around $56,000) which is then leased to the Shenzhen Bus Company.

[97]Stanford Social Innvoation Review -https://ssir.org/articles/entry/chinas_quest_to_adopt_electric_vehicles
[98]World Resources Institute - http://www.wri.org/blog/2018/04/how-did-shenzhen-china-build-world-s-largest-electric-bus-fleet

- Moreover, because of the support from the local government and BYD (an EV OEM), Potevio was able to buy the batteries at a subsidized price.
- Today, Shenzhen has the world's largest EV bus fleet of 16,359 buses[98] .

4. Hangzhou: Flexible rental model

- Hangzhou's Rental Model is similar to Shanghai and is targeted at high initial capital cost of an EV.
- This model is termed flexible as here, the customers can choose to either lease the entire car or just the battery separately (Swapping model).

5. Chongqing: Fast-charging Model

- Chongqing has taken pilot initiatives for grid intensive fast-charging EV technology.
- Other cities were operating on various other models such as:

  i. Shenzhen and Hangzhou: swapping

  ii. Beijing and Shanghai: slow-charging stations

- Chongqing's model is based on some strategic motivations:

  i. Chongqing is near the robust 'Three Gorge Power Grid' which is a 940-kilometre bipolar high-voltage direct current (HVDC) transmission line .

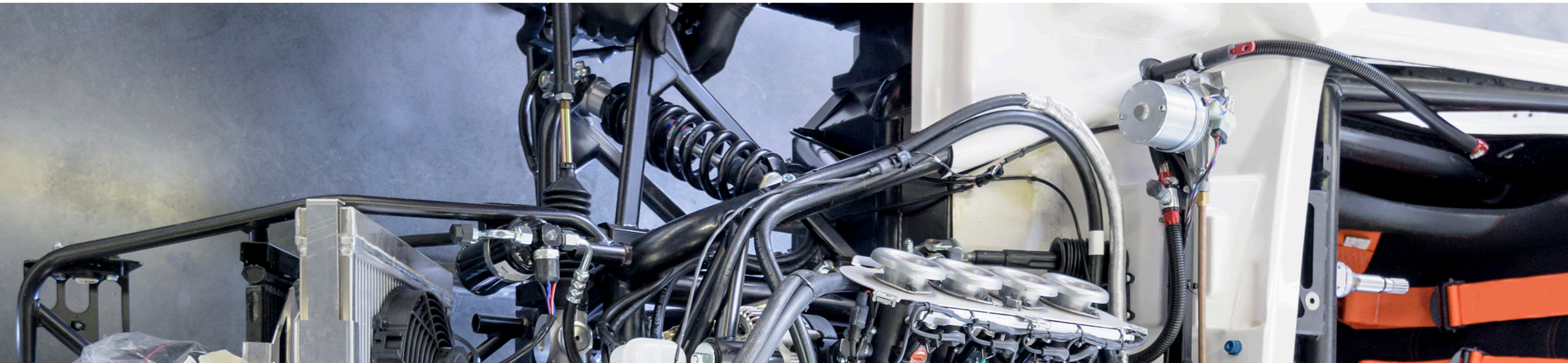
  ii. Being a mountainous region, Chongqing is generally unsuitable for swapping which requires flat surface area.

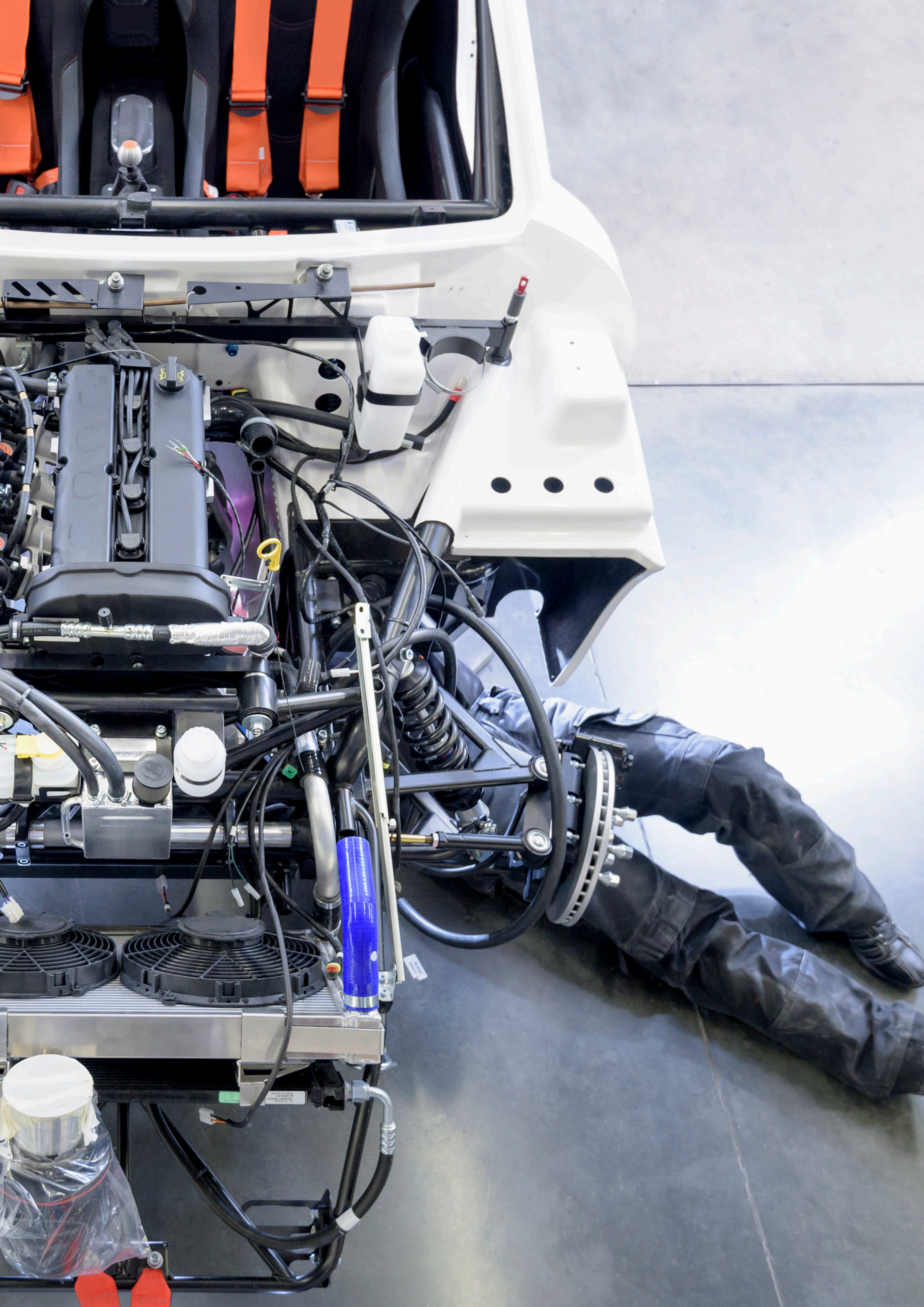
  iii. Chongqing is home to fast-charging auto manufacturers that provide industrial support for its strategy.

[99]https://en.wikipedia.org/wiki/HVDC_Three_Gorges_%E2%80%93_Changzhou
[100]Stanford Social Innvoation Review -https://ssir.org/articles/entry/chinas_quest_to_adopt_electric_vehicles
[101]Fitch Ratings: China New Energy Vehicle Blue Book

	Beijing	Shanghai	Shenzhen	Hangzhou	Chongqing
Model	State Leadership Model	Platform-Led Business Innovation Model	Cooperative Commercialization Mode	Flexible Rental Model	Fast Charging Model
Action plan	▸ Government aligns itself and depends on favourable policies to create a strong EV industrial base. ▸ Important industry players cooperate actively.	▸ Jiading provides an EV international demonstration zone which is a platform to promote EV development. ▸ Planners intend to spread EV rental business across the city.	▸ Multiple industrial players participate actively. ▸ Potevio (a state-owned enterprise supervised by SASAC) introduced a financial leasing model which reduces cost of purchasing EVs.	▸ Rental model works on the principle that either car or battery (swap) can be rented. ▸ Battery swapping was first adopted in Hangzhou.	▸ Of all the pilot cities, Chongqing was the only one implementing fast-charging solutions.

Figure 22: Pilot models in "The Ten Cities, One Thousand Vehicles Program [100]





1.5.3. Fiscal and non-fiscal incentives for EV uptake in China

The government strengthened its support by deploying generous incentive packages for NEV producers and buyers, implementing innovative NEV license-plate schemes in large cities and setting clear targets and roadmaps for public-sector NEV deployment and electric-vehicle supply equipment construction[101] .

Table 23: Fiscal and non-fiscal incentives in China

Production	Purchase	Usage	Infrastructure
		Financial incentives	
Rewards for NEV research and development	Subsidies for NEV purchase and leasing.	Electricity tariff discounts and subsidies.	Subsidies for charging infrastructure construction.
Rewards for NEV and sales	Purchase tax waiver; import tariff cut.	Vehicle circulation and ownership tax waiver.	Subsidies for NEV parking infrastructure construction.
	Replacement subsidies for NEVs.	Free charging at public charging facilities.	
	Discounts for large NEV orders.	Parking discounts and priority.	
	Subsidies for NEV dealership store construction.	Road and bridge toll waiver.	
		Subsidies for e-bus and e-taxi operations.	
		Subsidies for battery recycling	
		Insurance premium discounts.	
		Non-financial incentives	
Setting corporate-average fuel consumption (CAFC)/ NEV credit targets. Regulators require automakers to reduce their CAFC to 5.0L/100km by 2020, 4.0L/100km by 2025 and 3.2L/100km by 2030.	Free license plates in ICE-restricted cities like Beijing, Shanghai, Shenzhen, Tianjin, Hangzhou and Guangzhou.	Rights to use dedicated bus lanes.	Fast-tracked approval for charging infrastructure projects.
	NEV promotion and marketing.	No restrictions on accessing urban areas.	Priority in land allocation.
	Setting targets for NEV shares in vehicle deployment.	Priority in annual inspections.	Online management system for public charging poles.
	Setting e-car targets for government use.		
	Priority in commercial operating license issuance, for example, taxi and logistic vehicles.		

Subsidies

Central government, since early 2000, has allocated heavy subsidies for the proliferation of PEVs. The total amount of the subsidies allocated for a PEV can be upto 60% of the total value of the PEV. Due to the allotted subsidies, a consumer paid less than half the actual price of the PEV, e.g., a Geely Zhidou costed 49,800 CNY after a subsidy of 109,000 CNY[93]

Table 24: Subsidies in the initial years[88]

Type	Range	2013	2014	2015
Plug-in hybrid electric car (includes extended range EV)	> 50 km	35,000 CNY	33,250 CNY	31,500 CNY
Electric car	80 - 150 km	35,000 CNY	33,250 CNY	31,500 CNY
	150 -250 km	50,000 CNY	47,500 CNY	45,000 CNY
	> 250 km	60,000 CNY	57,000 CNY	54,000 CNY

Subsidies 2016 onwards

The new central government subsidy scheme gradually declines subsidy support for PEVs. Moreover, this new incentive scheme raises the bar for an electric car range to minimum 100 km (earlier 80km) and maximum speed to 100 km/hr. (earlier 80 km/hr). Even after the decline of subsidies, the sale of EVs in 2017 tipped over 600,000[103] .

Table 25: : Subsidies allocated at present in China[104]

Type	Range	2016	2017-18	2019-2020
Plug-in hybrid electric car (includes extended range EV)	> 50 km	30,000 CNY	2016 × 80%	2016 × 40%
Electric car	100 -150 km	25,000 CNY		
	150 -250 km	45,000 CNY		
	> 250 km	55,000 CNY		

[102]EY analysis
[103]https://www.forbes.com/sites/salvatorebabones/2018/03/06/china-could-be-the-worlds-first-all-electric-vehicle-ecosystem/#284ed728130f
[104]EY analysis

1.5.4. Standards adopted in China[105]

EV standardization sub-committee

Standardization Administration of China (SAC) is the governing body for the EV infrastructure which forms four levels of Chinese standards

- National standards: GB/GBT
- Ministry standards: JB/JBT, YY/YYT, etc.
- Provincial standards: DB/DBT
- Enterprises standards: QB/QBT

Out of the four standards, national standards and enterprise standards are known for Electric Mobility industry.

A detailed list of standards can be referred from annexure Table 79: Standards adopted in China

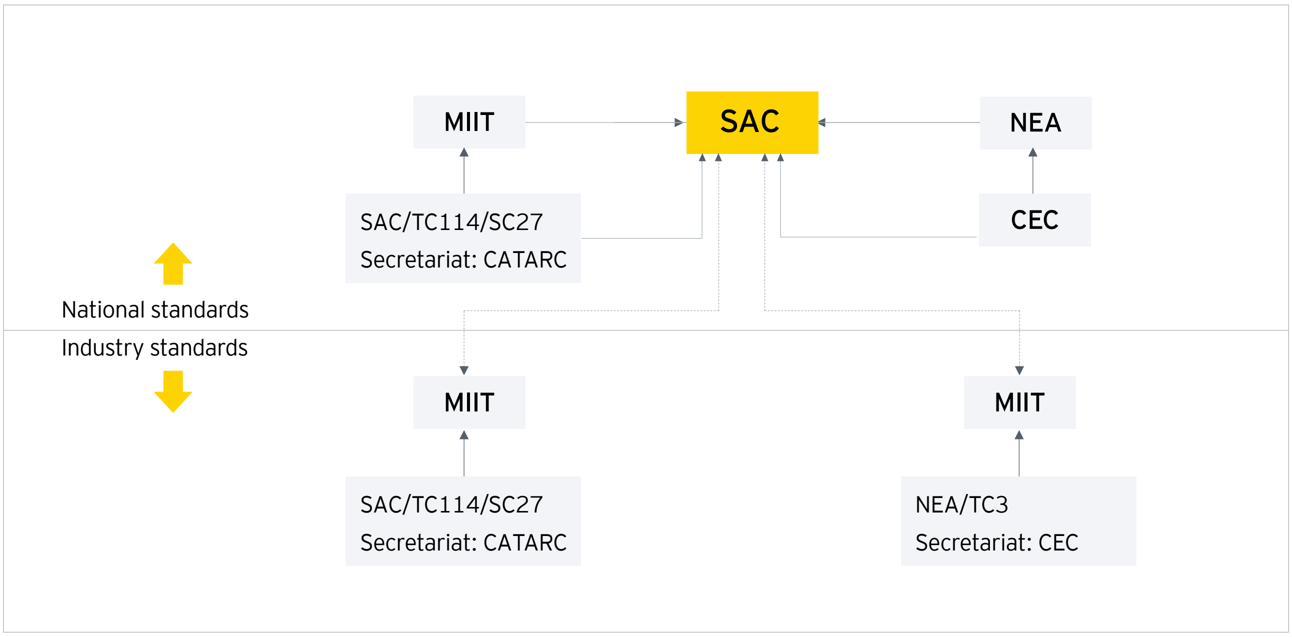


Figure 23: Regulatory framework of standardization in China[106]

1.5.5. Key technological enablers for EV proliferation

Batteries

China is abundant in Lithium and Cobalt reserves which are the two primary components of a Li-ion chemistry battery. China's current production capacity of Lithium is 2,000 tonnes (ranked 4th largest) and for cobalt is 7,700 tonnes (ranked 2nd largest).

Battery technology was originated in Japan; then further developed by companies in Korea; and is now shifting strongly towards China. China has built an integrated battery product line with the largest production capacity and market demands globally.

The economies of scales would be an essential factor of cutting the battery cost down to meet the target.

By 2017, there were 140 EV battery manufacturers in China, who are estimated to become a US$240 billion global industry in the next 20 years, led by BYD (Shenzhen) with a 20 GWh of battery cell capacity and CATL (Ningde, Fujian province) with 7.7 GWh of battery capacity. CATL is estimated to reach 50 GWh of capacity by 2020[107] .

[105]CATARC; UNECE - https://www.unece.org/fileadmin/DAM/trans/doc/2012/wp29grsp/EVS-1-08.pdf
[106]CATARC; UNECE - https://www.unece.org/fileadmin/DAM/trans/doc/2012/wp29grsp/EVS-1-08.pdf
[107]Forbes: https://www.forbes.com/sites/jackperkowski/2017/08/03/ev-batteries-a-240-billion-industry-in-the-making/#7849db503f08
[108]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

Types of chargers

China is abundant in Lithium and Cobalt reserves which are the two primary components of a Li-ion chemistry battery. A brief information about different types of chargers currently deployed in China is mentioned in the following table [108].

Table 26: Types of EV charging adopted in China[109]

	Conventional plugs	Slow chargers		Fast chargers		
Level	Level 1	Level 2		Level 3		
Current	AC	AC		AC, tri-phase	DC	
Power	<= 3.7 kW	> 3.7 kW and <= 22 kW	<= 22 kW	> 22 kW and <= 43.5 kW	Currently < 200 kW	
China	Type 1	GB/T 20234 AC	Tesla		GB/T 20234 DC	

1.5.6. EV ecosystem in China

China is transitioning towards an unbundled electricity market and a market structure similar to that of Germany, though major players still remain "State Grid Corp of China (SGCC)" operating in 26 provinces in North, West and East China and, "China Southern Power Grid (CSPG)" which covers the other five southern provinces (Guangdong, Guangxi, Yunnan, Guizhou and Hainan)." In 2014, the government opened the EV charging market to private players. Several private players such as the BYD, ABB, Shanghai Xundao New Energy Technology and other state-owned entities have been investing in building and operating of the charging stations.

Business models

In accordance with the above-mentioned ecosystem, roles played by the key stakeholders are mentioned below

Utilities: utilities are involved in the complete development of charging infrastructure from establishing grid infrastructure to installing charging stations. Utilities also provide installation and maintenance services.

Power retailer: as per the market structure of China, power retailer has to charge the charging point operators (CPOs) for supplying electricity. However, CPOs are free to choose the retailer for procuring power.

Charging point operator: charging point operator is responsible for procuring requisite equipment. In most of the cases, maintenance services are outsourced to a third-party. As the market is gradually being unregulated, the output tariff (tariff charged to EV owners) will be market driven. However, in this case, CPOs charge EV owners as per different pricing methods such as pay per kWh and pay per hour.

Charging network provider: the network provider is paid a subscription fee/usage fee by the charging point operator and the end consumer who utilizes the installed charging infrastructure.

Various business models adopted in China are mentioned below:

- **BM1: Charging point operator provides free public charging**
  CPO is a commercial entity (restaurant/retail store owner). The EV owners are offered free charging at their premises. Accordingly, the CPO gets benefits through increased customer attraction at the site.
- **BM2: Pay per click model**
  Utilities collaborate with shopping malls, restaurants or gas stations to install fast chargers in their premises. They can receive a fixed sum of money from the owner of the premises, each time the charger is used by the customers.

[109]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

- **BM3: Subscription model**
  Utilities can own and operate charging infrastructure in this model. They can charge a subscription fee from customers for using their charging facility. The subscription fee could include free charging.

Taking a cue from the prevalent models for deployment of charging infrastructure globally, it is inferred that Federal support in the forms of subsidy and push with stringent policy measures have been instrumental in proliferation of electric mobility.

However, the story for India could be completely different with minimal federal support in form of purchase subsidy. Additionally, well designed incentive mechanisms can help in accelerating the adoption especially in a country like India as the consumers are highly price sensitive and adoption pattern is driven by commercial viability of the solution.

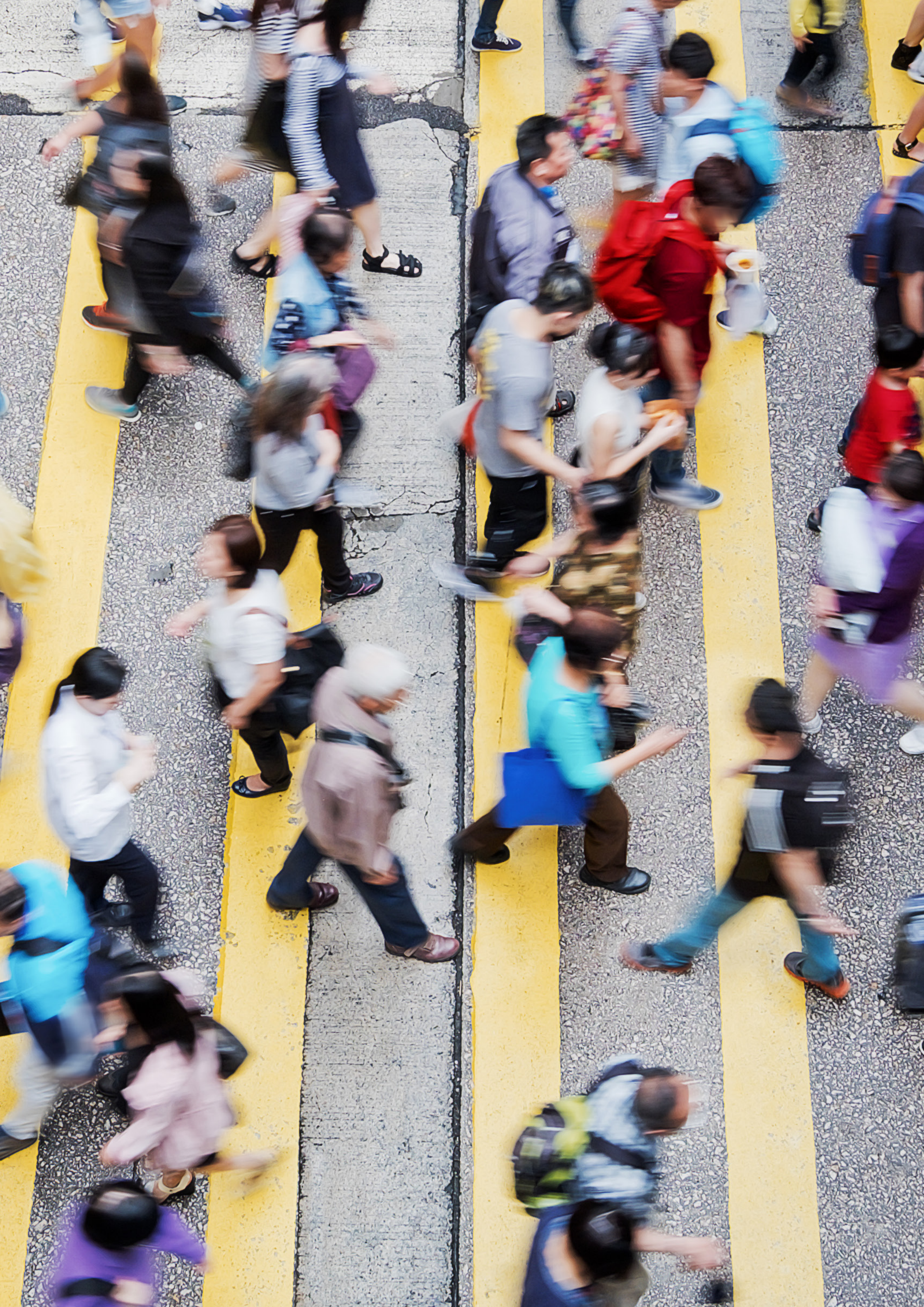
Regulations on tariff

Electricity sector in China is undergoing deregulation, though throughout the process, the Electricity tariffs are expected to be regulated. Following table provides information on electricity tariffs in various regions with the service fee [110]

Table 27: Electricity tariff and service fee for EV charging in major cities

Cities	Electricity tariff (CNY/kWh)	Service fee (CNY/kWh)
Beijing	Peak: 1.004, Normal: 0.6950, Valley: 0.3946	0.8
Shanghai	**Summer** Peak: 1.138, Normal: 0.710, Valley: 0.268 **Off-summer** Peak: 1.113, Normal: 0.685, Valley: 0.333	1.3
Wuhan	0.6348	0.95
Nanjing	0.667	1.44
Tianjin	0.7109	1
Hefei	0.675	0.75 (DC Charging), 0.53 (AC Charging)
Yantai	0.5146	0.65
Taiyuan	0.5292	0.45

[110] China – National Energy Administration; https://blog.cometlabs.io/china-expands-ev-charging-to-satisfy-millions-of-evs-on-the-road-d6c977da9a31



2 EV charging infrastructure landscape: India

Electric mobility market of India differs from those of the countries having higher levels of penetration of electric vehicles and mature market conditions. The difference is primarily due to various aspects such as geographical area, public policy, social norms as well as economy. Heterogeneous development in urban areas, large population, low availability of public infrastructure and low affordability pose several barriers to mass scale adoption of e-vehicles.

In order to address the barriers, governments at both central and state levels have taken proactive steps. Initiatives such as National Electric Mobility Mission Plan (NEMMP) and Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles (FAME) have been crucial in increasing the participation of private sector in electric mobility space. In addition, MOP's landmark clarification that operation of charging infrastructure shall not be considered as resale of electricity has further given a boost to the sector.

In addition to the policy and regulatory initiatives, standardization plays a critical role in proliferating uptake of any technology.

However, as per the observations in globally mature markets, resorting to a technology agnostic approach (allowing adoption of standards as per market conditions) has been a key strategy for increasing the market uptake. Accordingly, stations can provide all options (Bharat charger AC001, DC001, CHAdeMO, CCS and GB/T) to EV users on a common board/kiosk.

Responding to the proactive approach of the policy makers, the electric mobility market has witnessed strategic partnerships between the various players of the EV supply chain. This has been done with dual objectives of diversifying product portfolio and reducing operational risks thereby increasing readiness of the industry to respond to the electric mobility disruption.

Accordingly, the section below briefs about the policy and regulatory framework for electric mobility in India, assesses the supply chain readiness of automotive players and reviews the standardization landscape of India as compared to global markets. Based on this, recommendations have been made on policy level initiatives, on key strategies for collaborations between supply side players and on the most prevalent standards for EVs, EVSE and testing standards.

2.1.

Policy landscape in India

India's sustained commitment towards an improved energy security, green house gases (GHG) emissions and air quality has initiated a paradigm shift towards electric mobility in the nation. It is estimated that with the uptake of electric mobility, India will save US$330 billion[111] (INR20 lakh crore) on oil imports by 2030. Furthermore, this shall result in 300 MT of reduction in CO2 emissions by 2030[112] .

2.1.1. Institutional framework

Electric mobility initiatives in India, initially, were led by the Ministry of Heavy Industries and Public Enterprises (MoHIPE) which launched National Electric Mobility Mission Plan (NEMMP) in 2013 and Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) scheme in 2015.

[111]FICCI - http://ficci.in/spdocument/20975/RMI-Report-20-Nov.pdf
[112]Planning Commission of India (Now NITI Aayog) http://planningcommission.nic.in/sectors/index.php?sectors=National%20Transport%20Development%20Policy%20Committee%20(NTDPC)

Later, it was realized that electric mobility is a complex area with linkages across each segment of energy and transport value chain. Hence, in order to approach a multi-stakeholder scenario, various government ministries were roped in. NITI Aayog has been given the responsibility to anchor the EV policy roadmap for India. The figure below highlights the key roles played by various ministries:

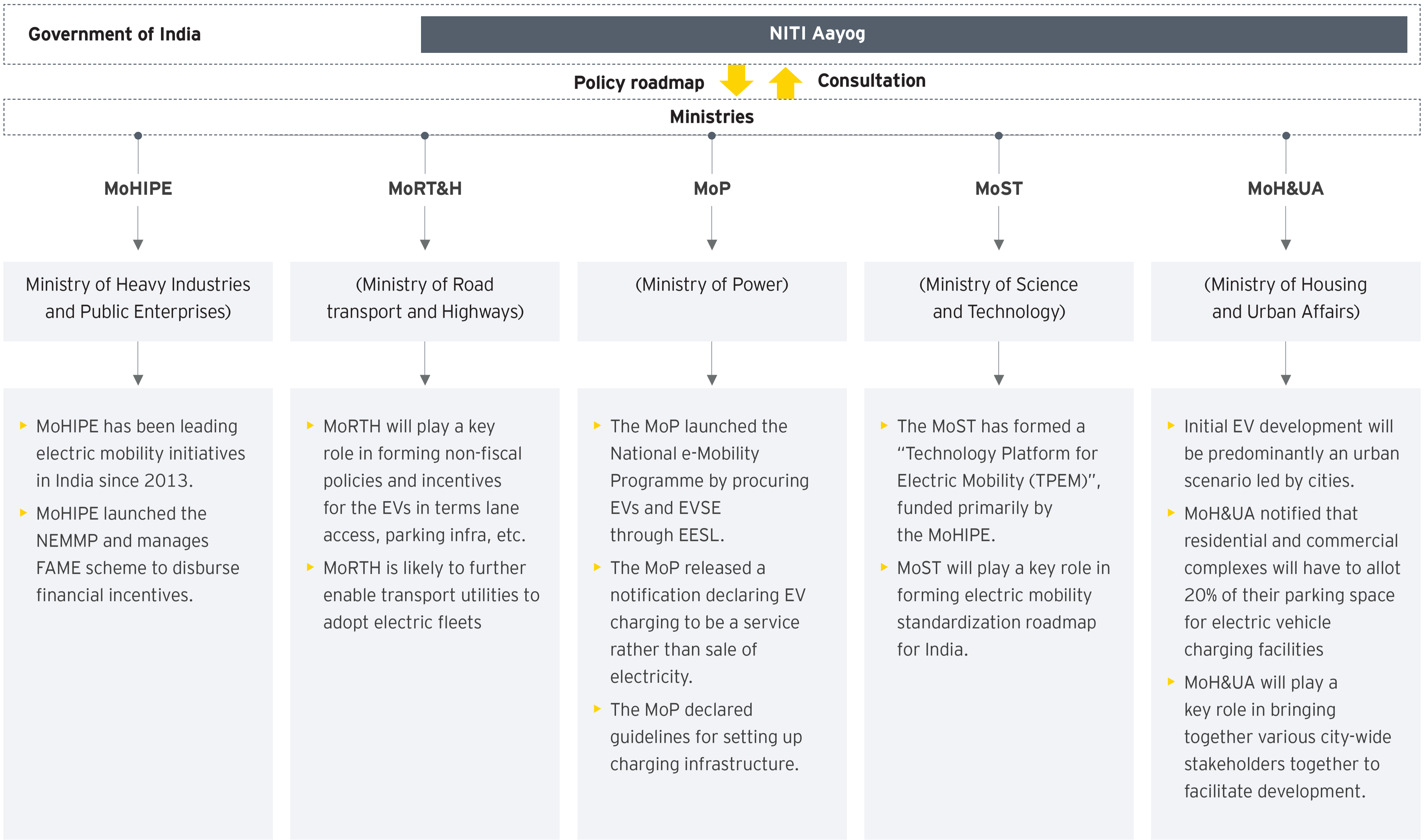


Figure 24: Key role played by various ministries in India[113]

[113]EY Analysis

2.1.2. Policy roadmap

In 2010, the Ministry of New and Renewable Energy (MNRE) first launched the Alternate Fuels for Surface Transportation Program which was followed by National Electric Mobility Mission Plan (NEMMP) in 2013. NEMMP laid the foundation of electric mobility developments in India by setting a goal to achieve 6-7 million EVs by 2020. The following table represents the electric mobility policy roadmap of India since its inception.

Table 28: Schemes by GoI for promoting EVs[115]

Key initiatives for electric mobility proliferation			
S.no.	Initiative	Timeline	Description

1	Alternate Fuels for Surface Transportation program	2010	▸ The program promotes research, development and demonstration projects on electric vehicles.
			▸ Incentives given include:
			  ▸ Package worth INR950 million was provided
			  ▸ 20% on the ex-factory prices of electric vehicles

2	National Electric Mobility Mission Plan (NEMMP)	2013	▸ NEMMP envisaged a total investment of US$6-US$7 billion for the promotion of electric mobility with investments in R&D and electric vehicle infrastructure.
			  ▸ Proposed investment by the government is US$2.7-US$3 billion.
			  ▸ Proposed investment by private sector US$4-US$4.5 billion.
			▸ Demand incentives have been included in government investments.
			▸ Target to achieve 6 to 7 million on road electric vehicles by 2020.
			▸ The vehicle target will enable fuel savings of 2.2 to 2.5 million tonnes.
			▸ Savings from the decrease in the consumption of liquid fossil fuel as a result of a shift to electric mobility alone will far exceed the support provided, thereby making this a highly economically viable proposition.
			▸ Carbon dioxide emissions as a result of vehicular emissions will decrease by 1.3%-1.5% in 2020.
			▸ Develop phase-wise strategy for research and development (R&D), demand and supply incentives, manufacturing and infrastructure upgrade.

3	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles	2015 Phase 1: 2015- 2017 (extended till September 2018) Phase 2: 2019 – 2023 (Expected)	▸ The program promotes research, development and demonstration projects on electric vehicles. ▸ Incentives given include: ▸ Package worth INR950 million was provided ▸ 20% on the ex-factory prices of electric vehicles ▸ By 2017, under the government's FAME I scheme, incentives worth INR211.74 crores (~US$31.6 million) have been disbursed[114] . ▸ 11 cities across India were selected for pilot projects to promote electric vehicle developments. These include:

[114]Government of Uttar Pradesh - https://niveshmitra.up.nic.in/Documents/DraftPolicies/Uttar_Pradesh_Electric_Vehicles.pdf
[113]EY Analysis

<table>
<tr><th colspan="4">Key initiatives for electric mobility proliferation</th></tr>
<tr><th>S.no.</th><th>Initiative</th><th>Timeline</th><th>Description</th></tr>
<tr><td></td><td></td><td></td><td>

390 electric buses
370 electric taxis
720 electric autos
INR40 crores for charging infrastructure
The following subsidy will be provided based on the vehicle class

<table>
<tr><th></th><th>Vehicle segment</th><th>Minimum subsidy</th><th>Maximum subsidy</th></tr>
<tr><td>Scooter</td><td>Two-wheeler</td><td>INR1,800</td><td>INR22,000</td></tr>
<tr><td>Motorcycle</td><td>Two-wheeler</td><td>INR3,500</td><td>INR29,000</td></tr>
<tr><td>Auto rickshaw</td><td>Three-wheeler</td><td>INR3,300</td><td>INR61,000</td></tr>
<tr><td>Cars</td><td>Four-wheeler</td><td>INR11,000</td><td>INR1,38,000</td></tr>
<tr><td>Light commercial vehicle (LCVs)</td><td>Light commercial</td><td>INR17,000</td><td>INR1,87,000</td></tr>
<tr><td>Buses</td><td>Buses</td><td>INR3,00,000</td><td>INR66,00,000</td></tr>
</table>

FAME II scheme, with a subsidy package of INR9,381 crores (~US$1.4 billion), is expected to be launched for a period of five years from 2018-2023.

</td></tr>
<tr><td>4</td><td>Clarification on charging infrastructure for electric vehicles</td><td>2018</td><td>
The MoP clarified that EV charging will be considered a service and not a resale of electricity.
The charging of battery involves utilization of electrical energy which gets stored in the battery. Thus, the charging of battery of an EV involves a service by the charging station and earning revenue from the EV's owner.
The electricity is consumed within the premises owned by the charging station and hence is not a sale of electricity.
This landmark notification has opened the charging infrastructure market and within a month of the notification, various projects were launched within the country.
</td></tr>
</table>

[114]Government of Uttar Pradesh - https://niveshmitra.up.nic.in/Documents/DraftPolicies/Uttar_Pradesh_Electric_Vehicles.pdf
[115]EY analysis

State electric mobility policies

In addition to the central level initiatives, various states have also announced dedicated policies for increasing EV market uptake. Key highlights of these policies are mentioned below:

Table 29: Policies and schemes promoting EVs in India [116]

<table>
<tr><th colspan="6">State policy</th></tr>
<tr><th>S.no.</th><th>Policy/ initiative</th><th>Timeline</th><th colspan="3">Description</th></tr>
<tr><td>1</td><td>Karnataka</td><td>2017</td><td colspan="3">
- Separate tariff has been included (4.85/kWh) for EVs
- Government of Karnataka intends to make Karnataka the EV capital of India and aims to achieve 100% electric mobility by 2030 in the following segments:
  - Auto rickshaws
  - Cab aggregators
  - Corporate fleets
  - School buses/vans
- Karnataka aims to attract investments of INR31,000 crores
- Four strategies defined by the state are:
  - Special initiatives for EV manufacturing
  - Support for charging infrastructure
  - Support for R&D and skill development
  - Incentives and concessions
- State transport - BMTC, KSRTC, NWKSRTC and NEKRTC will introduce 1,000 EV buses during a time period of five years.
Support for charging infrastructure
- **Certifications/standards:** the government will encourage private players to set up ARAI compliant/BIS standards EV charging infrastructure.
- **Land identification and leasing:** the government will identify potential places and allocate government lands wherever available on long lease for setting up of EV fast charging stations and battery swapping infrastructure by following a transparent bidding process.
- **Subsidy:** the government will offer incentives in the form of capital subsidy based on the type of charging stations.
</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Fast charging stations
Battery swapping stations</td><td>Battery swapping stations</td></tr>
<tr><td></td><td></td><td></td><td>Eligibility</td><td>First 100 stations</td><td>First 100 stations (2W/3W)
First 50 stations (4W)
First 50 stations (buses)</td></tr>
<tr><td></td><td></td><td></td><td>Subsidy amount</td><td>25% on equipment and machinery (maximum INR10 lakhs per station)</td><td>**2W/3W swapping station**
25% on equipment and machinery (maximum INR3 lakhs per station)</td></tr>
</table>

[116]State Policies; EY analysiss

Key initiatives for electric mobility proliferation			
S.no.	Policy/ Initiative	Timeline	Description

			4W swapping station
			25% on equipment and machinery (maximum INR5 lakhs per station)
			Buses swapping station
			25% on equipment and machinery (maximum INR10 lakhs per station)
			- **Building code amendments:** the amendments will be made to building bye-laws for providing charging infrastructure for EVs in all high-rise buildings/technology park/apartments in the state.
			- The government has exempted EV users from paying taxes on all electric non-transport and transport vehicles including e-rickshaws and e-carts.
			Incentive and concessions for EV and component manufacturing enterprises
			- Investment promotion subsidy
			  - For micro enterprises: 25% of the value of fixed assets (maximum INR15 lakhs)
			  - Small enterprises: 20% of the value of fixed assets (maximum INR40 lakhs)
			  - Medium manufacturing enterprises: INR 50 lakhs
			- 100% exemption from stamp duty on loan agreement, credit deeds, hypothecation deeds, etc.
			- Concessional registration charges for all loan documents and deeds.
			- 100% reimbursement of land conversion fee from agriculture to industrial use.
			- Subsidy for setting up effluent treatment plant (ETP).
			  - One-time capital subsidy up to 50% of the cost of ETP, subject to a ceiling of INR50 lakh till medium level enterprises and INR 200 lakhs for large and above enterprises.
			- Exemption from tax on electricity tariff.
			- Interest free loan on net SGST to large and above large-scale enterprises for certain number of years.

2	Maharashtra	2018	**Incentive and assistance for EV charging** - **Separate tariff** has been included (2.06 /kWh) for EVs. - **Common charging points** in residential areas, societies, bus depots, public parking areas, railway stations, fuel pumps, etc. will be allowed. After the receipt of the application for setting up a charging point, the concerned planning authority and electricity supplying agency shall grant the permission within 15 days. - **Petrol pumps** will be allowed to setup charging stations freely subject to the areas qualifying under fire and safety standard norms under relevant acts/rules. - **Commercial public EV charging stations** for two-wheelers, two-wheelers, cars and buses will be eligible for 25% capital subsidy on equipment/machinery (limited up to INR10 lakhs per station) for the first 250 commercial public EV charging stations. - As per the requirement, the facility of robotic battery swapping arm will be created at public bus stations.

<table>
<tr><th colspan="8">Key initiatives for electric mobility proliferation</th></tr>
<tr><th>S.no.</th><th>Policy/ Initiative</th><th>Timeline</th><th colspan="5">Description</th></tr>
<tr><td rowspan="5"></td><td rowspan="5"></td><td rowspan="5"></td><td colspan="5">Incentives and provisions for EV buyer
▸ The following incentives (user subsidy) in addition to central subsidy will be provided to the private/public passengers whose vehicles are registered in the state over a policy period of five years
▸ Exemption from road tax and registration fees for electric vehicles.</td></tr>
<tr><td></td><td>2-wheeler</td><td>3-wheeler</td><td>4-wheeler</td><td>5-wheeler</td></tr>
<tr><td>Eligibility</td><td>First 70,000 EVs</td><td>First 20,000 EVs</td><td>First 10,000 EVs</td><td>First 1,000 EVs</td></tr>
<tr><td>Subsidy on base price</td><td>15% (maximum limit of INR5,000 per vehicle)</td><td>15% (maximum limit of INR12,000 per vehicle)</td><td>15% (maximum limit of INR1 lakh per vehicle)</td><td>10% (maximum limit of INR20 lakhs per vehicle)</td></tr>
<tr><td>Subsidy Realization</td><td>3 months from the purchase date</td><td>3 months from the purchase date</td><td>3 months from the purchase date</td><td>3 months from the purchase date</td></tr>
<tr><td>3</td><td>Delhi</td><td>2017</td><td colspan="5">Separate EV tariff has been included (5.5/kWh) for kWh for LT and HT connection</td></tr>
<tr><td>4</td><td>Telangana</td><td>2017</td><td colspan="5">▸ Telangana State Transport Corporation has set a target of 100% electric buses by 2030 for intra-city, intercity and interstate transport (key milestones – 25% by 2022, 50% by 2025 and 100% by 2030).
▸ Government vehicles (owned and contractual) are planned to switch to electric by 2025, in a phased manner. Contract carriage permits will be given to private operators with EV fleet operations.
  ▸ Corporate offices with annual turnover of INR100+ crores operating within Greater Hyderabad Municipal Corporation (GHMC) limits to compulsorily migrate 25% of their employee commuting fleet to EVs by 2022 and 100% by 2030.</td></tr>
<tr><td>5</td><td>Andhra Pradesh</td><td>2017</td><td colspan="5">▸ Separate tariff has been included (INR6.95 /kWh) for EVs.
▸ The state government is seeking to attract investments of INR30,000 crores in the EV industry by providing capital subsidies to automakers and charging-equipment manufacturers.</td></tr>
<tr><td>6</td><td>Gujarat</td><td>2017</td><td colspan="5">▸ 1000 EV buses will be introduced by the state by 2030, in different phases Separate tariff has been included (INR4.1/kWh) for EVs.</td></tr>
<tr><td>7</td><td>Uttar Pradesh</td><td>2018</td><td colspan="5">▸ 1000 EV buses will be introduced by the state by 2030, in different phases - 25% in phase I by 2020, remaining 35% in phase II by 2022 and the rest (40%) in phase III by 2030.
▸ UP will incentivize manufacturing of Lithium batteries with higher mileage per charge. The state will also incentivize manufacturing of hydrogen-powered fuel cells and solar powered cells, as an alternative clean energy source.
▸ The state government will also provide 100% road tax exemption for EVs purchased in Uttar Pradesh.</td></tr>
</table>

To give a further boost to EV demand in India, there is a need for the policy level initiatives to focus on financial and non-financial incentives. These incentives need to be supported at central, state and city levels. The early adopters will be primarily from urban areas with major sales coming from the metro cities because of large population and high-incomes. Hence, city level policies will play an important role in the development of EV ecosystem in India.

To meet this objective, each state has started preparing its policy document for EV. This policy document shall define clear guidelines, targets and roadmap to all the stakeholders. The policy should incentivize stakeholders (manufacturers, user, service providers, etc.) across value chains to attract investments in different states.

Some of the key incentives that can be considered by the central and various state governments (if not taken into consideration) have been covered in the following section:

2.2. Policy level recommendations

Table 30: Recommended incentives[117]

S.no.	Incentive	Vehicle segment	User	Responsible agency	Recommendations
Fiscal measures					
1	GST	All	All	Central and state	▸ The GST rate for EV may be brought down from 12%. ▸ If the above is not feasible, then state government may exempt SGST.
2	Road tax	All	All	Central and state	▸ The road tax should be fully exempted in EV for the first few years. ▸ The above amendment in Motor Vehicle Act can act as an enabler.
3	Financing interest rate	All	All	Central and RBI	▸ Setting up manufacturing units, charging stations and EV purchase can be considered under priority sector lending.
4	Income tax benefits	All	Institution corporates	Central	▸ The EV buyer can avail accelerated depreciation of 40% similar to the solar sector ▸ The EV charging stations can be promoted with solar or energy storage solutions to avail such benefits.
Non-fiscal measures					
5	Power tariff	All	All	State	Following tariff changes might be adopted by India: ▸ Relaxing the additional fixed/demand charges coming from EVs for all connection categories. This could be time bound for the first five years and on evaluation, it can be extended further. ▸ For (not-for-profit) home and office/work charging, allowing an option to move to three-phase connection with TOD tariff or continue with the same tariff category.

S.no.	Incentive	Vehicle segment	User	Responsible agency	Recommendations
					▸ For (profit) commercial EV charging or EV leasing as a service (with some minimum number of chargers or kW load), allowing new separate meter under new EV tariff category. This tariff category to be kept competitive like Delhi order of fixed 5 and 5.5 INR/kWh for LT and HT connections. Keeping this tariff tied to average cost of supply (ACoS) of Discoms and allowing maximum loading of 10%-15% for AT&C losses could be a good way for all states to support. ▸ Also allowing such businesses to mark up their charging services prices (including electricity) at market rates ▸ Allowing such businesses to opt for an easy open access (if meeting minimum kW load requirements).
6	Toll charges	All	All	State	▸ This can be exempted for EV buyers till year 2022-23.
7	Entry tax	PV and buses	Commercial	State	▸ The state entry taxes may be fully exempted.
8	Parking Fees	All	All	State	▸ The parking fees may be exempted for types of EVs.
9	Permits	3W and PV	Commercial	State	▸ The permit cost may be fully exempted
10	2W/3W taxi	2W/3W	Commercial	Central and state	▸ Motor Vehicle Act may be amended to allow 2W and 3W as fleet/taxi business and allow corporate ownership.
11	Green plates	All	All	Central	▸ The green plates can be given to EV buyers. Some EVs (cars, buses) with green plates could be given access to dedicated lanes and parking areas.

In addition to the policy level initiatives, regulatory level push is also critical to address the barriers faced by stakeholders at each step of the e-mobility value chain. The next section identifies current regulations regarding e-mobility space in India.

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S.no.	Stage in setting up EV charging infrastructure	Regulatory framework				
		Regulation	Article	Center/ state level	Verbatim	Description
3	Right of way	Electricity Act, 2003[120]	PART VIII - Works of licensees	State (DISCOM is a state subject)	Section 67. (Provisions as to opening up of streets, railways, etc.): Section 68. (Provisions relating to overhead lines): Section 69. (Notice to telegraph authority).	The act defines the provisions to obtain right of way as per the Sections 67, 68 and 69.
4	Other approvals	Supply code	2. and Annexures - Form A1	State	Application for power supply/additional power supply. A-1 application form (To be used for residential and other connections except Agriculture and industrial.	Relevant forms that an individual or entity needs to fill for placing a request for connection to a distribution utility.
5	Safety and standards and quality of hardware	CEA (2010 and later amended), supply code (state) and electricity rules 2005 and draft regulations of Distributed Generation Resources ,[121] [122]	Supply code - 9, 10 and 11	Center and state	9. DISCOM-specific supply mains and apparatus. 10. Wiring on consumer's premises 11. Consumer's apparatus	As per the provisions of the supply code, electricity rules and distributed generation resources regulations, the standards for connectivity of a charging station to distribution infrastructure needs to be ensured.
6	Installation implementation and cost of incurrence by DISCOM	conditions for determination of wheeling tariff and retail supply tariff regulations, 2011 [123]	5.6	State	Return on Capital Employed (RoCE) shall be used to provide a return to the Distribution licensee shall cover all financing costs, without providing separate allowances for interest on loans and interest on working capital.	As per the provisions of state-level conditions for determination of tariff which suggests methodology for calculation of return on capital employed (RoCE

[120]Central Electricity Authority (CEA) http://www.cea.nic.in/reports/regulation/draft_tech_std_dgr_2018.pdf (last
[121]Central Electricity Authority (CEA) http://www.cea.nic.in/reports/regulation/draft_tech_std_dgr_2018.pdf (last accessed 07 Aug. 18)
[122]Central Electricity Authority (CEA) http://www.cea.nic.in/reports/regulation/draft_tech_std_dgr_2018.pdf (last accessed 07 Aug. 18)

S.no.	Stage in setting up EV charging infrastructure	Regulatory framework				
		Regulation	Article	Center/ state level	Verbatim	Description
7	Tariff determination methodology	Draft Amendments to National Tariff Policy 2016 [124]	8.3	Center	(a) Tariff shall be less than or equal to the average cost of supply determined based on AT&C loss level of 15% or actual, whichever is lower, an (b) there shall be single part tariff for this purpose in the initial three years.	The proposed amendments to National Tariff Policy, 2016 vide letter number 23 February 2018, the R&R specifies that tariff for charging the station's operations should not be a two-part tariff but a single part and the tariff should be the average cost of supply of DISCOM with an assumption of 15 % AT&C losses blended into it.
8	Tariff setting	Electricity Act (EA), 2003	U/S 86	State	a) Determine the tariff for generation, supply, transmission and wheeling of electricity, wholesale, bulk or retail, as the case may be, within the state.	State Electricity Regulatory Commission has been empowered by EA 2003 to determine the tariff as per the ARR filed.
9	Standard for metering	Installation and Operation of Meter Regulations, 2006	Part III	Center	The consumer meter may have the facilities to measure, record and display one or more of the parameters depending upon the tariff requirement for various categories of consumers.	Existing provisions, as mentioned in supply code, with reference to metering regulations mentions the parameters to be measured for consumer meter

[123]Delhi Electricity Regulatory Commission (DERC) - http://www.derc.gov.in/regulations/dercregulations/Regulations2011/Distribution.pdf
[124]Ministry of Power - https://powermin.nic.in/sites/default/files/webform/notices/Proposed_amendments_in_Tariff_Policy_0.pdf

S.no.	Stage in setting up EV charging infrastructure	Regulatory framework				
		Regulation	Article	Center/ state level	Verbatim	Description
10	Future EV charging infrastructure investments by DISCOM	EA 2003 and Treatment of income from other business	U/S 51	Center and state	A distribution licensee may, with prior intimation to the appropriate commission, engage in any other business for optimum utilization of its assets: Provided that a proportion of the revenues derived from such business shall, as may be specified by the concerned state commission, be utilized for reducing its charges for wheeling.	With consent of SERC, the DISCOMs can invest in deployment of charging infrastructure and maintain books as per the regulations for non-tariff income specified by SERCs
11	Retail pricing/ tariff to EV users	Clarification on charging infrastructure for electric vehicles	4	Center	Charging of batteries of electric vehicles by charging station does not require any license under the provisions of the Electricity Act, 2003	Clarification note of the MoP specifies charging of EV is a service and does not require any license. This enables operator of charging infrastructure to charge innovative pricing to EV users such as INR/kWh, INR/km, INR/min, etc.

Apart from the policy and regulatory level initiatives, effective modes of collaborations between market players is crucial to improve the operational efficiency and increase overall business viability. Accordingly, identification of key risks for suppliers of technology products and for service providers in the e-mobility value chain is critical. The section below tries to identify the current readiness of supply side players for the e-mobility disruption. Accordingly, possible modes of collaborations for mitigating key risks have been suggested.

2.4.

EV supply chain readiness and R&D in India

The large volumes of electric vehicles are bound to disrupt the existing supply chain of the automotive industries. This transition from ICE to electric engines is also likely to open new opportunities for the technology companies and start-ups. Hence, the established players need to re-invent themselves to adopt to new EV technology before they start losing their businesses.

The design complexity in EV is less compared to ICE vehicles because of the involvement of less moving parts. This may lead to the commoditization of the vehicle once the technology matures. In such a case, it is important for the existing players to increase their value proposition in order to differentiate their offerings in the market. These offerings may include owning dedicated charging stations and providing free charging, warranty, post-sales service and other relevant services.

In order to differentiate product offerings, reduce possible risks due to market disruption and improve operational efficiency, various players in the supply chain have adopted different modes of collaborations. The section below highlights the various components in the EV supply chain, impact of e-mobility's uptake on the existing automotive value chain and possible modes of collaborations.

2.4.1. Components of EV supply chain

Electric vehicle manufacturing: EVs penetration in India is happening at various levels - individual (2-wheeler, 4-wheeler), commercial (3-wheeler, 4-wheeler fleet, buses) public (intra-city and inter-city buses) and goods and logistics (2-wheeler, 3-wheeler, 4-wheeler) vehicle segments. Existing and new vehicle manufacturers are launching and developing new models.

Lithium-Ion batteries (LIB): the heart of any EV is battery. This is the single largest component in the EV cost. The cell-level chemistry, battery packs and thermal management will play a critical role in the overall performance of the vehicle. Some key battery performance parameters are range (distance travelled per charge), density (weight and volume per kWh), battery capacity degradation with usage, maximum charging and discharging power, fast charging time and battery life cycles. There is trade-off between cost and different battery characteristics. NMC battery is the cheapest, LTO costliest, and LFP is in between the two in terms of cost and also performance.

Electric motors: the internal combustion engines will be replaced by electric motors. Motor technology will define the key characteristic of the vehicle performance such as top speed. To communicate between motors and other vehicle components will be achieved through sophisticated controllers and microprocessors. Both brushless DC (BLDC) and AC traction motors are currently prevalent in the market. Though BLDC motors have a better control and are more efficient, but the use of permanent magnets make them costlier, and they pose risk to supply chain with higher volumes. Some new innovations in motors design like Switch Reluctance Motors (SRM) are in R&D stage. SRM motors do not need permanent magnets, but have fairly complex design and are difficult to control.

Chargers: the design of the chargers would depend upon the type of vehicle (2W, 3W, 4W and buses), which in turn depends on the selection of batteries, vehicle electronics and system architecture. EVs can be charged using AC or DC charger. When charged using AC charger, the vehicle will need an on-board charger to convert the AC into DC and then charge the batteries. The power level of the charger and ability of the EV to use that power level will determine the speed with which full charging will take place. Usually AC chargers provide slow charging (four to eight hours), while DC chargers can charge fast (0.5 to 2 hours). Usually, for high power charging, communication protocols between charger-grid and between charger-EV are needed, to ensure proper safety during charging. India has adopted AC-001 (15A, 3.3kW, IEC 60309 connector) and DC-001 (200A, 15kW, GB/T 20234 connector) for low voltage EV applications. India is in the phase to define similar standards for medium and high voltage applications. The EV chargers would create more demand for inverters and DC-DC converters, going forward.

Charging network operator: this is an open ground for all the market participants. There will be a huge demand for the charging infrastructure on most city roads and also on highways. A good charging facility and demand aggregation strategy would be critical for the success of the charging infra business. Accordingly, different ownership models (private, public, PPP), price determination, bundling strategies (INR/full-charge, INR/km, INR/min, INR/kWh, subscription, etc.) and payment options shall emerge. All chargers and charging stations shall be new additions on the grid and it is important that the grid gets some signal on the charging demand to be able to optimize peak-load management. This data management and analytics around EV charging for improved grid management shall emerge as a new business opportunity.

Post-sales support: the elimination of engines from EV may decrease the demand of consumable items such as lubricants and oil, and also bring down the after-sales maintenance cost. New EVs will have more electronic parts and will require skilled labors and skill up (gradation/training) of the existing workforce.

Re-cycling: different OEMs are giving different warranties on battery life ranging from three to eight years[125]. EVs, being new in India, have not generated enough legacy data on performance of Lithium-Ion batteries (LIBs) in Indian charging and discharging conditions (road, use, temperature, etc.). These parameters have high impact on battery's life cycle use and capacity degradation. It is expected that once LIBs complete useful life cycles in EVs, they can still be used for stationary applications, before being taken up for final recycling. Re-cycling with current technologies can extract 80%-100% of existing precious material used in the cells/batteries[126], and provide an important link to mitigate the risk of supply of precious metals for manufacturing the new cells/LIB.

2.4.2. Impact of EVs on automotive supply chain

The map given below represents the impact of EVs on automotive supply chain. This may be helpful in identifying the focus areas, and in planning investments for portfolio diversification and capacity building.

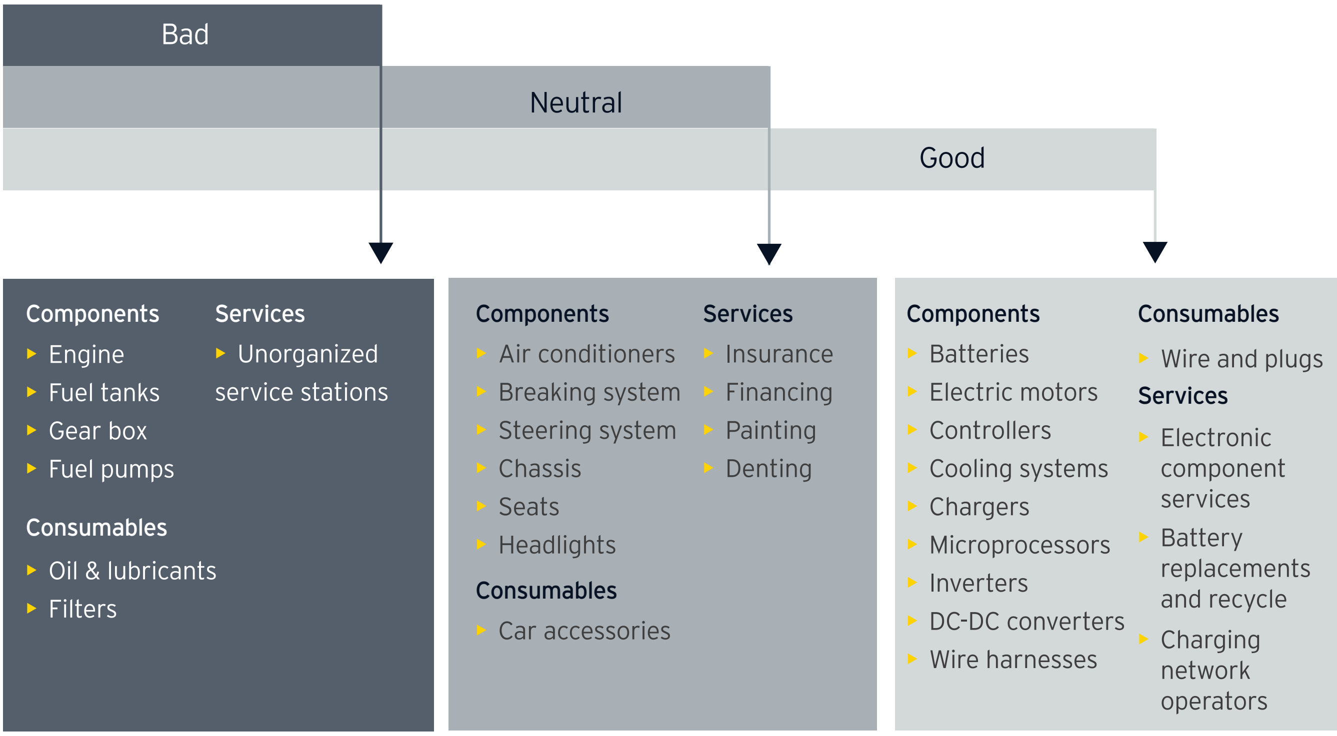

Figure 25: Impact of EVs on automotive supply chain[127]

[125] Inside EVs - https://insideevs.com/tesla-model-3-battery-warranty-include-70-retention-guarantee/
[126] Li-Cycle - https://www.li-cycle.com/blog
[127] EY analysis

The EV market uptake is also expected to boost demand of the following raw materials:

- **Aluminum:** the use of light weight materials for better vehicle dynamics to compensate for heavy weight batteries.
- **Copper:** the use of electric motors and need of wiring harnesses.
- **Carbon fibre:** lightweight material suitable for better vehicle dynamics. However, high prices will keep the demand in check.
- **Lithium:** the primary component used in the manufacturing of Lithium-Ion batteries.

It is evident from the above discussion that value addition by the OEMs will shrink as EVs' business grow. To protect their interest, OEMs need to focus on in-house battery development and manufacturing to retain their share in the total value chain.

The impact on value chain will be also be dependent upon the design strategy adopted by the automobile companies. This strategy could be conversion design or purpose design. Conversion design is based on conventional car concepts. In this design, the conventional architecture is retained and only the electric motor replaces the IC engines. The body structures may be modified. The biggest advantage of this strategy is economies of scale and less initial investments in R&D and production line. This strategy is likely to be adopted by most of the players as a market strategy for entry.

On the other hand, the objective of purpose design is to develop new vehicles which allow more innovations, features and functionalities. The design is developed particularly to meet the needs of electric mobility. Hence, the selection of design strategy will have an impact on the value chain of the automobile manufacturers and their ability to differentiate their product offerings.

The disruption in the supply chain may have implications on the logistics management as well. Earlier, it was easy to manage the movement of goods but in case of EVs' batteries, it would pose new challenges. The EVs' battery is costly, heavy and bulky and contains hazardous chemicals. Hence, the distance between the battery factories and assembling units would be important to keep logistic, freight and insurance costs under control.

2.4.3. Modes of collaborations

As discussed above, battery technology and logistics management would be a key to success. Some of the strategies that can be adopted by the automobile manufacturers to stay relevant in the industry are highlighted below:

1. Joint venture: for e.g., the automobile and battery manufacturer enter into a joint venture.

2. Acquisition: for e.g., the automobile manufacturer acquires the battery manufacturer.

3. Vertical integration: the automobile manufacturer develops and in-house R&D team and production line.

4. Strategic suppliers: the automobile manufacture continues to procure batteries from their strategic local and global players.

Accordingly, different stakeholders have already taken such initiatives to increase their product offerings and reduce supply side risks. The section below highlights various strategic measures taken by EV component manufacturers, OEMs, fleet aggregators and charging station operators.

2.4.4. EV component and their manufacturers

The manufacturing of EV components is witnessing several collaborations across the globe. Indian market is geared up to embrace electric mobility. Though manufacturers grapple with scale, they are still seeking active support from the government to lower the upfront costs for end users. Some manufacturers are also collaborating with operators to assure demand and improvize the existing products.

Table 31: EV component manufacturers[128]

S.no.	EV component	Manufacturer's name	Key notes
1	Cells/battery packs	Tesla	▸ Signed exclusive partnership with Panasonic. ▸ Aims to reduce battery pack's cost by 30% for Tesla vehicles. ▸ The investment to establish Gigafactory is US$5 billion. The production capacity is 35 GWh.
2	Cells/battery packs	Panasonic	▸ Toyota partners to develop lithium batteries. ▸ Market leader in automotive Lithium-Ion battery cell suppliers.
3	Cells/battery packs	Automotive Energy Supply	▸ 2nd largest automotive Lithium-Ion cell supplier by market share.
4	Cells/battery packs	LG Chem	▸ 3rd largest automotive Lithium-Ion cell supplier by market share. ▸ The plant is located in Wroclaw, South Poland.
5	Cells/battery packs	Samsung SDI	▸ 4th largest automotive Lithium-Ion cell supplier by market share. ▸ Three global production units.
6	Cells/battery packs	Mahindra and Mahindra	▸ Partnered with LG Chem to develop cells exclusively for applications in India. ▸ The battery module and pack is expected to go into production line in the last quarter of 2019-20.
7	Cells/battery packs	Exicom	▸ Company plans to scale up the production capacity to 1 GWh in 2018-19. ▸ One of the largest supplier of Lithium batteries in India with current deployment of 600 MWh in storage applications.
8	Battery packs	Reliance	▸ There are reports that Reliance is looking to establish 25 GWh Gigafactory in India at an estimated investment of US$3.5 billion.
9	Motor	Borg Warner	▸ They have technology which has already received good response in Chinese market. ▸ In India, the company will invest locally when the demand picks up. There is no defined plan yet.
10	Motor	Hitachi	▸ They plan to sell technology to other customers as well. ▸ The investment is pegged at US$44.69 millions. ▸ Honda announced JV with Hitachi to design, develop and manufacture motors for future EVs.

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S.no.	EV component	Manufacturer's name	Key notes
11	Motor	BHEL	▸ Signed an agreement with Ashok Leyland and Tata Motors for developing a propulsion system for buses.
12	Chargers	Ather Grid	▸ Signed an agreement with Sanmina Corporation, a leading integrated manufacturing solutions company headquartered in San Jose, California. ▸ Manufactures slow AC home charger for their e-bikes. ▸ Manufactures fast DC chargers for their public charging stations.
13	Chargers	ABB	▸ Running pilot with nine OEMs. ▸ Installed 50kW fast charger in NITI Aayog's premises. ▸ Plans to setup 4,500 charging stations in India.
14	Chargers	Exicom	▸ Installed AC and DC charger in the MoP's office, Delhi. ▸ The company will supply 1,080 AC chargers of 3.3kW and 100 DC fast chargers of 15kW, which will be used to charge Tata Motors' Tigor and Mahindra & Mahindra's eVerito cars procured by Energy Efficiency Services Limited (EESL).
15	Chargers	Delta Electronics India	▸ Plans to make US$150 million investment in India ▸ Installs first 15 kW DC fast charger in Maharashtra Mantralaya ▸ BHEL and Delta to supply 100 DC chargers under EESL tender
16	Chargers	BHEL	▸ BHEL and Delta to supply 100 DC chargers under EESL tender
17	Chargers	SBD Green Energy and Infra	▸ To supply 720 AC chargers under EESL tender

Note:

1. This is not a complete list and the above information is provided to highlight the preparedness of the EV suppliers to meet the growing demand of EVs.
2. The other companies which participated in EESL tender for supplying EV chargers are Analogies Tech India, EVI Technologies, Imperial Engineering, Ornate Agencies, RRT Electro Power, Siemens, and VIN Semiconductors.

2.4.5. EV fleet and public charging station operators

Some of the key charging station operators in India are mentioned below:

Table 32: Key charging station operators in India[129]

S.no.	EV component	Number of cities	Number of cars	Number of charging stations	Key notes
1	OLA	Number of cities - 110 (only one city have EV operation	Fuel - 6,00,000 EVs - 65	Nagpur (4)	▸ Partnered with Mahindra Electric to pilot EV in Nagpur. ▸ IOCL to setup charging stations ▸ India's first charging station was established by Ola in Nagpur. ▸ Car charging took four to five hours due to which driver working hours increased significantly. ▸ Nagpur pilot investment was INR50 crores. ▸ Plans to add 10,000 EV in one year, majority being e-rickshaws.
2	Tata Power	Mumbai	-	Mumbai (12)	▸ Partnership with Tata Motors to support their EV deployment
3	Ather	Bangalore	-	Bangalore (30)	▸ Signed an agreement with Sanmina Corporation, a leading integrated manufacturing solutions company headquartered in San Jose, California. ▸ Sanmina will exclusively manufacture Ather's charging system, battery management systems and dashboards at its state-of-the-art manufacturing facility in Chennai, India. ▸ Free charging for the vehicle owners for first 12 months. ▸ Free charging shall be followed by monthly subscription fee towards charging, support and maintenance.
4	Lithium Urban cabs	Bangalore, New Delhi	EV- 400	Bangalore (70), Delhi (20)	▸ B2B strategy ▸ Plans to setup 60 public chargers across Delhi-NCR. State government to provide financial assistance. ▸ Plans to expand operations in Pune, Mumbai, Chennai and Hyderabad.

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S.no.	EV component	Number of cities	Number of cars	Number of charging stations	Key notes
5	SmartE cabs	Delhi-NCR, Gurugram, Faridabad	e-rickshaws-600 (Planned-1,000)		▸ Partnership with Delhi Metro to rollout e-rickshaws. ▸ Signed partnership with more than 15 organizations. ▸ Served more than 20 million passengers in the first two years of operation ▸ Make revenues from internal/external brandings in e-rickshaw.
6	Hyderabad Metro Rail Limited (HRML)	Hyderabad	-	24 (under implementation)	▸ Partnership with L&T and PGCIL ▸ This is done on a pilot basis to understand market response.
7	Bangalore Electricity supply company Ltd. (BESCOM)	Bangalore	-	11 (Under- Implementation-10)	▸ Charges end-users on ToD basis once approved by the state commission.
8	Fortum (Finnish Clean Energy Company)	No presence	-	None	▸ Fortum signed an MoU with NBCC (India) for developing changing infrastructure across India in an upcoming project. ▸ Plans to setup 150 charging stations in the next 12-18 months.
9	BSES	Delhi	-	2	▸ MoU with Indian Railways ▸ This will be a pilot project. Indian Railways will pay 8 cents/kWh as charging tariff once approved by the regulator.
10	Mahindra Reva electric	Bangalore, Pune, Delhi	-	Bangalore (25), Delhi (6)	▸ Installed under FAME scheme

Note:

1. This is not a complete list and some information provided above may differ. The data is consolidated to show efforts being made by various governments/private organizations to develop EV ecosystem in India.
2. EESL has deployed only 250 out of 500 EVs procured in Phase 1. Out of 250, 150 EVs are deployed in Delhi while 100 EVs in Andhra Pradesh. The slow pace of setting up charging station is the main reason for the delay in EVs' deployment. There are approx. 250 charging stations across India, out of which major deployments are in Delhi and Bangalore.

2.4.6. Key automobile players in India and their EV strategy

The key players in the automobile players in India and their EV strategies for India are highlighted below:

Table 33: Key automotive players in India[130]

S.no.	Automobile players	Vehicle category	EV running models	Key notes
1	Mahindra Electric	Four wheelers	eSupro (2) e20 Plus eVerito	▸ Zoomcar partners with Mahindra Electric to offer self-drive EV cars in Mumbai, Hyderabad, Mysore. ▸ Mahindra Electric has joined hands with Meru Cabs to deploy electric vehicles. ▸ LG Chem is Mahindra Electric's Lithium battery technology partner. ▸ Signs an MoU with Government of Maharashtra for EV manufacture and deployment. ▸ Partnered with Ola for Nagpur pilot. ▸ New EV SUV models to be launched soon. ▸ Plan to deploy 1,000 EVs in the next one year in Maharashtra. ▸ Surpassed 50 million electric km. ▸ Investment planned in next four years is INR900 crores starting 2017.
2	Tata Motors	Four wheelers	Tigor	▸ Has signed an MoU with Government of Maharashtra to deploy EV and setup charging infrastructure. ▸ Tata Motors to setup charging infrastructure with the help of Tata Powers. ▸ Entry Market strategy: conversion design ▸ Plans to deploy 1,000 EVs that includes both commercial and passenger vehicles. ▸ EESL Phase - 1,250 EV cars production completed ▸ Lowest cost bidder in EESL tender to procure 10,000 EVs. ▸ Work on more than a dozen EV solutions is in progress. ▸ Cars are manufactured exclusively for EESL. For public, to be launched soon.
3	Maruti Suzuki	Four wheelers	None (First expected EV is by 2020)	▸ In September 2017, Suzuki announced partnership with Denso and Toshiba for Lithium battery technology. ▸ In November 2017, partnered with Toyota Motor Corp to benefit from its electric car technology for Indian market. ▸ Plan to invest US$14.5 billion for the development of EV technology. ▸ The company is yet to commercially launch its EV.

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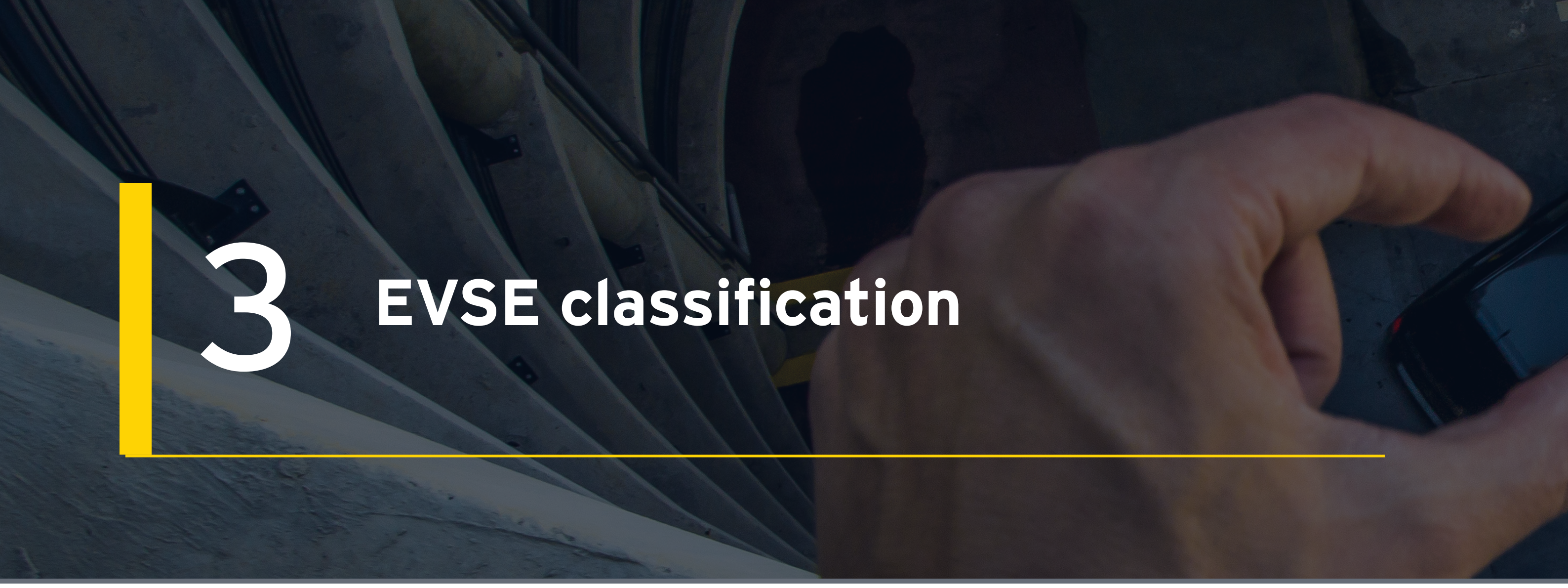
S.no.	Automobile players	Vehicle category	EV running models	Key notes
				▸ Market strategy: conversion design ▸ Plans to install charging stations in collaboration with its dealers and business partners. ▸ Plans to manufacture 35,000 units by 2020-21. ▸ In December 2017, announced a survey to understand customer preference.
4	Honda	Four wheelers	None	▸ General Motors and Honda announced an agreement for new advanced chemistry battery components, including the cell and the module. ▸ Launched EVs in the US and Europe in 2017. ▸ No plans to launch EVs in India soon. The reason cited are lack of clarity on its policy, especially EV charging. ▸ Honda revealed electric power packs to charge cars and scooter. User can swap the batteries as well.
5	Hyundai	Four wheelers	None (Expected to launch Ioniq EV or Kona EV by 2019)	▸ Plans to invest INR6,300 crores in India in next three years towards new products and offices, starting 2017. ▸ Will import first EVs as completely knocked down (CKD) units and assemble them at Chennai plants.
6	Nissan	Four wheelers	Nissan Leaf	▸ E.ON and Nissan formed a strategic partnership focusing on EV charging, Vehicle to grid (V2G) services and distributed renewables plus storage systems ▸ Three battery manufacturing units. ▸ Nissan Leaf is one of the highest selling electric cars in the world. ▸ Plans to import complete units in initial years.
7	Ashok Leyland	Buses	Circuit S	▸ Circuit-S is developed in partnership with Sun Mobility. It works on the principle of battery swapping. ▸ To supply 40 e-buses for Ahmedabad. ▸ 500 kg battery in the Circuit-S can be swapped in just two and a half minutes. ▸ The charging stations would be powered with solar energy to charge EV batteries. ▸ Procure batteries from suppliers across the world.
8	Tata Motors	Buses	Starbus (Hybrid) Ultra-Electric	▸ To setup charging stations in partnership with Tata Powers. ▸ To supply 190 e-buses to six cities.
9	Eicher Motors	Buses	Smart Electric Skyline Pro E	▸ Developed in collaboration with KPIT Technology. ▸ The buses are 9m in length.

S.no.	Automobile players	Vehicle category	EV running models	Key notes
10	Goldstone-BYD	Buses	eBuzz K6 Goldstone BYD K9 Goldstone BYD K7	▸ Golden Infratech is an Indian partner of Chinese Giant EV Manufacturer BYD. ▸ Present production capacity: 600 per year ▸ Present localization content: 35% ▸ Plans to manufacture 5,000 electric buses per year in India with 70% localization by March 2021. ▸ Plans to make India its manufacturing hub for exporting to South Asian markets. ▸ Made an investment of INR 500 crores in setting up a manufacturing unit in Karnataka. ▸ Plans to manufacture 7m, 9m and 12m buses. ▸ To start assembling Lithium battery packs in India by 2018. ▸ To setup their own charging infrastructures along the bus routes. ▸ Buses in Operation: 31 ▸ To supply 290 e-busses in three cities Mumbai, Bangalore and Hyderabad. ▸ The investment of INR 100 crores has been made so far.
11	Ather Energy	Two-wheelers	Ather 340 Ather 450	▸ Start-up backed by Hero MotoCorp with investment of INR205 crores. ▸ Received funding from the founders of Tiger Global and Flipkart Founders. ▸ The hardware start-up was founded in 2013 by IIT Madras. ▸ Plans to setup chain of charging stations in Bangalore. Over 30 charging points (fast DC chargers) already in place. ▸ It plans to setup charging point every 4 kms. ▸ Launched 'One Plan' for support and maintenance. ▸ Provides slow home chargers with vehicles. ▸ In-house team to design Lithium-ion battery packs. ▸ Plans to expand footprints in Pune and Chennai.
12	Bajaj	Two-wheelers	None	▸ Company plans to launch EV under a brand name, Urbanite, by 2020.
13	TVS	Two-wheelers	None	▸ Partnership with technology institutions to create intellectual property (IP). ▸ Plans to develop battery packs in-house. The battery cells will be outsourced from international suppliers. ▸ Plans to invest INR200 crores in IP development. ▸ Planning to launch e-bike in 2018.

S.no.	Automobile players	Vehicle category	EV running models	Key notes
14	Okinawa Autotech	Two-wheelers	Praise Ridge	▸ Founded in 2015 ▸ Launched first electric scooter in January 2017. ▸ Its plant is based out in Rajasthan with production capacity of 90,000 units. ▸ 100% focus on electric scooter manufacturing. ▸ Over 210 dealers network and over 10,000 test rides. ▸ Plans to invest INR 270 crores in the next three years.
15	Hero Electric	Two-wheelers	High Speed Series (3) Super Economy Series (5) Electric NYX E5	▸ Sold 30,000 units in 2017-18 ▸ Plans to sell 20X units by 2022-23 ▸ Total Investment of INR400 crores is already made. Plans to make further investment of INR500 crores to strengthen the manufacturing capabilities. ▸ Some models are available in lead acid battery pack to keep product price within the reach of mass consumers.
16	Hero Electric	Two-wheelers	Raahi (e-rickshaw) Rex 400 E-Tipper E-Loader	▸ Sold 30,000 units in 2017-18 ▸ Plans to sell 20X units by 2022-23 ▸ Total Investment of INR400 crores is already made. Plans to make further investment of INR500 crores to strengthen the manufacturing capabilities. ▸ Some models are available in lead acid battery pack to keep product price within the reach of mass consumers.
17	Mahindra Electric	Three-wheelers	eAlpha	
18	Lohia	Two-wheelers	OMA Star OMA Star Li	▸ Partnership with the US-based UM International. ▸ Over 100 dealers with presence in more than 40 cities.
19	Lohia	Three-wheelers	Humrahi Series (2) Narain Series (1) Comfort Series (3)	▸ Partnership with US-based UM International. ▸ Over 100 dealers with presence in more than 40 cities
20	Kinetic Green	Three-wheelers	Safar (1) Buggies (5)	▸ Partners with SmartE to deploy 10,000 EVs. ▸ First 500 EVs have been deployed in Gurgaon in collaboration with Delhi Metro Rail, HSIIDC and Rapid Metro Gurgaon.

Note:

1. This is not a complete list and actual information may differ. The above information is consolidated to show the overall EV trend in India across all vehicle segments i.e., 2W/3W/4W/buses.



3 EVSE classification

Standards are documented consensus agreements containing safety or technical specifications or other precise criteria to be used consistently as rules or guidelines, of characteristics for materials, products, processes and services. It is important to develop standards, as today, many devices and services found in homes, hospitals, the workplace and industry run off electricity. Such machines and equipment can be dangerous if they malfunction, causing explosions, fires or electrocution to users or anyone who comes in their contact, in addition to damaging property. The adoption of technical standards facilitates the expansion of both domestic and international markets. They also provide users with an assurance that products and services from various sources meet quality to the extent that such products and services are interchangeable. Technical standards also promote competition among suppliers and offer increased prospects for cost efficiencies.

In the context of electric mobility, despite improvements in the electric vehicle entering the market, charging infrastructure still suffers from fragmentation, inconsistent data availability, and a lack of consistent standards in most markets. Open standards for vehicle-charge point communication and payment may mitigate some of these issues by enabling interoperability between charging networks, increasing innovation and competition, and reducing the costs to drivers. With the continuous advancement of electric vehicle charging technology, several standards and guidelines have become widely accepted across the industry.

India, being a tropical country, witnesses higher temperature. Presently, the standards for charging infrastructure are as per the European ambient conditions. Hence, India needs to modify the existing standards so that the products comply with Indian conditions without jeopardizing on the efficiency. Further, the adoption of electric vehicles in India has been in the segment of vehicles running on low voltage and power requirements. The volumes of such vehicles are huge mostly consisting of two and three-wheelers. It is vital to create standards for such a category of vehicle which operates on low voltages. In addition, India can also approach a technologically agnostic approach for adopting standards for AC/ DC charging connectors allowing adoption as per the market demand.

The sections below assess the existing landscape for standardization in India. The existing standards have been mapped with global standards to identify possible synergies and gaps. Finally, recommendations on improving the standards have been given.

3.1.

EVSE classification

Electric Vehicle Supply Equipment (EVSE) is an equipment or a combination of equipment providing dedicated functions to supply electric energy from a fixed electrical installation or supply network to an EV for the purpose of charging. There are different ways to classify an EVSE depending on power supply (AC or DC), power rating levels, speed of charging and communication and connector type. The sections below give a brief about each of these classifications.

3.1.1. EVSE Technology Classification

Rapid fast charging

Fast charging systems are generally described as chargers providing high power output capable of charging a vehicle to 80% in as little as 15 minutes. Such charge points are common at present and are in the range of 20-50kW. Charging solutions for 100kW level may be available in the medium term. Such systems are generally applicable for major road networks, highways and other places where drivers might need a quick top-up for their onward journey, while chargers closer to the 20kW level may provide a suitable solution where the electricity supply is restricted. Further, fast charging is used where large vehicles with very big batteries need the higher power to achieve an acceptable charge time [131] [132]

Battery swapping

In the battery swapping mechanism, the battery is separated from the vehicle and will not be owned by the vehicle owner but an energy operator (provider of charged battery as a service). The energy operator will buy the batteries, charge them and lease it to the vehicle owners at convenient charge-cum-swap centers. In this mechanism, the batteries can be swapped at a swapping station by replacing a discharged battery with a charged one. The vehicles, therefore, do not need to be fast-charged or have very large batteries.

Range extension (RE) systems

RE systems are incorporated as a vehicle designed with a small built-in fixed battery and a removable secondary battery called "range-extension swappable lock smart (LS) batteries (or RE battery). The smaller battery can be regularly conductively charged catering to smaller distances and in the case of a long-range journey, the RE battery can be swapped in for an extended range. RE systems, as a result, reduce upfront costs of a vehicle and also reduce the weight, which is a key efficiency metric in the EVs.

[131] BEAMA – Guide to EV Charging Infrastructure
[132] Intel - https://www.intel.com/content/dam/www/public/us/en/documents/solution-briefs/transportation-abb-terra-smart-connect-brief.pdf

Wireless charging

To enable longer service hours, smaller battery packs and autonomous solutions, EVs with in-motion (dynamic) wireless charging have emerged as a potential solution. Qualcomm Technologies, Inc. introduced Halo™ Wireless Electric Vehicle Charging (WEVC) system, enabling quick charging with high power WEVC, supporting wireless power transfers at 3.7 kW, 7.4 kW, 11 kW and 22 kW with a single primary base pad and wireless power transfer efficiency of above 90%. The main drawbacks currently in wireless charging are the EV-charger alignment issue and foreign objects' interference [133].

Renewable energy charging

The impact of operating an EV on climate depends largely on the sources of electricity used to charge up the vehicles' batteries. Adoption of wind and solar based charging for EVs could increase the adoption and penetration levels of renewable energy sources. This will further increase the green energy charging ratio of EVs. The coupling of renewable energy sources (RES) and EVs would require synchronization between the EV charging periods with RES production periods and – if vehicle-to-grid (V2G) capabilities are available – to discharge EVs in case of substantial RES production shortfall [134] [135] .

3.1.2. By EVSE output - AC or DC

In case of an AC EVSE, the vehicle has an on-board charger that converts AC into the DC first. An AC EVSE comes in different power ratings ranging from 3.3 kW to 43 kW. A DC EVSE is able to supply higher power rating ranging from 10 kW to 240+ kW.

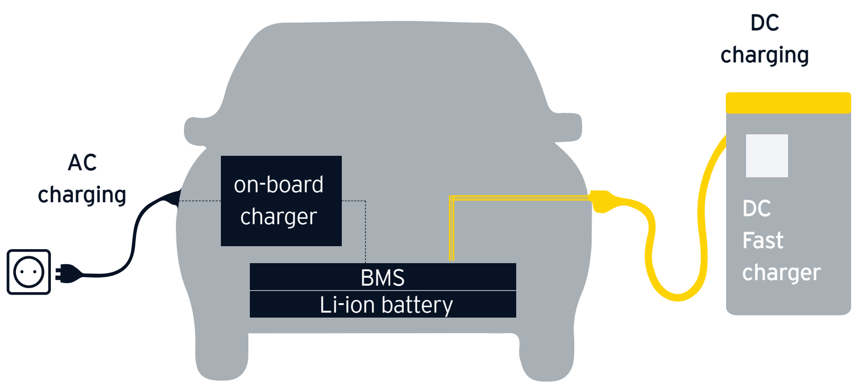


Figure 26: AC DC Charging scenario

[133] Power Electronics - https://www.powerelectronics.com/automotive/wireless-charging-electric-vehicles
[134] Hyper Articles en Ligne (HAL) - https://hal.archives-ouvertes.fr/hal-01660228/document
[135] Battery University - https://batteryuniversity.com/learn/article/charging_with_solar_and_turbine

3.1.3. By EVSE power rating – levels 1, 2, 3

AC and DC chargers come with different power ratings and accordingly are classified into Level-1, Level-2, and Level-3. These level definitions are different for AC and DC chargers as shown in table below:

Table 34: Power ratings of chargers[136]

	AC chargers	DC chargers
Level 1	120V single phase AC up to 1.9 kW (up to 16A)	200-450V DC up to 36 kW (up to 80A)
Level 2	240V single phase AC up to 19.2 kW (up to 80A)	200-450V DC up to 90 kW (up to 200A)
Level 3	Greater than 20 kW	200-600 V DC up to 240 kW (up to 400A)

3.1.4. By charging speed – slow, fast or ultra-fast

Different type of chargers take different duration of time to charge a vehicle's battery fully. If the charging time for a charger is four to eight hours, it is usually referred to as a slow charger. If the charging time is one hour, the charger is usually referred to as a fast charger and if charging time is less than 30 minutes, the charger is usually referred to as an ultra-fast/super-fast/rapid charger. The use of Slow/Fast/Ultra-fast charger depends not only upon the availability of these chargers (along with power), but also on the size, thermal management of battery and type of battery used. A 10kW charging for a vehicle with 100 kWh battery would be considered as slow charging, whereas for a vehicle with 12kWh battery, the same charger would be considered fast.

3.1.5. By charging communication and connector type – CCS, GB/T, CHAdeMO

In order to charge Lithium-Ion batteries, constant current/constant voltage (CC/CV) is often adopted for high efficiency charging and sufficient protection. The battery (or the vehicle having the battery) and the charger need to communicate with each other continuously during charging. When the charger (EVSE) is external to the vehicle (EV), a communication protocol is needed for the battery and the charger to communicate; this is referred to as EV-EVSE communication protocol. There are three standard EV-EVSE communication protocols which are associated with three charging standards from three different countries/continent. Each of these protocols define the kind of connector to be used, maximum power and voltage for the connection, the communication link to be used and the communication protocols. The table below briefs about the various charging protocols:

Table 35: Prominent charging protocols[137]

	CCS	GB/T	CHAdeMO
Country following the standards	Worldwide adopted	China	Worldwide adopted
Charging standard	SAE J1722	GB/T-20234	IEC 62196-4
Physical layer for EVSE-EV communication	PLCC	CAN	CAN
Communication protocol	CCS	GB/T	CHAdeMO
Type of charging	AC and DC	AC and DC	DC
Charging limit	1000V 350A 350 kW	750V 200A 150 kW	500V 125A 400kW

[136] EY analysis
[136] EY analysis

	CCS	GB/T	CHAdeMO
AC connector	TYPE 1 5-pin Mechanical lock  IEC 62196-2/SAE J1722 TYPE 1 5-pin Mechanical lock  IEC 62196-2	7-pin Mechanical (optional electronic) lock  GB 20234.2-2011	5-pin Mechanical and electronic lock  IEC 62196-2/SAE J1722
DC connector	TYPE 1 5-pin Mechanical lock  IEC 62196-3  IEC 62196-3	9-pin Mechanical (optional electronic lock)  IEC 62196-3	4-pin Mechanical and electronic lock  CHAdeMO/IEC 62196-3
AC + DC combo connector	TYPE 1 7-pin Mechanical lock  SAE J1772/IEC 62196-3 TYPE 2 9-Pin  SAE J1772/IEC 62196-3	Not available	Not available

The communication between EVSE and Central Management System (CMS) is a common global standard, referred to as Open Charge Point Protocol (OCPP). It enables controlling the charging rate depending upon the grid supply's availability. It also enables metering at different rates.

3.2

Global EVSE related Standards

Standardization have been a key consideration for increasing uptake of electric vehicles in global markets. Various standardization bodies have identified key global standards regarding overall safety for charging station, EVSE safety, AC/ DC charging connector, EV- EVSE communication protocols and Vehicle to Grid (V2G). Brief description of each of these standards is mentioned in the table below:

Table 36: Standards list[138]

Category	Standard name	Description and applicability	Coverage
Overall charging station related safety	IEC 61851-1	Electric vehicle conductive charging system - part 1: general requirements Applies to EV supply equipment for charging electric road vehicles, with a rated supply voltage up to 1,000 V AC or up to 1,500 V DC and a rated output voltage up to 1,000 V AC or up to 1,500 V DC.	Power supply input and output characteristics, environment conditions, protection against electric shock, description of charging modes and their functions, communication between EVSE and EV, communication between EVSE and management system, conductive electrical interface requirements, requirements for adaptors, cable assembly requirement, EV supply equipment constructional requirements and tests, overload and short-circuit protection, automatic reclosing of protective devices, etc.
	IEC 61851-21-1	Electric vehicle conductive charging system - Part 21-1 electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply. It applies only to on-board charging units, either tested on the complete vehicle or tested on the charging system component level (ESA - electronic sub assembly).	General test conditions, test methods and requirements, immunity of vehicles, immunity of electromagnetic radiated RF-fields and pulses on supply lines, emission test conditions, emission of harmonics and voltage changes, high frequency conducted and radiated disturbances, etc.
	IEC 61851-23	Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station It gives the requirements for DC electric vehicle (EV) charging stations, herein also referred to as DC charger, for conductive connection to the vehicle, with an AC or DC input voltage up to 1000 V AC and up to 1500 V DC according to IEC 60038.	Rating of the supply AC voltage, general system requirements and interface, protection against electric shock, connection between power supply and the EV, specific requirements for vehicle coupler, charging cable assembly requirements, EVSE requirements, specific requirements for DC EV charging station, communication between EV and DC EV charging station, etc.

Category	Standard name	Description and applicability	Coverage
	IEC 61851-24	Electric vehicle conductive charging system - Part 24: digital communication between a DC EV charging station and an electric vehicle for control of DC charging This part together with IEC 61851-23, applies to digital communication between a DC EV charging station and an electric vehicle (EV) for the control of DC charging, with an AC or DC input voltage up to 1000 V AC and up to 1500 V DC for the conductive charging procedure.	System configuration, digital communication architecture, charging control process, overview of charging control, exchanged information for DC charging control, etc.
	GB/T 18487.1-2015	Electric vehicle conductive charging system. Part 1: general requirements	Charging system general requirements, communication protection against electric shock, vehicle and power supply interface, EVSE construction and performance requirements, overload and short circuit protection, etc.
	GB/T 18487.2-2001	Electric vehicle conductive charging system AC/DC electric vehicle charging station	Standard conditions for operation in service and for installation, rating of AC input and DC output voltages and current, general test requirements, functions, electrical safety, dielectric insulation test, environment tests, specific connector requirements, communication between EV and DC charging stations, etc.
	ISO 17409	Electrically propelled road vehicles - connection to an external electric power supply - safety requirements	Environment conditions, requirement for protection of persons against electric shock, protection against thermal incident, specific requirements for the vehicle inlet, plug and cable; additional requirement for AC electric power supply; additional requirement for DC electric power supply, operational requirements and test procedures.
EVSE safety	IEC 61140	Protection against electric shock - common aspects for installation and equipment	Protection against electric shock, elements of protective measures, provisions for basic protection, fault protection, enhanced protective, protective measures, coordination between electrical equipment and protective provisions within an electrical installation, special operating and servicing conditions, etc.
	IEC 61000-6-2	Electromagnetic compatibility (EMC) - Part 6-2: generic standards - immunity standard for industrial environment	Performance criteria, conditions during testing, product documentation, applicability, measurement, uncertainty, immunity test requirements, etc

Category	Standard name	Description and applicability	Coverage
	IEC 61000-6-3	Electromagnetic compatibility (EMC) - Part 6-3: generic standards - emission standard for residential, commercial and light-industrial environments.	Conditions during testing, product documentation, applicability, emission requirements, measurement uncertainty, application of limits in tests for conformity of equipment in series production, compliance with this standard, emission test requirements, etc
AC charging and connectors	IEC-62196-2 (normal + high power)	Plugs, socket-outlets, vehicle connectors and vehicle inlets - conductive charging of electric vehicles - Part 2: dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories It applies to plugs, socket-outlets, vehicle connectors and vehicle inlets with pins and contact-tubes of standardized configurations, herein referred to as accessories	provisions, resistance to ageing of rubber and thermoplastic material, construction of socket outlets, connectors and vehicle inlets, insulation resistance, temperature rise, breaking capacity, flexible cables and their connection, mechanical strength, current carrying parts and connections, creep-age distances, resistance to heat and fire, corrosion and resistance to rusting, conditional short-circuit current withstand test, EMC, resistor coding, etc.
	IEC 60309-1	Plugs, socket-outlets and couplers for industrial purposes - Part 1: general requirements It applies to plugs and socket-outlets, cable couplers and appliance couplers, with a rated operating voltage not exceeding 690 V DC or AC and 500 Hz AC, and a rated current not exceeding 250 A. It is primarily intended for industrial use, either indoors or outdoors.	Standard rating, marking and dimensions, electric shock protection, earthing provisions, resistance to ageing of rubber and thermoplastic material, construction of outlets, plugs, connectors and inlets, insulation resistance, temperature rise, breaking capacity, flexible cables and their connection, mechanical strength, current carrying parts and connections, creepage distances, resistance to heat and fire, corrosion and resistance to rusting, conditional short-circuit current withstand test, electromagnetic compatibility, etc.

Category	Standard name	Description and applicability	Coverage
	IEC 60309-2	Plugs, socket-outlets and couplers for industrial purposes — Part 2: dimensional interchangeability requirements for pin and contact-tube accessories It applies to plugs and socket-outlets, cable couplers and appliance couplers with a rated operating voltage not exceeding 1000 V, 500 Hz and a rated current not exceeding 125 A.	Standard rating, marking and dimensions, electric shock protection, earthing provisions, resistance to ageing of rubber and thermoplastic material, construction of outlets, plugs, connectors and inlets, insulation resistance, temperature rise, flexible cables and their connection, mechanical strength, current carrying parts and connections, creepage distances, resistance to heat and fire, corrosion and resistance to rusting, conditional short-circuit current withstand test, electromagnetic compatibility, etc..
	SAE J 1772 (Type 1)	SAE Electric Vehicle Conductive Charge Coupler It is also known as a "J plug", is a North American standard for electrical connectors for electric vehicles maintained by the SAE International.	General conductive charging system description, control and data, general EV and EVSE requirements, coupler requirements, etc.
	GB/T 20234.2-2015 AC	Connection set for conductive charging of electric vehicles - Part 2: AC charging coupler Electric vehicle connection set - AC charging coupler	General requirements, function definitions, rated values of AC charging coupler, functions of charging coupler, parameters and dimensions of AC charging coupler for conductive charging of electric vehicles, etc.
DC Charging and Connectors	IEC-62196-3 (normal + high power)	Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers Intended for use in electric vehicle conductive charging systems which incorporate control means, with rated operating voltage up to 1500 V DC and rated current up to 250 A, and 1000 V AC and rated current up to 250 A.	Connection between EVSE and EV, design and construction of socket outlets, plugs, vehicle connectors, vehicle inlets, interlocks, earthing, protection against shock; insulation, resistance, normal operations, temperature rise, breaking capacity, cables and connections, distances, EMC, short circuit test, etc.

Category	Standard name	Description and applicability	Coverage
	GB/T 20234.3-2015	Connection set for conductive charging of electric vehicles - Part 3: DC charging coupler This part is applicable to vehicle coupler in charging mode 4 and connection mode C, of which the rated voltage shall not exceed 1,000 V (DC) and the rated current shall not exceed 250 A (DC).	General requirements, function definitions, rated values of DC charging coupler, functions of vehicle coupler, parameters and dimensions of DC charging coupler for conductive charging of electric vehicles, etc.
Vehicle to grid standard	ISO 15118-1	Road vehicles - vehicle to grid communication interface - Part 1: general information and use-case definition It specifies terms and definitions, general requirements and use cases as the basis for the other parts of ISO 15118. It provides a general overview and a common understanding of aspects influencing the charge process, payment and load levelling	Requirements for communication concept, user specific, OEM specific, utility specific, start of charging process, communication set-up target setting and charging scheduling, end of charging process, etc.
	ISO 15118-2	Road vehicles - Vehicle to grid communication interface - Part 2: network and application protocol requirements	Basic requirement for V2G communication, service primitive concept of OSI layered architecture, security concept, V2G communication states and data link handling, data, network and transport layer, V2G transfer protocol, V2G message definition, V2G communication session and body element definitions, V2G communication timing, message sequencing and error handling, etc.
	ISO 15118-3	Road vehicles - vehicle to grid communication interface - Part 3: physical and data link layer requirements	System architecture, EV and EVSE system requirements, connection coordination, plug-in phase for EV and EVSE side, loss of communication for EV and EVSE side, plug-out phase, timings and constants, matching EV – EVSE process, EMC requirements, signal coupling, Layer 2 interfaces, etc.
	ISO 15118-4	Road vehicles - Vehicle to grid communication interface - Part 4: network and application protocol conformance test	Test architecture reference model, platform and SUT adapter interfaces, test suite conventions, test case descriptions for 15118-2 V2GTP, SDP messages and V2G application layer messages

Category	Standard name	Description and applicability	Coverage
Other Vehicles related safety	ISO 6469-4	Electrically propelled road vehicles - Safety specifications - Part 4: post-crash electrical safety It specifies safety requirements for the electric propulsion systems and conductively connected auxiliary electric systems of electrically propelled road vehicles for the protection of persons inside and outside the vehicle.	Applied crash test procedures, electrical safety requirements, electric shock protection, protection against overcurrent, RESS electrolyte spillage, test conditions, test procedures for electrical safety, test procedures for RESS electrolyte spillage, etc.
	ISO 26262	Road vehicles – functional safety It is intended to be applied to electrical and/or electronic systems installed in "series production passenger cars" with a maximum gross weight of 3500 kg. It aims to address possible hazards caused by the malfunctioning behavior of electronic and electrical systems.	It is a risk-based safety standard, where the risk of hazardous operational situations is qualitatively assessed and safety measures are defined to avoid or control systematic failures and to detect or control random hardware failures or mitigate their effects.

3.2.1. Country specific mapping of Standards

Mature markets such as US, Europe, China and Japan have laid emphasis on standardization for EVSE and overall safety, AC/ DC connectors, communication protocols and vehicle to grid interaction. Although CCS and Chademo have been prevalent standards for connectors in US and Europe respectively, it can be seen from the table below that these markets have been technologically agnostic allowing adoption based on market demand.

Table 37: Country wide mapping of standards[139]

Category	Standard Name	US	Europe	China	Japan
Overall Charging Station Related Safety	IEC-61851	✔	✔		✔
	IEC 61851-1	✔	✔		✔
	IEC 61851-21-1	✔	✔		✔
	IEC 61851-23	✔	✔		✔
	IEC 61851-24	✔	✔		✔
	GB/T 18487-20 t101			✔	
	ISO 17409	✔	✔		✔
EVSE Safety	IEC 61140	✔	✔		✔
	IEC 61000-6-2	✔	✔		✔
	IEC 61000-6-3	✔	✔		✔
	IEC 61508	✔	✔		✔
AC Charging and Connectors	IEC-62196-2 (normal + high power)		✔		
	IEC 60309-1	✔	✔	✔	✔
	IEC 60309-2	✔	✔	✔	✔
	SAE J 1772 (Type 1)	✔			✔
	GB/T 20234.2-2015 AC			✔	
	TESLA AC	✔	✔	✔	✔
DC Charging and Connectors	IEC-62196-3 (normal + high power)	✔	✔		
	CCS Combo Type 1	✔			
	CCS Combo Type 2		✔		
	CHAdeMO	✔	✔		✔
	GB/T 20234.3-2015			✔	

[138] EY analysis
[139] EY analysis

Category	Standard Name	US	Europe	China	Japan
Vehicle to grid standard	ISO/IEC 15118 (all parts)	✔	✔		
	CHAdeMO V2X	✔			✔
Other vehicles related safety	ISO 6469-4	✔	✔		✔
	ISO 26262	✔	✔		✔

3.2.2. India EVSE related Standards

In India, IS 15886 was drafted for standardization of electric and hybrid vehicles and their components by Bureau of Indian Standards (BIS). Some standards were drafted by ARAI. These include:

AIS-138 (Electric Vehicle Conductive AC Charging System) for DC charging system for electric vehicles with assistance from existing international standards including IEC 61851-1(General Requirements), IEC 61851- 23 (electric vehicle charging station) and IEC 61851-24 (Digital communication).

ARAI has also published Automotive Industry Standard (AIS) document including AIS-102 (Part 1 and 2) on CMVR Type Approval for Hybrid Electric Vehicles, AIS-123 on CMVR Type Approval of Hybrid Electric System Intended for Retro-fitment and AIS 131 on type Approval Procedure for Electric and Hybrid Electric Vehicles introduced in market for pilot/ demonstration projects intended for government schemes.

In late 2017, the Ministry of Heavy Industries instituted "Committee on Standardization of Protocol for Electric Vehicles" which framed draft standards for charging stations – Bharat EV charger AC – 001 and Bharat EV charger DC – 001.

Brief about the above-mentioned standards is mentioned in the table below:

Table 38: India EVSE standards

Name of standard	Description and applicability	Coverage, global reference	Notification status	Point of distinction
AIS 138 (Part 1)	For charging electric road vehicles at standard AC supply voltages (as per IS 12360/IEC 60038) up to 1000 V and for providing electrical power for any additional services on the vehicle if required when connected to the supply network. Applicable for 1) AC slow charging (230 V, 1 Phase, 15 A outlet with connector IEC 60309) and 2) AC fast charging (415 V, 3 Phase, 63 A outlet with connector IEC 62196).	IEC 61851 Part 1, 22; SAE J1772; GB/T 18487 Part 1,2,3	With DST and BIS for notification as IS standard	IEC 61851 has ambient temperature of -25 to 40 ºC. For Indian conditions, AIS has suggested it 0 to 55 ºC. CEA, in its recommendations, have suggested higher +60 ºC.
AIS 138 (Part 2)	For DC EV charging stations for conductive connection and digital communication to the vehicle, with an AC or DC input voltage up to 1000V AC and up to 1500V DC (as per IS 12360/IEC 60038).	IEC 61851 Part 1, 23, 24	With DST & BIS for notification as IS standard	

Name of standard	Description and applicability	Coverage, global reference	Notification status	Point of distinction
AC-001	It presents the specifications of a public metered AC outlet (PMAO) which is to provide AC input to the vehicle which has on-board chargers. This document applies to electric road vehicles for charging at 230V standard single-phase AC supply with a maximum output of 15A and at a maximum output power of 3.3kW. PMAO is a slow charger for low-power vehicles.	IS 12360; IEC 60309	Submitted to DHI	
DC-001	It prescribes the definition, requirements and specifications for low voltage DC electric vehicle (EV) charging stations in India, herein also referred to as "DC charger", for conductive connection to the vehicle, with an AC input voltage of 3-phase, 415 V. It also specifies the requirements for digital communication between DC EV charging station and electric vehicle for control of DC charging.	IEC 61851 Part 1,23; GB/T 20234.3	Submitted to DHI	

3.3

Recommendations to modify/improve Indian EVSE related standard

Energy performance standards

The recommendations made by the CEA are:of each of these standards is mentioned in the table below:

"The stored energy available shall be less than 20 J (as per IEC 60950). If the voltage is greater than 42.4 V peak (30 Vrms) or 60 V DC, or the energy is 20 J or more, a warning label shall be attached in an appropriate position on the charging stations".

Grid Connectivity Regulations

The following recommendations were made by the CEA, regarding standards for charging station, prosumer or a person connected or seeking connectivity to the electricity system are:

- Applicant shall provide a reliable protection system to detect various faults/abnormal conditions and provide an appropriate means to isolate the faulty equipment or system automatically. The applicant shall also ensure that fault of his equipment or system does not affect the grid adversely.
- The licensee shall carry out an adequacy and stability study of the network before permitting connection with its electricity system.

Power Quality Standards

- The limits of injection of current harmonics at point of common coupling (PCC) by the user, method of harmonic measurement and other matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.
- Prosumer shall not inject direct current greater than 0.5% of the rated output at interconnection point.
- The applicant seeking connectivity at 11 kV or above shall install power quality meters and share data as and when required by the licensee. Users connected at 11 kV or above shall comply with this provision within 12 months of notification of these regulations.
- In addition to harmonics, the limits and measurement of other power quality parameters like voltage sag, swell, flicker, disruptions, etc. shall be as per relevant BIS standards or as per IEC/IEEE standards if BIS standards are not available.

Considerations for Oil and Gas companies setting up stations

- Requirement under Rule 102 of the Petroleum Rules, 2002 lays down that no electrical wiring shall be installed, and no electrical apparatus shall be used in a petroleum refinery, storage installation, storage shed, service station or any other place where petroleum is refined, blended, stored, loaded/filled or unloaded unless it is approved by the chief controller of explosives. It is in this context that electrical equipment, which has to be used in a hazardous area covered under Petroleum Rules, 2002 shall require an approval from the chief controller of explosives.
    - For installation of electrical equipment, the areas have been divided into three categories under hazardous areas, namely:
    - Zone "0" area, where inflammable gas and vapors are expected to be continuously present, e.g., inside the tank.
    - Zone "1" area, where inflammable gas and vapors are expected to be present under normal operating conditions, e.g., on the mouth of the vent pipe or near the fill point, unloading point, etc., during the operation.
    - Zone "2" area, where inflammable gas and vapors are expected to be present under abnormal operating condition, e.g., during the failure or rupture of the equipment.

Considerations for V2G, integration of solar PV and storage

- Globally, low level EVSE does not require communication. However, for India it is essential for low level EVSEs or slow chargers to also have a provision for communications. EVs, being charged with a slow charger, can better support in grid stability through V2G application as these vehicles would be parked for longer duration and connected to grid. As time of connection to grid is longer as compared to EV connected through fast chargers, higher reliability is likely to be achieved. Users of fast chargers are likely to be connected for very short duration and could support only minimally.

- The peak hours of solar and wind might match with EV charging patterns. Power generation with the help of GRPV to cater to the demand of EV charging could help address technical losses and stability concerns of distribution utilities.
- With applications such as vehicle to home or vehicle to the grid that utilizes batteries of EVs as dynamic storage media, multiple points of injection of power in the distribution networ k is likely to take place. If the system is designed well, managing the multiple injection points could aid the grid in enhancing its resilience.
- However, power flow studies and load flow analysis would need to be conducted to understand if the network nodes are resilient enough to absorb the impact of a sudden power injection and drawls. There is a need for holistic assessment of the impact of VRE, storage and EV charging on distribution networks.
- Hence, the regulations also need to be evaluated as the points of reverse power flows in the network could increase drastically, that too with a lot of uncertainties.

Following Regulation shall be added after Regulation 13 of the Principal Regulation:

Registration in the Registry maintained by CEA:

- The applicant shall get its generating unit(s) of 500 kW capacity and above registered after which a unique registration number gets generated online from the e-registration facility at the portal of Central Electricity Authority when such scheme is made available.
- No applicant shall be granted connectivity with the grid without the unique registration number subsequent to implementation of the registration scheme.
- The users shall comply with the above-mentioned provision within a period, specified by the authority separately, of implementation of the registration scheme.

3.4

Testing standards

Electrification of transport plays an important role in achieving clean and efficient transportation that is crucial to the sustainable development of the whole world. In the near future, electric cars are expected to have a major impact in the auto industry given advantages of reduced pollution levels, less dependence on oil and expected rise in gasoline prices. For development and adoption of EVs, it is important to have the right ecosystem.

Apart from standardization of EVs and EVSE, testing standards shall be playing a critical role in facilitating this ecosystem. There are different components of EVs which need to be tested before they are made available to the public. For India, Automotive Research Association of India (ARAI)has prepared draft standards for testing of EVs, batteries, etc. to ascertain quality and efficiency which are the most essential parameters to be validated. Moreover, performance standards need to be developed to give users an informed choice to select the right product.

Accordingly, the section below assesses the current testing landscape of as per Indian standards. The same have been mapped with global equivalent standards to identify gaps. Further, US's star labelling program has been assessed to derive key learning about testing procedures and guidelines.

3.4.1. Introduction to EV testing

The different types of components which are tested are given below:

Electric vehicles testing

In order to deliver safe and high-performing electric vehicles, components need to be evaluated properly as unsafe components can cause danger to vehicle operators in hazardous conditions. Wiring tests for high voltage cables are also done to ensure smooth working of electrical components. To ensure safety, graphical symbols test and emission test are carried out to ensure conformity.

Batteries testing

Battery plays an important part of the EV ecosystem. Batteries come in many conditions and their charge can easily mask a symptom allowing a weak battery to perform well. Likewise, a strong battery with low charge shares similarities with a pack that exhibits capacity loss. Battery characteristics are also swayed by a recent charge, discharge or long storage. Hence, testing of battery is essential as manufacturers must be aware of all applicable components as well as infrastructural and OEM requirements to ensure their long-term performance and compatibility with new charging equipment.

EVSE testing

Electric vehicle chargers (otherwise known as Electric Vehicle Supply Equipment – EVSE) are a fundamental part of the plug-in electric vehicle system. For integrated safety performance and interoperability, EVSEs are tested according to all industry recognized standards. On-board battery chargers, charging inlet, electrical connectors, charging station/cod sets, charging plug, personal protection circuitry, etc. are tested as part of EVSE testing. Currently, there are three major types of EVSE: AC level 1, AC level 2, and DC fast charging.

3.4.2. Energy Star Program: eligibility criteria for Electrical Vehicle Supply Equipment

Performance testing procedure for EVSE

In the US, the Energy Star Test method is used for determining the product compliance with the eligibility requirements of the Energy Star Program. The requirements of the Energy Star Test are dependent on the feature set of the product, i.e., electric vehicle supply equipment (EVSE) being evaluated[140]

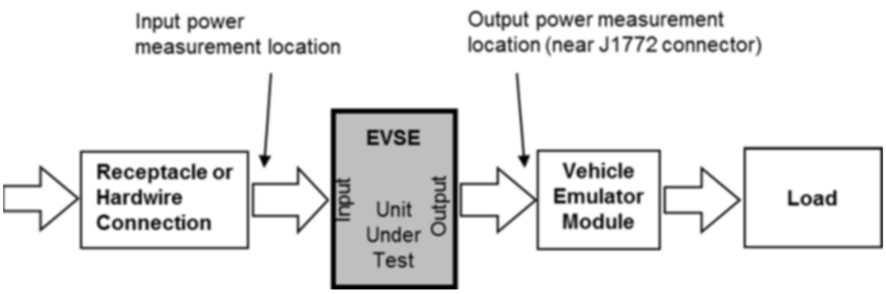


Figure 27: EVSE testing procedure setup system

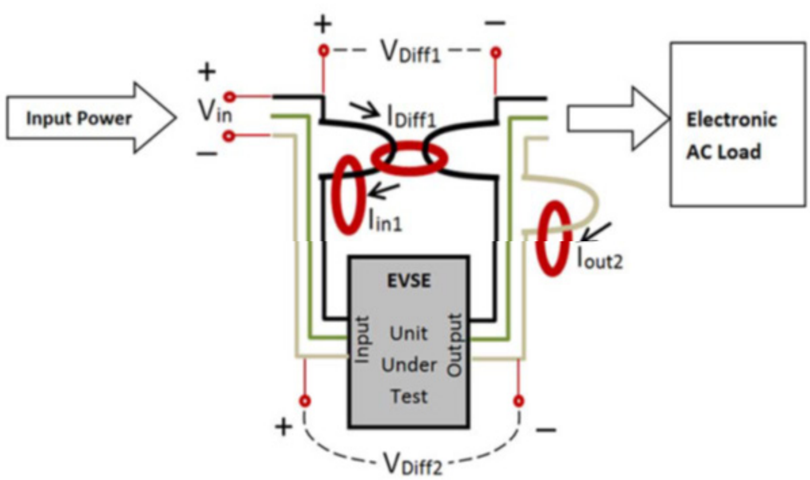


Figure 28: EVSE test measurement points (Source: Energy Star Program Requirements) [141]

[140] United States Department of Energy https://www.energystar.gov/sites/default/files/Final%20Version%201.0%20EVSE%20Program%20Requirements.pdf
[141] EY analysis

Components of EVSE performance test setup

- The electrical system operates on AC input power.
- The EVSE is a unit under test (UUT). It operates at the highest rated voltage and at a rated frequency combination. The UUT is designed to operate at multiple voltage ranges (SAE standard Level 1 and Level 2 functionality). However, the voltage tolerance specified is +/- 4.0%, maximum total harmonic distortion as 5.0% and frequency tolerance specified is +/- 1.0%.
- The input supply requirements are as follows:

Figure 28: Input supply requirements [142]

Voltage	Frequency
240 V AC	60 Hz
208 V AC	60 Hz
120 V AC	60 Hz

- Components of EVSE performance test setup
  - Cables: All power cables for the test shall be the default provided by the manufacturer
  - For EVSE equipped with input plug(s) and cord(s), the corresponding receptacle will be used to provide power to the input plug(s) of the EVSE. If this is a multi-input EVSE, the inputs shall be connected together in parallel, requiring only one power supply and one power meter. An Input Measurement Apparatus (IMA) shall be used with EVSE that are provided with input plug(s) and cord(s). The IMA enables input current and input voltage measurements of EVSE without the need to modify the EVSE input cord(s).
  - EVSE intended for hardwire connection, the UUT's input power is connected to AC input power source with cables and optional connectors that are rated for voltage and current levels that will be encountered during testing.
- The test needs to be conducted at 25°C ± 5°C with the relative humidity (RH) set between 10% and 80%.
- Test loads are required to be connected to the EVSE output in lieu of a vehicle: Vehicle Emulator Module (VEM) and AC load. VEM allows current and voltage measurements of the UUT output without modifying or altering the UUT output cable(s). AC load, on the other hand, has the capability to sink AC current up to the related RMS current of the UUT.
- Power meter should have the following attributes:
  - Multiple channels such as – one channel to measure the AC power of the internal components of UUT, the other to measure power loss across the EVSE on line 1 and the third channel to measure power loss across the EVSE on Line 2/N[143]
  - Crest factor
  - Minimum frequency response set on 3.0kHz
  - Minimum resolution set for values less than 10 W will be 0.01 W; for measurement values less than 10 W to 100 W, it will be 0.1 and for measurement values greater than 100 W, it is set on 1.0 W
  - Accuracy: +/- 0.1% of reading PLUS +/- 0.1% of full scale
  - Measurements and calculations: cable length (ft.), cable gauge (AWG), power factor (PF), apparent power (S), voltage (RMS), current (RMS), average power (W), frequency (Hz)

[142] EY analysis
[143] In a four-conductor system, the conductor labeled L2/N will actually be two separate conductors: L2 and N.

Guidance for implementation of the EVSE test procedure

- The model unit should be tested in its default configuration as shipped.
- The UUT should have network connection capabilities.
- Any peripherals shipped with the UUT should be connected to their respective ports as per the manufacturer's instructions.
- The UUT should maintain the live connection to the network for the duration of testing, disregarding any brief lapses.
- Connection to the wide area network, if required, in the manufacturer's instructions.
- If the UUT needs to install any software updates, wait until these updates have occurred; otherwise, if it will operate without updates or skip the updates.
- In the case of a UUT that has no data/network capabilities, the UUT shall be tested as "shipped".
- Luminance testing should be performed for all products at 100% of screen brightness possible.
- All products with Automatic Brightness Control (ABC) enabled by default should be tested in two luminance conditions—light and dark—to simulate daytime and nighttime conditions.
- Light source alignment for testing products with ABC should be enabled by default.

Test procedure

- The first step that needs to be followed for testing all the products is to ensure that the UUT is prepared. UUT preparation includes activities such as –

a. Setting up of the UUT,

b. Connect VEM output to AC load,

c. Connect the power meter,

d. Connect an oscilloscope or other instruments to measure the duty cycle of the control pilot signal, voltage at the VEM between charging point (CP) and grid voltage measurement connections.

e. Connect the UUT input connection, providing input power to the EVSE input connection(s).

f. Power on the UUT and perform initial system configuration, as applicable

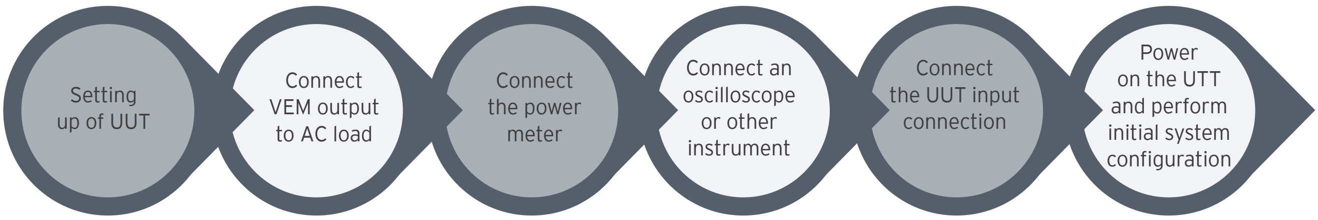


Figure 29: Test procedure[144]

g. Ensure the UUT settings are in their as-shipped configuration, unless otherwise specified in the Test Method and report the test room ambient temperature, relative humidity and the presence of ABC and occupancy sensor.

[144] United States Department of Energy

- No Vehicle Mode (State A) Testing

It will be conducted for all products. For conducting the test, a UUT should be prepared, UUT output connector is unplugged from the Vehicle Emulator Module (VEM) should be verified and the UUT input power should be measured and recorded (power is measured according to the IEC 62301 ed 2.0 – 2011).

- Partial On Mode (State B) and Idle Mode (State C) Testing

In this mode, the testing is conducted for two operational states of the J1772 interface (State B and State C). The first step involves preparation of the UUT. Once the UUT is prepared, demand – response functionality or timer should be disabled followed by conducting the UUT power consumption (power is measured according to IEC 62301 Ed 2.-2011).

- Operation Mode (State C) Testing

In operation Mode (State C) testing, the test is conducted with the VEM(s) in State C (S2 closed).

- Full Network Connectivity Testing

Full network connectivity testing is suitable for products with data/networking capabilities. Full network connectivity is determined by testing the UUT for network activity in partial on mode.

Determination of power loss across an EVSE

The power loss is determined for each output under the no vehicle mode, partial on mode and operation mode.

The following measurements shall be taken for calculation of losses:

- Stability of input power is checked by ensuring the input current does not drift beyond 1% within five minutes of connection, else measurement of power is done as per IEC Standard 62301.
- After five minutes of connection, measurement of RMS input current, RMS input voltage, power factor and RMS of output current of each output is recorded.
- Measurement of EVSE internal power loss.
- The internal power loss is calculated as a product of ‘differential current measured (Idiff1)’ and ‘input voltage supply to UUT (Vin)’.
- The conductive power loss on the line1 is calculated as a product of differential voltage (Vdiff1) and input current (Iin1) measured across the UUT.
- The conductive power loss on line 2 of figure 2 is calculated as a product of differential voltage (Vdiff2) and (Iout2).
- The total power loss (Ploss) is calculated as follows:

Ploss = (Idiff1 x Vin) + (Iin1 x Vdiff1) – (Iout2 x Vdiff2)

3.4.1. Global EV testing landscape

Mapping of EV testing standards

The table below maps the standards around EVs, battery, battery performance and EVSE in mature markets country-wise.

Table 39: Global EV testing standards[145]

	Standard Name	Japan	China	Germany	USA	Finland
EV	IEC 60086	✓	✓	✓	✓	✓
	SAE J2907				✓	
	SAE J2908				✓	
	UL 2231				✓	
	GB/T 18488.1-2015		✓			
	ISO 19363			✓		
Battery	SAE J2464	✓	✓	✓	✓	✓
	SAE J2929	✓	✓	✓	✓	✓
	IEC 61000	✓	✓	✓	✓	✓
	UL 2580	✓	✓	✓	✓	✓
	IEC 62133	✓	✓	✓	✓	✓
	IEC 62660-2	✓	✓	✓	✓	✓
	ISO 6469	✓	✓	✓	✓	✓
	ISO 12405	✓	✓	✓	✓	✓
	SAE J1766:2005	✓	✓	✓	✓	✓
	SAE J2464:2009	✓	✓	✓	✓	✓
	SAE J2929:2011	✓	✓	✓	✓	✓
	UL 2580:2011	✓	✓	✓	✓	✓
	UN 38.3 (refer 2)	✓	✓	✓	✓	✓
	SAE J2380	✓	✓	✓	✓	✓
	GB/T 31484/ 31485/ 31486		✓			

[145] EY analysis

	Standard Name	Japan	China	Germany	USA	Finland
	GB/T 31467.3:2015		✔			
	GB/T 18384.1:2015		✔			
	GB/T 31498:2015		✔			
	GB/T 24549:2009		✔			
Battery performance standards	IEC 61982	✔	✔	✔	✔	✔
	IEC 62660-1	✔	✔	✔	✔	✔
	SAE J1798				✔	
	SAE J551				✔	
	QC/T 743-2006		✔			
Battery Battery performance standards	IEC 61982	✔	✔	✔	✔	✔
	IEC 62660-1	✔	✔	✔	✔	✔
	SAE J1798				✔	
	SAE J551				✔	
	QC/T 743-2006		✔			
EVSE	UL 2251					
	UL 2594					
	UL 2202					
	IEC 62196	✔		✔	✔	✔
	GB/T 20234-2011		✔			
	IEC 61851	✔		✔	✔	✔
	GB/T 18487-2001		✔			
	GB/T 27930-2011		✔			
	SAE J2894				✔	
	SAE J2293				✔	
	SAE J1772	✔	✔	✔	✔	✔
	ISO 17409	✔	✔	✔	✔	✔
Integrated	JARI A 0201:2014based on IEC 61851-1	✔				

Global testing agencies

Below mentioned are the key testing agencies for testing in key global markets:

Table 40: Global list of EV testing agencies[146]

Countries	USA	Germany	Finland	Japan	China
Agencies	Met Laboratories	Deutscher Kraftfahrzeug-Überwachungs-Verein (DEKRA)	Finnish Transport and Communications Agency (Traficom)	Japan Automobile Research Institute (JARI)	China Automotive Technology and Research Center (CATARAC) Automotive Technology and Reseach Center (CATARAC)
	Underwriters Laboratory (UL)	Technischer Überwachungs verein (TUV)	Finnish Transport and Communications Agency (Traficom)		Chroma Automatic Testing Equipment (ATE)

List of testing standards

Brief description of standards around EVs, battery, battery performance and EVSE in mature markets is described in the table below. This includes standards adopted for standardizing battery dimensions, motor power ratings, overall vehicle power, and safety for supply circuits, vibrations and other key aspects.

Table 41: Global list of testing standards[147]

Standards	Countries complying	Description and Applicability	Coverage
IEC 60086	Japan, China, Germany, the US and Finland	Intended to standardize primary batteries with respect to dimensions, nomenclature, terminal configurations, markings, test methods, typical performance, safety and environmental aspects	Requirements for battery dimensions, terminals, designations and interchangeability; discharge performance; dimensional stability; pen circuit voltage limits; safety; performance testing; discharge testing; open circuit voltage (OCV) testing; leakage and dimensions; performance test conditions; voltage and mechanical measurement; battery packaging, etc.
SAE J2907	The US	Motor power ratings standard support	Specifies the procedures for the assessment of motor net power and maximum 30-minute power.
SAE J2908	The US	Vehicle power tests for electrified powertrains	Provides test methods for evaluating the maximum power of electrified vehicle powertrain systems by direct measurement at the drive wheel hubs or axles by conducting powertrain system power test. Additional tests are included specifically for PHEVs to measure electric-only propulsion power and for HEVs to measure electric power assist and regenerative braking.

[146] EY analysis
[147] EY analysis

Standards	Countries complying	Description and Applicability	Coverage
UL 2231-1	The US	Standard for Safety of Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: general requirements	Specifies general requirements to reduce the risk of electric shock to the user from accessible parts, in grounded or isolated circuits for charging electric vehicles.
UL 2231-2	The US	Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for use in Charging Systems	States the particular requirements for protection devices like construction of circuits, performance tests consisting of conditioning tests, system operational test requirements, resistance to environmental noise test, normal temperature test, dielectric voltage withstand test, overload test, endurance test, low resistance ground fault test, supervisory circuit test, abnormal operations test, extra low resistance ground fault test, terminal lead strain relief test, power supply cord strain relief test, mechanical test, leakage cancellation test, etc.
ISO 12405-1	Japan, China, Germany, the US and Finland	Test specification for Lithium-Ion traction battery packs and systems: high-power and high energy applications	Specifies test procedures of general tests like preconditioning and standard cycle; performance tests like energy and capacity at room temperature, power and internal resistance test, no load state of charge(SoC) loss, SOC loss at storage, cranking power at low/high temperature, energy efficiency, cycle life, reliability tests like dewing temperature change, thermal shock cycling, vibration, mechanical shock and abuse tests like short circuit protection, overcharge protection, over discharge protection, etc.
ISO 12405-3	Japan, China, Germany, the US and Finland	Test specification for Lithium-Ion traction battery packs and systems: safety	Specifies the requirements for safe performance of the EVs. It consists of general requirements, mechanical tests - vibration and mechanical shock, climatic tests - dewing and thermal shock cycling, simulated vehicle accidents – inertial load at vehicle crash, contact force at vehicle crash, electrical tests and system functionality tests.
SAE J1766	Japan, China, Germany, the US and Finland	Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing	Specifies test methods and performance criteria which evaluate high voltage system spillage, battery retention, and electrical system isolation in Electric, Fuel Cell and Hybrid vehicles during specified crash tests.
SAE J2464	Japan, China, Germany, the US and Finland	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing	Guides toward standard practice and is subject to change to keep pace with the experience and technical advances. It describes a body of tests which may be used as needed for abuse testing of electric or hybrid electric vehicle batteries to determine the response of such batteries to conditions or events which are beyond their normal operating range.

[148]Category M: used for the carriage of passengers. Category N: used for the carriage of goods

Standards	Countries complying	Description and Applicability	Coverage
SAE J2929	Japan, China, Germany, the US and Finland	Safety standard for electric and hybrid vehicle propulsion battery systems utilizing Lithium-based rechargeable cells.	Defines a minimum set of acceptable safety criteria for a Lithium-based rechargeable battery system to be considered for use in a vehicle propulsion application as an energy storage system connected to a high voltage power train.
IEC 61000-4	Japan, China, Germany, the US and Finland	Electromagnetic compatibility (EMC) – Part 4-4: testing and measurement techniques – electrical fast transient/burst immunity test.	Specifies immunity requirements and test procedures related to electrical fast transients/ bursts. It additionally defines ranges of test levels and establishes test procedures. The objective of this standard is to establish a common and reproducible reference in order to evaluate the immunity of electrical and electronic equipment when subjected to electrical fast transient/bursts on supply, signal, control and earth ports.
IEC 62660-2	Japan, China, Germany, the US and Finland	Secondary Lithium-Ion cells for the propulsion of electric road vehicles - Part 2: reliability and abuse testing.	Specifies test procedures to observe the reliability and abuse behavior of secondary Lithium-Ion cells used for propulsion of electric vehicles including battery electric vehicles (BEV) and hybrid electric vehicles (HEV). Electrical measurements like capacity, SOC adjustment, power, energy, storage, cycle life and energy efficiency are included in the standard.
SAE J2380	Japan, China, Germany, the US and Finland	Vibration testing of electric vehicle batteries.	Specifies the vibration durability testing of a single battery (test unit) consisting of either an electric vehicle battery module or an electric vehicle battery pack.
UL 2580	Japan, China, Germany, the US and Finland	This standard evaluates the electric energy storage assembly and modules based upon the manufacturer's specified charge and discharge parameters at specified temperatures.	Specifies tests like mechanical – shock, drop, immersion, crush/crash, rollover, vibration; electrical – external short circuit, overcharge/ overdischarge, thermal shock and cycling; thermal stability, fire, and chemical – emissions and flammability.
UL 38.3	Japan, China, Germany, the US and Finland	It presents a combination of significant environmental, mechanical and electrical stresses from transportation of dangerous goods.	Specifies includes tests like thermal, vibration, shock, impact, crush, external short circuit, overcharge, forced discharge and altitude simulation for safety of battery during transportation.
ECE R100	Germany and Finland	Safety requirements with respect to the electric power train of road vehicles of categories M and N[148].	Specifies the requirements for protection against electrical shock, safety requirements of rechargeable energy storage system (REESS), Functional Safety. Tests include determination of hydrogen emissions. The REESS will be subjected to vibration, thermal shock and cycling, mechanical impact, fire resistant, external short circuit protection, overcharge protection, over discharge protection, over temperature protection and emission to determine safety.

Standards	Countries complying	Description and Applicability	Coverage
USABC	The US	This manual determines the test for EVs, batteries, storage abuse and configuration guidelines.	Specifies tests like mechanical – shock, drop, penetration, immersion, crush/crash, rollover, vibration; electrical – external short circuit, overcharge/over discharge, thermal shock and cycling, thermal stability, overheat, fire, extreme cold temperature and chemical – emissions, flammability.
FreedomCAR	The US	Electrical Energy Storage System Abuse Test Manual for Electric and Hybrid Electric Vehicle Applications	Specifies tests like mechanical – shock, drop, penetration, immersion, crush/crash, rollover, vibration; electrical – external short circuit, overcharge/over discharge, thermal shock and cycling; thermal stability, fire; and Chemical – emissions, flammability.
KMVSS	Korea	This standard specifies the general rules and safety standards for vehicles in Korea.	Specifies tests like drop, immersion, external short circuit, overcharge/over discharge, thermal stability, fire, etc.
QC/T 743	China	Applicable to Lithium-Ion batteries for electric vehicles, of which the nominal voltage of monomer is 3.6V and modules are n×3.6V (n is number of battery).	Specifies tests like drop, penetration, crush/crash, vibration, external short circuit, overcharge/over discharge, thermal stability, etc.
UL 2251	The US	Standard for safety of plugs, receptacles and couplers for electric vehicles. These requirements cover EV plugs, EV receptacles, vehicle inlets, vehicle connectors and EV breakaway couplings, rated up to 800 amperes and up to 600 volts AC or DC.	Specifies construction, performance tests like accelerated aging test, mold stress relief, moisture absorption resistance, humidity conditioning, insulation resistance, dielectric withstand, dew point test, conductor secureness and pull-out, cable secureness test, impact, crush, vehicle drive over, withdrawal force, grounding path current, short circuit, overload, endurance, electromagnetic, temperature rise, resistance to arcing, polarization integrity, resistance to corrosion, vibration, etc., along with ratings and markings.
UL 2594	The US	This standard covers conductive electric vehicles' (EVs') supply equipment with a primary source voltage of 600 V AC or less, with a frequency of 50 or 60 Hz, and intended to provide an AC power to an electric vehicle with an on-board charging unit.	spacing, separations of circuits, control circuits, capacitors, resistors and suppressors, over current protective devices, transformers specifications, information on protection of users against injury, performance tests which includes dielectric voltage withstand test, abnormal tests, strain relief test, grounding test, bonding conductor test, additional environmental test, etc.

Standards	Countries complying	Description and Applicability	Coverage
UL 2202	The US	It covers conductive and inductive charging system equipment intended to be supplied by a branch circuit of 600 V or less for recharging the storage batteries in over the road EV. The equipment is loaded on or off boarded from the vehicle.	Provides general construction specifications, tests pertaining to protection of users against injury, performance tests like dielectric voltage withstand test, abnormal tests, strain relief test, tests for permanence of cold tag, manufacturing and production tests, ratings, markings, etc.
IEC 62196	Japan, Germany, the US, Finland	Establishes general characteristics, including charging modes and connection configurations, and requirements for specific implementations (including safety requirements) of both electric vehicles (EVs) and electric vehicle supply equipment (EVSE) in a charging system	Specifies the general requirements, ratings, connections between power supply and electric vehicles, classification of accessories, marking, dimension, protection against electric shock, size and color of protective earthing conductors, mechanical strength, temperature rise, electromagnetic compatibility, etc.
IEC 61851-1	Japan, Germany, the US, Finland	Electric vehicle conductive charging system. Applies to EV supply equipment for charging electric road vehicles, with a rated supply voltage up to 1,000 V AC or up to 1,500 V DC and a rated output voltage up to 1,000 V AC or up to 1,500 V DC.	Specifies power supply input and output characteristics; environment conditions; protection against electric shock; charging modes description and their function; communication between EVSE and EV; communication between EVSE and management system; conductive electrical interface requirements; requirements for adaptors; cable assembly requirement; EV supply equipment constructional requirements and tests; overload and short-circuit protection; automatic reclosing of protective devices, etc.
IEC 61851-21-1	Japan, Germany, the US, Finland	Electric vehicle conductive charging system – Part 21-1: electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply. It applies only to on-board charging units either tested on the complete vehicle or charging system component level (ESA - electronic sub assembly).	Specifies general test conditions; test methods and requirements; immunity of vehicles; immunity of electromagnetic radiated RF-fields and pulses on supply lines; emission test conditions; emission of harmonics and voltage changes; high frequency conducted and radiated disturbances, etc.
IEC 61851-23	Japan, Germany, the US, Finland	Electric vehicle conductive charging system – Part 23: DC electric vehicle charging station. It gives the requirements for DC electric vehicle (EV) charging stations, for conductive connection to the vehicle, with an AC or DC input voltage up to 1 000 V AC and up to 1 500 V DC.	Provides rating of the supply AC voltage; general system requirements and interface; protection against electric shock; connection between power supply and the EV; specific requirements for vehicle coupler; charging cable assembly requirements; EVSE requirements; specific requirements for DC EV charging station; communication between EV and DC EV charging station, etc.

Standards	Countries complying	Description and Applicability	Coverage
IEC 61851-24	Japan, Germany, the US, Finland	Electric vehicle conductive charging system - Part 24: Digital communication between a DC EV charging station and an electric vehicle for control of DC charging. This part, together with IEC 61851-23, applies to digital communication between a DC EV charging station and an electric vehicle (EV) for control of DC charging, with an AC or DC input voltage up to 1000 V AC and up to 1500 V DC for the conductive charging procedure	Provides system configuration; digital communication architecture; charging control process; overview of charging control; exchanged information for DC charging control, etc.
SAE J2894	The US	Power Quality Requirements for Plug-In Electric Vehicle Chargers	Specifies those parameters of PEV battery charger that must be controlled in order to preserve the quality of the AC service. Identify those characteristics of the AC service that may significantly impact the performance of the charger. Identify values for power quality, susceptibility and power control parameters which are based on the current standards in the US and other countries. These values should be technically feasible and cost effective to implement into PEV battery chargers.
SAE J2293	The US	Energy Transfer System for Electric Vehicles - Part 1: Functional Requirements and System Architectures	Specifies requirements for EV and the off-board EVSE used to transfer electrical energy to an EV from an electric utility power system (utility). Covers all characteristics of the total EV energy transfer system (EV-ETS) that are necessary to ensure the functional interoperability of an EV and EVSE of the same physical system architecture. The ETS, regardless of the architecture, is responsible for the conversion of AC electrical energy into DC electrical energy that can be used to charge the storage battery of an EV.
SAE J1772	Japan, China, Germany, the US, Finland	SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler	Specifies general physical, electrical, functional and performance requirements to facilitate conductive charging of EV/PHEV vehicles in North America. This document defines a common EV/PHEV and supply equipment vehicle conductive charging method including operational requirements and the functional and dimensional requirements for the vehicle's inlet and mating connector.

Standards	Countries complying	Description and Applicability	Coverage
IEC 61982	Japan, China, Germany, the US and Finland	Secondary batteries (except Lithium) for the propulsion of electric road vehicles – performance and endurance tests	Accuracy of measuring instruments; dynamic discharge performance test; dynamic endurance test and performance testing for battery systems
IEC 62660-1	Japan, China, Germany, the US and Finland	Secondary Lithium-Ion cells for the propulsion of electric road vehicles - Part 1: performance testing	Test conditions; dimensions and mass measurement; electrical measurement; capacity; SOC adjustment; power; energy; storage test; cycle life test; energy efficiency test, etc.

3.5

India EV testing landscape

It is important to analyze the testing standards followed in the mature markets to identify the potential issues and gaps in the existing practices in India. Global mapping was done to see the existing standards followed in the mature markets. These mapping will help in benchmarking the standards around categories like EVs, battery, battery performance and EVSE in mature markets which can help us to develop the standards in the India. Accordingly, the table below describes the key considerations for testing according to the existing Indian standards and maps them to global equivalent standards.

Table 42: India EV landscape

Category	Standards adopted	Descriptions and coverage	Global equivalent
Electric vehicle	AIS 038	Electric Power Train Vehicles Construction and Functional Safety Requirements. It specifies the construction and functional safety requirements for L, M and N categories of electric power train vehicles as defined in Rule 2 (u) of Central Motor Vehicles rules (CMVR).	UN ECE R100
	AIS 039	Electric Power Train Vehicles- Measurement of Electrical Energy Consumption.	UN R101
	AIS 040	Electric power train vehicles - Method of Measuring the Range It specifies the method for measuring the range expressed in km for L, M and N categories of electric power train vehicles.	UN R101 Rev3

Category	Standards adopted	Descriptions and coverage	Global equivalent
	AIS 041	Electric power train vehicles Measurement of Net Power and the Maximum 30 Minute Power	UN ECE R85
	AIS 049	Electric Power Train Vehicles - CMVR Type Approval for Electric Power Train Vehicles. This standard prescribes the applicability of CMVR rules and corresponding standards for electric power train vehicles.	
Battery	AIS 048	Battery Operated Vehicles - Safety Requirements of Traction Batteries. This standard requires tests like electrical tests (short circuit tests, overcharge tests) and mechanical tests (vibration, shock, roll over test and penetration test).	IEC 60254 IS 13514
EVSE	AIS 138 Part I AC Charging System	Include characteristics and operating conditions of the supply device and the connection to the vehicle; operators and third-party electrical safety and the characteristics to be complied with by the vehicle with respect to the EVSE-AC, only when the EV is earthed.	IEC 61851
	AIS 138 Part II DC Charging System	This standard gives the requirements for DC electric vehicle (EV) charging stations, for conductive connection to the vehicle, with an AC or DC input voltage up to 1000 V AC and up to 1500V DC. This standard provides the general requirements for the control communication between a DC EV charging station and an EV. The requirements for digital communication between DC EV charging station and electric vehicle for control of DC charging are defined in this document.	

4 Viability assessment for setting up charging stations

Deployment of adequate charging infrastructure is necessary for accelerating the adoption of EVs. Due to low uptake of EVs that results in lower asset utilization in terms of utilization hours of charging stations, investors are sceptical in deploying such infrastructure. Further, due to rapid changes in battery technology and apprehension on standards of EVSE, the technology risk seems to be higher.

In order to address the concerns of potential investors, the GoI is planning to be technology agnostic in adopting the standards and looking at Viability Gap Funding (VGF) instruments to encourage the market. This chapter delves with viability assessment of operations of charging infrastructure and focusses on determining the key cost drivers that could help the policy makers and investors take measures for sustainable operations.

4.1. Viability assessment for deployment of a DC fast charger: with capital subsidy

One of the major barriers towards adoption of EVs is considered to be range anxiety. DC fast chargers seem inevitable for sustenance of the operation of organizations who operate large fleets and even for travelers, who desire to drive their EVs out of a city premises. However, DC fast chargers are expensive as of now and capital recovery is difficult.

Moreover, lower utilization due to lower number of EVs plying on roads may lead to stranded assets and high cost loading on retail pricing. This might be a deterrent for EV users to use public DC fast charging infrastructure. The model covered in this section intends to explore the viability of a DC fast charging infrastructure and captures the elements that could ease their deployment.

4.1.1. Deployment scenario

A charging station typically may be located at a public parking of a municipal corporation that leases parking space to an agency. Charging station deployed in such a parking lot may consist of AC slow chargers, DC fast chargers or a combination of both depending upon the location and purpose for which people park their vehicles.

The model developed for the purpose of the study is based on a scenario wherein the parking lot operating agency installs a fast DC charging station of 22 kW at its parking lot. The charging station has a single DC charging point and is used to charge vehicles with average battery capacity of 18.55 kWh. It has been further assumed on the basis of the existing electric cars available in Indian market that the vehicle would deliver a range of 130 km on a single full charge. Further, it is assumed that the losses due to conversion and across other active and passive electrical components present in EVSE would be about 20%.

However, as the DC fast charger charges vehicles to 80% of their capacity in a constant current (CC) mode, the charging station operator shall need to procure 20% extra power to compensate for the power lost in EVSE and shall even load the loses to the EV users.

The DC fast charger deployed by a parking lot operator needs to apply for a separate metered connection for the purpose of charging EVs as a consumer of DISCOM. The tariff that the operator needs to pay to the DISCOM is INR7.5 per unit (kWh). The connection that the operator needs to apply shall be for a low tension commercial consumer or a special consumer category for EVs' charging. No mark-up shall be charged on electricity by the operator to pass on the benefit of preferential tariffs, if any, as provided by the DISCOM.

The operator shall, however, levy a mark-up of about 30% on fixed costs for recovery of investments made on installation and operation of the charging station.

Assumptions on location of deployment of a charging station

- The model delves around deployment of one DC fast charger with one fast charging point at public parking of Municipal Corporation of Delhi.
- The typical charges for parking of a vehicle is INR20 per hour with year-on-year (YOY) escalation of 5%.
- A mark-up of 30% has been considered over the parking charges of INR20 per hour for recovering the investment done on the charging station.
- It has been considered that an operator needs to pay INR10,000 per month as rent of the parking lot to the lessee of the parking lot.
- Annually, the charging station operation is done for 330 days.

assumptions on location of deployment of a charging station

- One charging point is available in a DC fast charging station.
- Power rating of DC fast charger is assumed to be 22kW.
- Cost of one DC fast charger has been assumed to be INR2.5 lakh.
- Capital subsidy on DC fast charger is considered as 75% .
- Service life of charger 10 years.
- Installation cost is 25% of capital cost of a DC fast charger.
- Annual maintenance costs have been considered to be 1% of the capital cost of a DC fast charger and a yoy escalation is considered to be 2%.
- It has been assumed that an electric vehicle shall be charged till 80% of its battery capacity.
- Further, the losses in charger has been assumed to be 20%.
- Utilization of a DC fast charger has been assumed to be six hours a day with an yoy improvement of 2%.

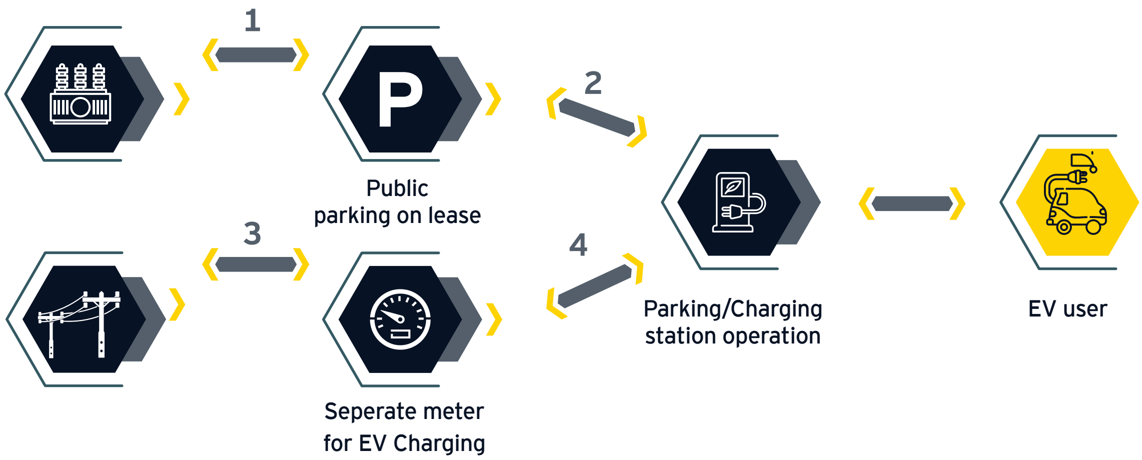
The cost of debt has been assumed to be 10% with a repayment period of 10 years and the weighted average cost of capital (WACC) is 13%. The debt to equity ratio for the model has been considered to be 70:30. The duration of the installation for a charger ranges from a few days to a month and hence, the moratorium period for repayment has not been considered.

Other assumptions

- For straight line value method (SLM), depreciation is considered to be spread over 10 years (life of charger).
- The written down value method (WDV) assumes 80% depreciation.
- Tax: basic tax – 30%, MAT – 19%, Surcharge – 12% and Cess – 3%.

4.1.2. Revenue model

The charging station operator pays to DISCOM for energy charges in per unit (kWh). The operator charges EV users who shall park their vehicles and get it charged. Hence, the operator shall charge EV users on the basis of time (per minute). As benefit of tariff of electricity for EV charging shall be passed on to the EV user, the mark-up of 30% on parking charges of INR20 per hour shall be charged for recovery of capital investments done by the operator. The operator shall charge the EV (end) user a blended price on per minute basis that shall comprise of both parking and energy charges.



1 Lease of parking lot to an operator by Municipal Corporation

2 Operation of parking lot by the operator who provides parking at INR 20 per hour for a 4 wheeler

3 DISCOM installs separate metered connection for EV charging

4 The tariff that operator needs to pay to DISCOM is in per unit (kWh) basis

5 Blended price per minute basis of charging= Losses in EVSE + Capital cost for charges+ One time installation cost + O&M costs is charged to EV user by operator

Figure 30: Deployment model for a DC fast charging station in a public parking EV charging[150]

[149]Department of Heavy Industry (DHI) - http://dhi.nic.in/writereaddata/UploadFile/FinalEoI31102017.pdf
[150]EY analysis

The above figure represents the deployment model for a DC fast charging station in a public parking. The following table is a summary of assumptions taken for the developed model.

Table 43: Assumptions taken for the model developed[151]

Deployement location	MCD parking lot
Charger type	DC fast charger
Installation cost (INR)	2,50,000
Capital subsidy %	75%
Installation cost (INR)	62,500
Maintenance cost %	1%
Cost of electricity (INR/kWh	7.50
Mark up on cost of electricity (%)	0%
Duration of charge event (hours per charge)	0.84
Number of charge events per day	7.12
Retail price per minute of charging paid by EV user (INR/min)	4.00
Weighted average cost of capital (WACC)	13%

[151]EY analysis

The internal rate of return (IRR) on equity has been determined to be 30.2% and net present value (NPV) was found to be INR48,161.

Sensitivities of the model

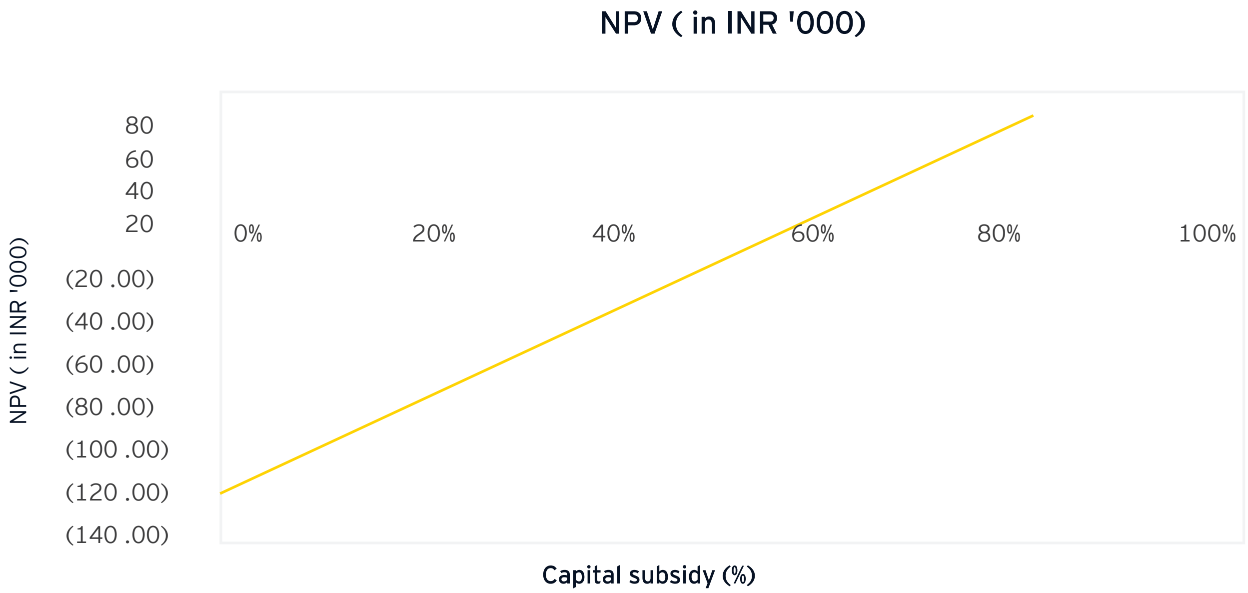


Figure 31: Net present value dependence on capital subsidy[152]

The above figure captures the sensitivity of an NPV with respect to the percentage of capital subsidy on purchase cost of the EVSE. It was determined that the project is viable, i.e., NPV is greater than zero, when capital subsidy is more than 45%. Moreover, as shown in figure 2, project is feasible if the subsidy is greater than 45%, as NPV becomes greater than zero and equity IRR becomes 30.2%, which is greater than weighted average cost of capital (WACC).

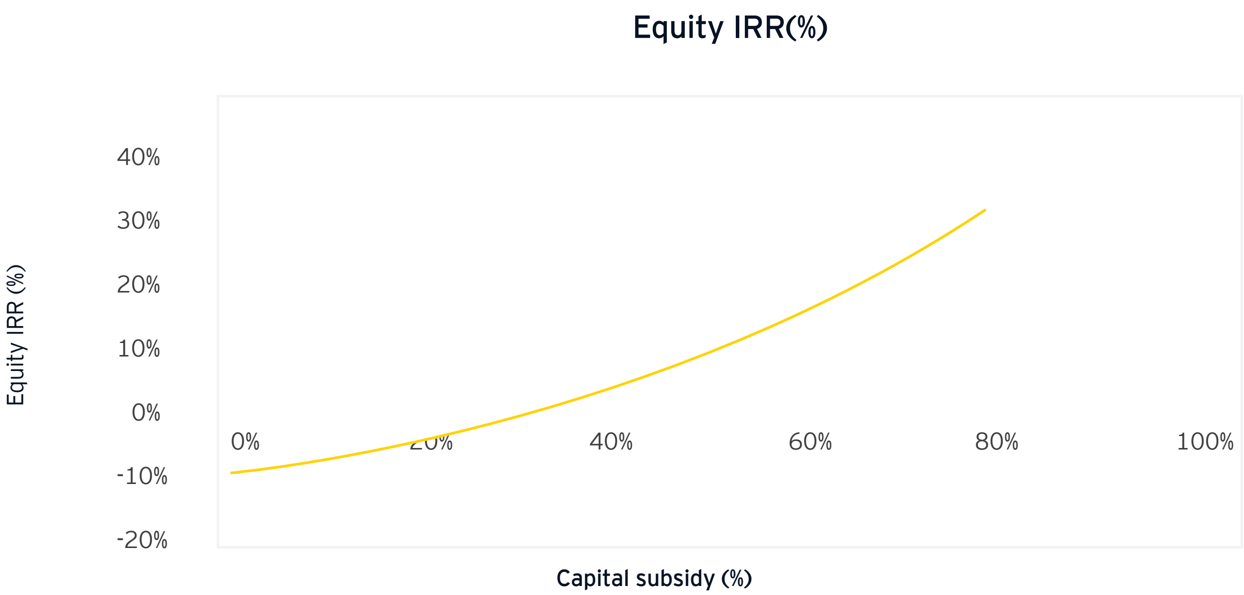


Figure 32: Equity IRR variation with capital subsidy[153]

[152] EY analysis
[153] EY analysis
[154] EY analysis

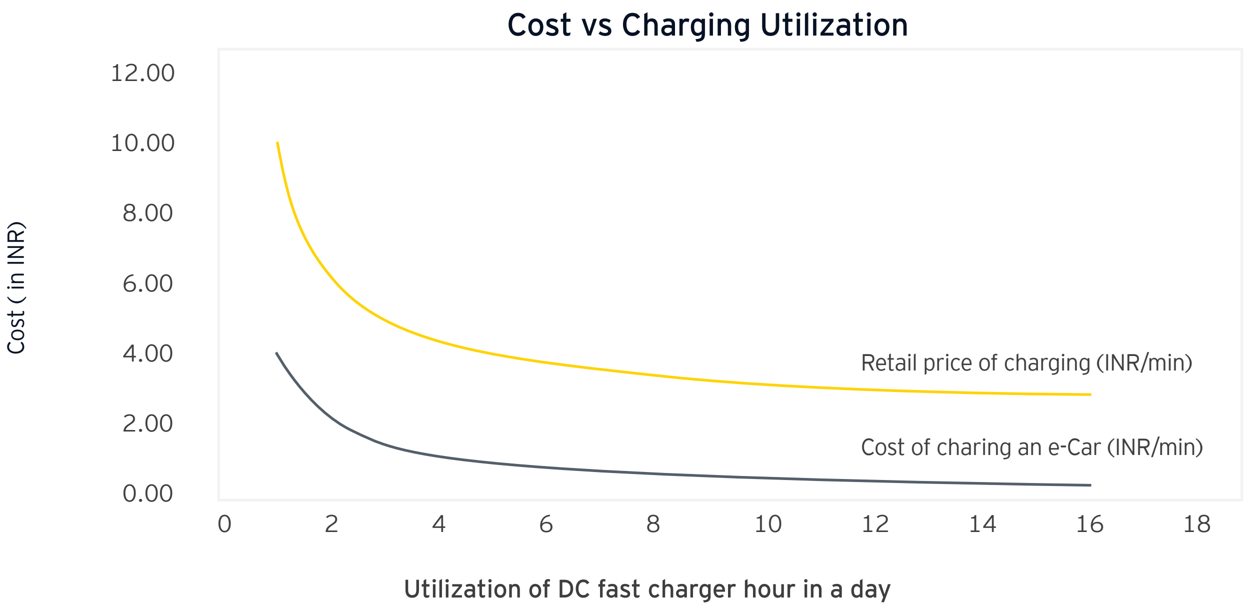


Figure 33: Impact of utilization of a DC fast charger on retail price of charging[154]

It has been observed that higher utilization of EVSE results in lower retail per minute pricing would be charged by a charging station operator. The retail pricing has been determined to be INR4 per minute of charging that the operator will charge the EV user considering that the utilization of the

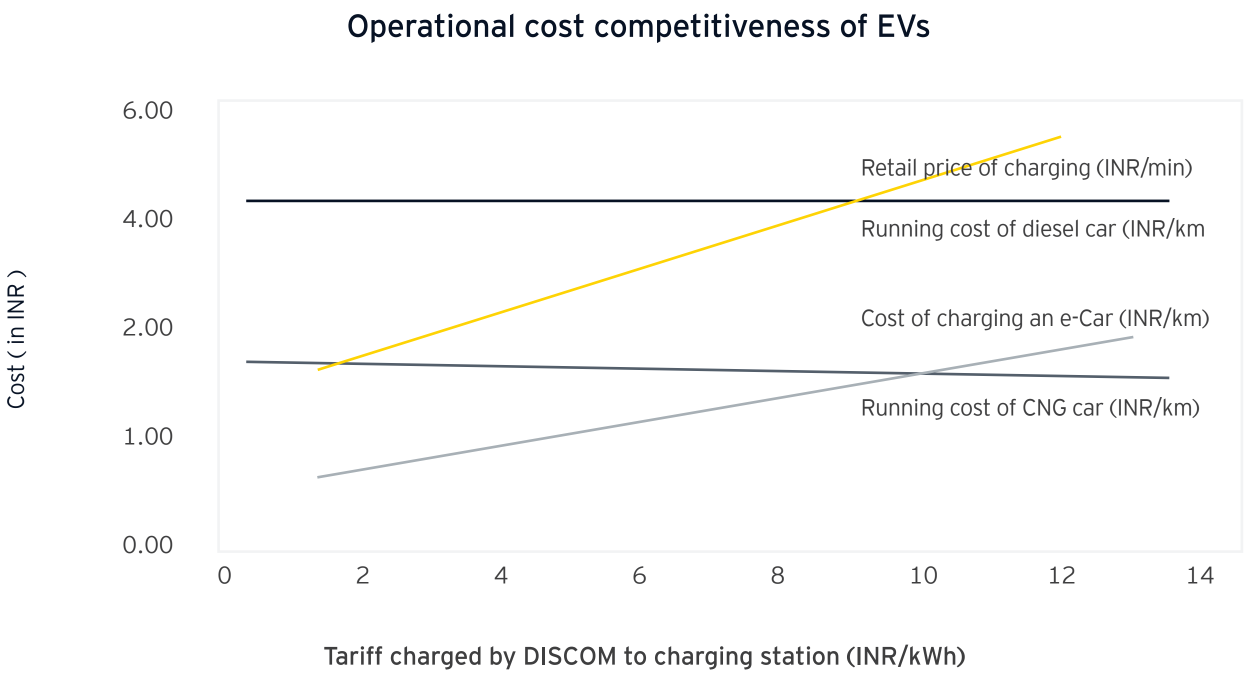


Figure 34: Operational Cost competitiveness of EVs

[154]EY analysis

charging station shall be effectively be about six hours in a day and being in operation for 330 days in a year. The model considers that the charging station shall in an average be in maintenance for 35 days in a year.

The cost of operation on electric car with a range of 130 km and battery capacity of 18.55 kWh has been determined to be INR1.54 per km. Further, cost of operations of equivalent diesel and CNG fuel fired internal combustion engine (ICE) car was found to be INR4.20 and INR1.85 per km, respectively. If the tariff charged by DISCOMs to charging station operators exceeds INR8.5 per kWh, then it is observed that EVs will lose the advantage of lower operational costs.

As per the Charging Infrastructure for Electric Vehicles – Guidelines and Standards – Regulation (dt. 14th December 2018), the tariff for supply of electricity to EV Public Charging Station shall be shall not be more than the average cost of supply plus 15%. This is a significant move considering that DISCOMs could be adequately compensated as ACS takes into account power purchase cost as well as losses. Such a decision shall not burden the DISCOMs unless they have losses more than 15%.

Hence, it shall serve the purpose of keeping the operational costs of EVs low so that there would be price advantage for fleet operators as well as individual users to switch to EVs. Further, this will support DISCOMs in increasing their consumer base and generate revenue to take up infrastructure augmentation projects so as to strengthen their distribution network.

4.2.

Viability assessment for deployment of a DC fast charger without capital subsidy

4.2.1. Deployment scenario

A charging station typically may be located at a public parking of a municipal corporation that leases parking space to an agency. Charging station deployed in such a parking lot may consist of AC slow chargers, DC fast chargers or a combination of both depending upon the location and the purpose for which people park their vehicles.

The model developed for the purpose of the study is based on a scenario, wherein the parking lot operating agency installs a charging a 22 kW fast DC charging station at its parking lot. The charging station has a single DC charging point and is used to charge vehicles with average battery capacity of 18.55 kWh. It has been further assumed on the basis of the existing electric cars available in the Indian market that the vehicle would deliver a range of 130 km on single full charge. Further, it is assumed that the losses due to conversion and across other active and passive electrical components present in EVSE would be about 20%.

However, as the DC fast charger charges vehicles to 80% of their capacity, the charging station operator shall need to procure 20% extra power to compensate for the power lost in EVSE and shall even load the loses to EV users.

The DC fast charger deployed by a parking lot operator needs to apply for a separate metered connection for charging the EVs as a consumer of DISCOM. The tariff that the operator needs to pay to the DISCOM is INR7.5 per unit (kWh). The connection that the operator needs to apply shall be for a low tension commercial consumer or a special consumer category for charging the EVs. No mark-up shall be charged on electricity by the operator to pass on the benefit of preferential tariffs, if any, as provided by the DISCOM.

The operator shall, however, levy a mark-up of about 30% on fixed costs for recovery of investments made on the installation and operation of charging station.

Assumptions on location of deployment of charging station

- The model delves around deployment of one DC fast charger with one fast charging point at public parking of Municipal Corporation of Delhi.

- The typical charges for parking of a vehicle is INR20 per hour with a year-on-year escalation of 5%.
- It has been considered that an operator needs to pay INR 10,000 per month as rent of the parking lot to the lessee/owner of the parking lot.
- Annually, the charging station operation is assumed for 330 days.

Assumptions regarding procurement and installation of charging station

- One charging point is available in a DC fast charging station.
- Power rating of a DC fast charger is assumed to be 22KW.
- Cost of one DC fast charger has been assumed to be INR2.5 lakh[155] .
- Capital subsidy on a DC fast charger is considered as 0%.
- Service life of a charger is 10 years.
- Installation cost is 25% of the capital cost of a DC fast charger.
- Annual maintenance costs have been considered to be 1% of the capital cost of a DC fast charger and the yoy escalation is considered to be 2%.
- It has been assumed that an electric vehicle shall be charged till 80% of its battery capacity.
- Further, the losses in charger has been assumed to be 20%.
- Utilization of a DC fast charger has been assumed to be six hours a day with a yoy improvement of 2%.

The cost of debt has been assumed to be 10% with a repayment period of 10 years and the weighted average cost of capital (WACC) is 13%. The debt to equity ratio for the model has been considered to be 70:30. The duration of the installation for a charger ranges from a few days to a month and hence, the moratorium period for repayment has not been considered.

Other assumptions

- For straight line value method (SLM) depreciation is considered to be spread over 10 years (life of charger).
- The written down value method (WDV) assumes 80% depreciation.
- Tax: basic tax – 30%, MAT – 19%, Surcharge – 12% and Cess – 3%.

1.5.1. Power market in China

A charging station typically may be located at a public parking of a municipal corporation that leases parking space to an agency. Charging station deployed in such a parking lot may consist of AC slow chargers, DC fast chargers or a combination of both depending upon the location and the purpose for which people park their vehicles.

The model developed for the purpose of the study is based on a scenario, wherein the parking lot operating agency installs a charging a 22 kW fast DC charging station at its parking lot. The charging station has a single DC charging point and is used to charge vehicles with average battery capacity of 18.55 kWh. It has been further assumed on the basis of the existing electric cars available in the Indian market that the vehicle would deliver a range of 130 km on single full charge. Further, it is assumed that the losses due to conversion and across other active and passive electrical components present in EVSE would be about 20%.

However, as the DC fast charger charges vehicles to 80% of their capacity, the charging station operator shall need to procure 20% extra power to compensate for the power lost in EVSE and shall even load the loses to EV users.

The DC fast charger deployed by a parking lot operator needs to apply for a separate metered connection for charging the EVs as a consumer of DISCOM. The tariff that the operator needs to pay to the DISCOM is INR7.5 per unit (kWh). The connection that the operator needs to apply shall be for a low tension commercial consumer or a special consumer category for charging the EVs. No mark-up shall be charged on electricity by the operator to pass on the benefit of preferential tariffs, if any, as provided by the DISCOM.

The operator shall, however, levy a mark-up of about 30% on fixed costs for recovery of investments made on the installation and operation of charging station.

Assumptions on location of deployment of charging station

- The model delves around deployment of one DC fast charger with one fast charging point at public parking of Municipal Corporation of Delhi.
- The typical charges for parking of a vehicle is INR20 per hour with a year-on-year escalation of 5%.
- It has been considered that an operator needs to pay INR 10,000 per month as rent of the parking lot to the lessee/owner of the parking lot.
- Annually, the charging station operation is assumed for 330 days.

Assumptions regarding procurement and installation of charging station

- One charging point is available in a DC fast charging station.
- Power rating of a DC fast charger is assumed to be 22KW.
- Cost of one DC fast charger has been assumed to be INR2.5 lakh .
- Capital subsidy on a DC fast charger is considered as 0%.
- Service life of a charger is 10 years.
- Installation cost is 25% of the capital cost of a DC fast charger.
- Annual maintenance costs have been considered to be 1% of the capital cost of a DC fast charger and the yoy escalation is considered to be 2%.
- It has been assumed that an electric vehicle shall be charged till 80% of its battery capacity.
- Further, the losses in charger has been assumed to be 20%.
- Utilization of a DC fast charger has been assumed to be six hours a day with a yoy improvement of 2%.

The cost of debt has been assumed to be 10% with a repayment period of 10 years and the weighted average cost of capital (WACC) is 13%. The debt to equity ratio for the model has been considered to be 70:30. The duration of the installation for a charger ranges from a few days to a month and hence, the moratorium period for repayment has not been considered.

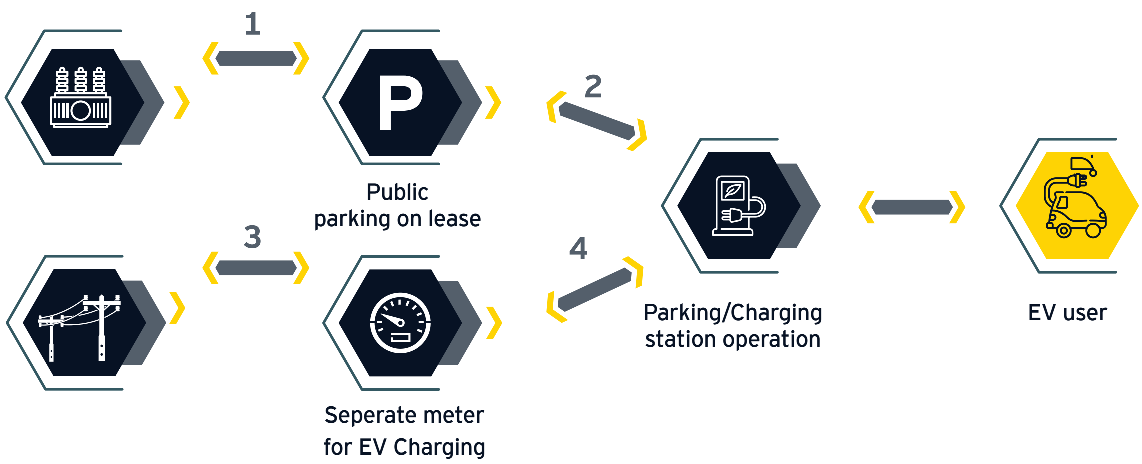
Other assumptions

- For straight line value method (SLM) depreciation is considered to be spread over 10 years (life of charger).
- The written down value method (WDV) assumes 80% depreciation.
- Tax: basic tax - 30%, MAT - 19%, Surcharge - 12% and Cess - 3%.

4.2.2. Revenue model

The charging station operator pays to DISCOM for energy charges in per unit (kWh) basis. The operator charges EV users who shall park their vehicles and get it charged. Hence, the operator shall charge EV users on the basis of time (per minute). As benefit of tariff of electricity for EV charging shall be passed on to the EV user, the mark-up of 30% on parking charges of INR20 per hour shall be charged for recovery of capital investments done by the operator. The operator shall charge the EV (end) user a blended price in per minute basis that shall comprise of both parking and energy charges.

The current revenue model has been designed to understand the effect on revenue, as the capital subsidy is set to 0%.



[150]EY analysis

[155]Alibaba - https://www.alibaba.com/product-detail/22KW-DC-Integrated-EV-Charger-EV_60655409710.html?spm=a2700.7724838.2017115.23.1fa9f17ezYIA0y

1 Lease of parking lot to an operator by Municipal Corpotaion

2 Operation of parking lot by the operator who provides parking at INR 20 per hour for a 4 wheeler

3 DISCOM installs seperate metered connection for EV charging

4 The tariff that operator needs to pay to DISCOM is in per unit (kWh) basis

5 Blended price per minute basisnof charging= Losses in EVSE + Capital cost for charges+ One time installation cost + O&M costs is charged to EV user by operator

Figure 35: Deployment model for a DC fast charging station in a public parking EV charging[156]

The above figure represents the deployment model for a DC fast charging station in a public parking.

There are two cases that have been taken into consideration for the study.

- Case 1: the capital subsidy is assumed to be 0%, whereas the effect on NPV and IRR is observed with the change in mark-up on lease expenses.
- Case 2: the capital subsidy is assumed to be 0% and the mark-up on lease expenses is assumed to be 40%, whereas the effect on NPV and IRR is observed with the change in mark-up on electricity prices charged to the EV owners.

Case 1

In the following scenario, the capital subsidy is assumed to be 0%, whereas the effect on NPV and IRR is observed with the change in mark-up on lease expenses. The following table is a summary of assumptions taken for the model developed.

Table 44: Summary table of assumptions taken for the model[157]

Deployement location	MCD parking lot
Charger type	DC fast charger
Charger cost (INR)	2,50,000
Capital subsidy %	0%
Installation cost (INR)	62,500
Maintenance cost %	1%
Cost of electricity (INR/kWh)	7.50
Mark up on cost of electricity (%)	0%
Duration of charge event (hours per charge)	0.84
Retail price per minute of charging paid by EV user (INR/min)	4.14
Weighted average cost of capital (WACC)	13%
Mark up on lease (%)	50%
Such that IRR>WACC	

[157]EY analysis://www.alibaba.com/product-detail/22KW-DC-Integrated-EV-Charger-EV_60655409710.html?spm=a2700.7724838.2017115.23.1fa9f17ezYIA0y

The internal rate of return (IRR) on equity has been determined to be 16.6% and net present value (NPV) was found to be INR21,074.

Sensitivities of the model

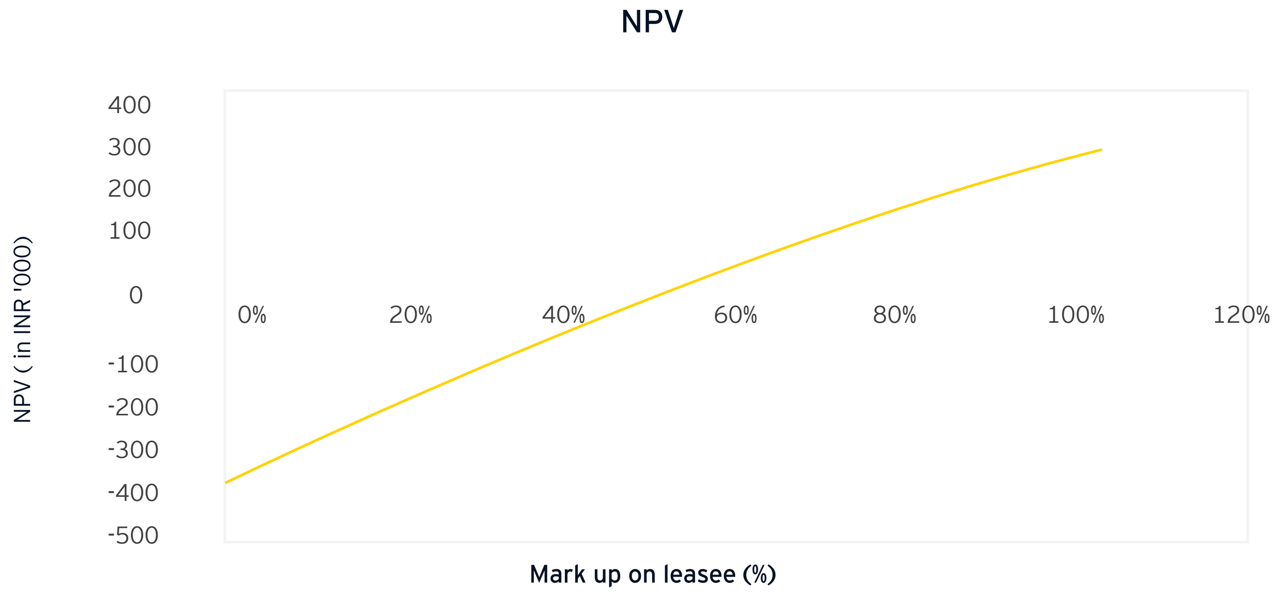


Figure 36: Net present value dependence on mark-up on lease [158]

The above figure captures the sensitivity of NPV with respect to percentage of mark-up on lease on the amount paid as per lease agreement. It was determined that the project is viable, i.e., NPV is greater than zero, when mark-up on lease is more than 50%. Moreover, as shown in figure 2, project is feasible if the mark-up on lease is greater than 50%, as NPV becomes greater than zero and equity IRR is 16.6%, which is greater than WACC.

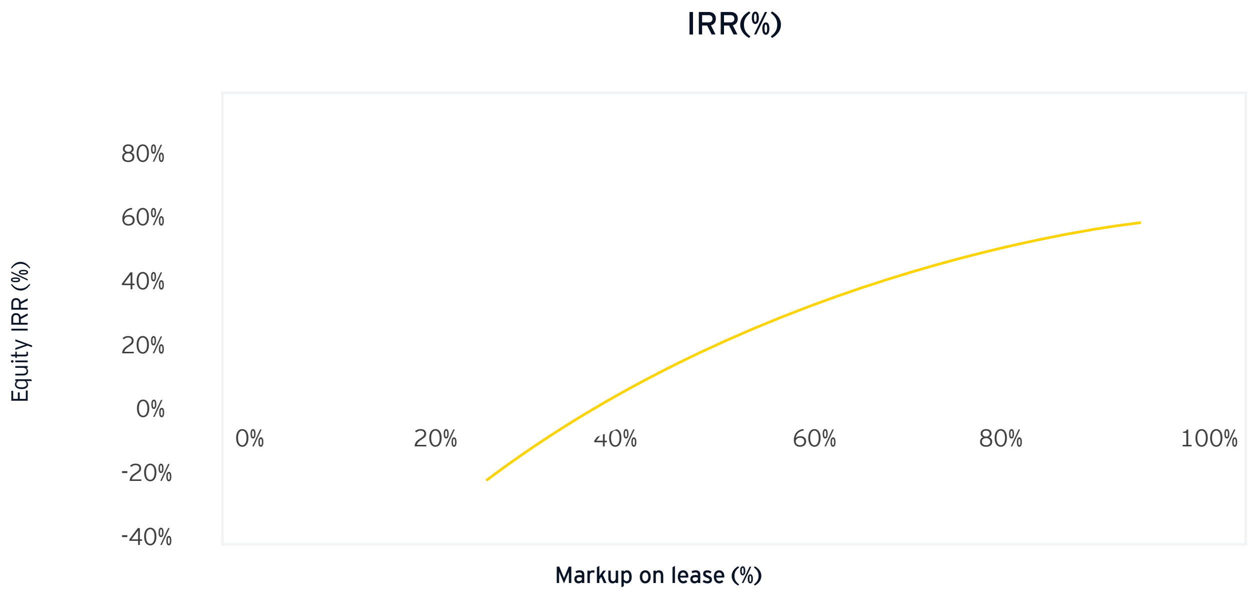


Figure 37: Equity IRR variation with change in mark-up on lease[159]

[158]EY analysis
[159]EY analysis

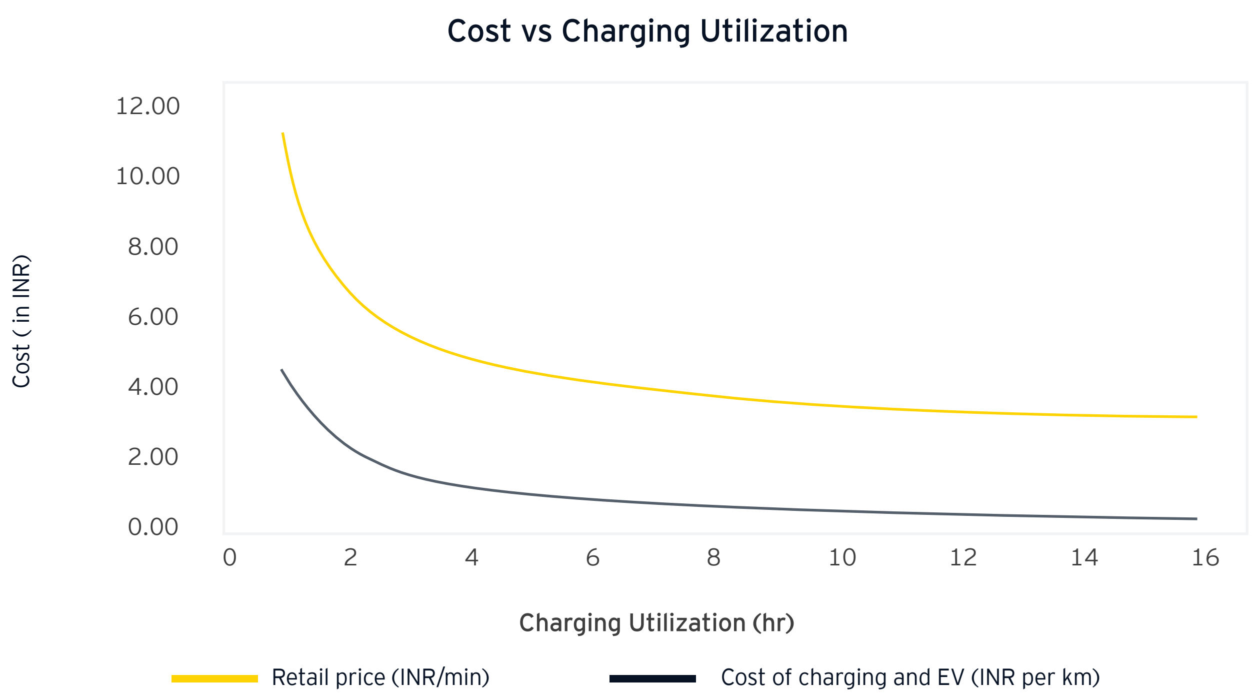


Figure 38: Impact of utilization of DC fast charger on retail price of charging[160]

It has been observed that higher utilization of EVSE results in lower retail per minute pricing charged by a charging station's operator. The retail pricing has been determined to be INR4.14 per minute of charging charged by an operator from an EV user considering the utilization of charging station shall be effectively be about six hours in a day and being in operation for 330 days in a year. The model considers that the charging station shall in an average be in maintenance for 35 days in a year.

The cost of operation on electric car with a range of 130 km and battery capacity of 18.55 kWh has been determined to be INR1.61 per km. Further, cost of operations of equivalent diesel and CNG fuel fired internal combustion engine (ICE) car was found to be INR4.20 and INR1.85 per km, respectively. If the tariffs charged by DISCOMs to charging station operators exceed INR9 per kWh, then it is observed that EVs will lose the advantage of lower operational costs.

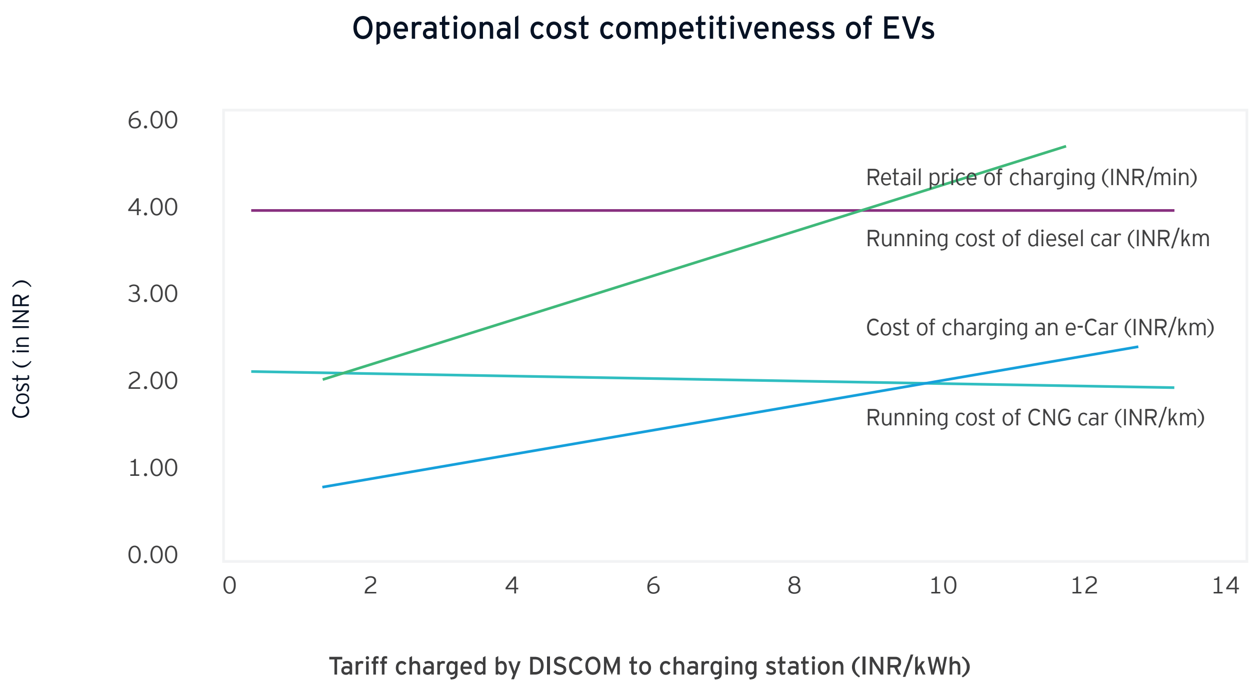


Figure 39: Operational cost competitiveness of EVs

Case 2

In the following scenario, the capital subsidy is assumed to be 0%, whereas the effect on NPV and IRR is observed with the change in mark-up on lease expenses. The following table is a summary of assumptions taken for the model developed.

Table 45: Summary table of assumptions taken for the developed model[157]

Deployement location	MCD parking lot
Charger type	DC fast charger
Charger cost (INR)	2,50,000*
Capital subsidy %	0%
Installation cost (INR)	62,500
Maintenance cost %	1%
Cost of electricity (INR/kWh)	7.50
Mark up on cost of electricity (%)	0%
Such that IRR>WACC	3%
Duration of charge event (hours per charge)	0.84
Retail price per minute of charging paid by EV user (INR/min)	4.13
Weighted average cost of capital (WACC)	13%
Mark up on lease (%)	40%

The internal rate of return (IRR) on equity has been determined to be 14.5% and the net present value (NPV) was found to be INR8,673.

Sensitivities of the model

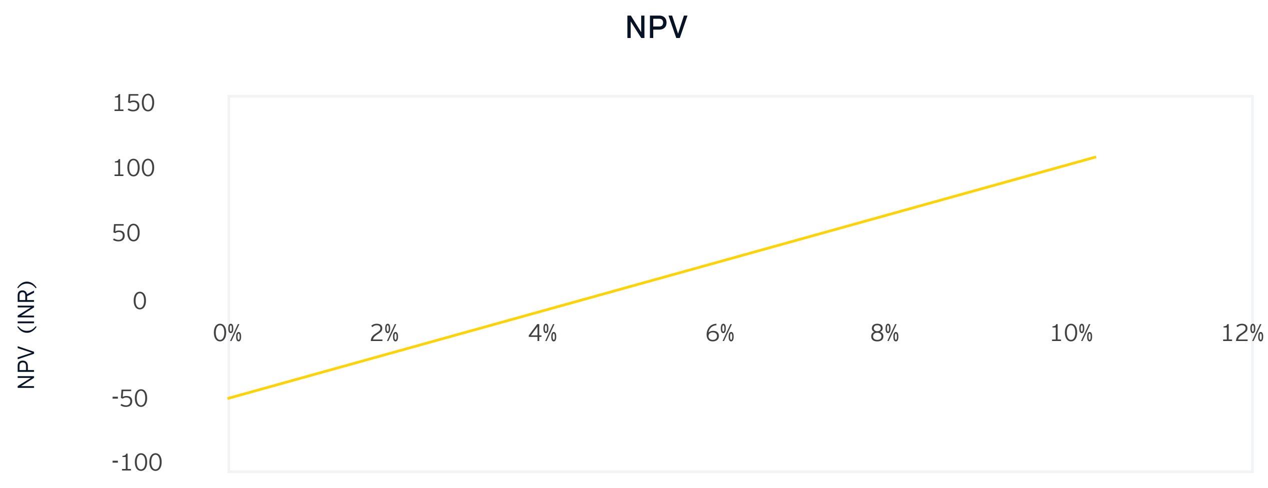


Figure 40: Net present value dependence on mark-up on electricity charged to EV owners[162]

[163]EY analysis

The above figure captures the sensitivity of NPV with respect to percentage of mark-up on cost of electricity levied on EV owners. It was determined that the project is viable, i.e., NPV is greater than zero, when mark-up on electricity is more than 3%. Moreover, as shown in figure 2, project is feasible if mark-up on electricity is greater than 3%, as NPV becomes greater than zero and equity IRR is 14.5%, which is greater than WACC.

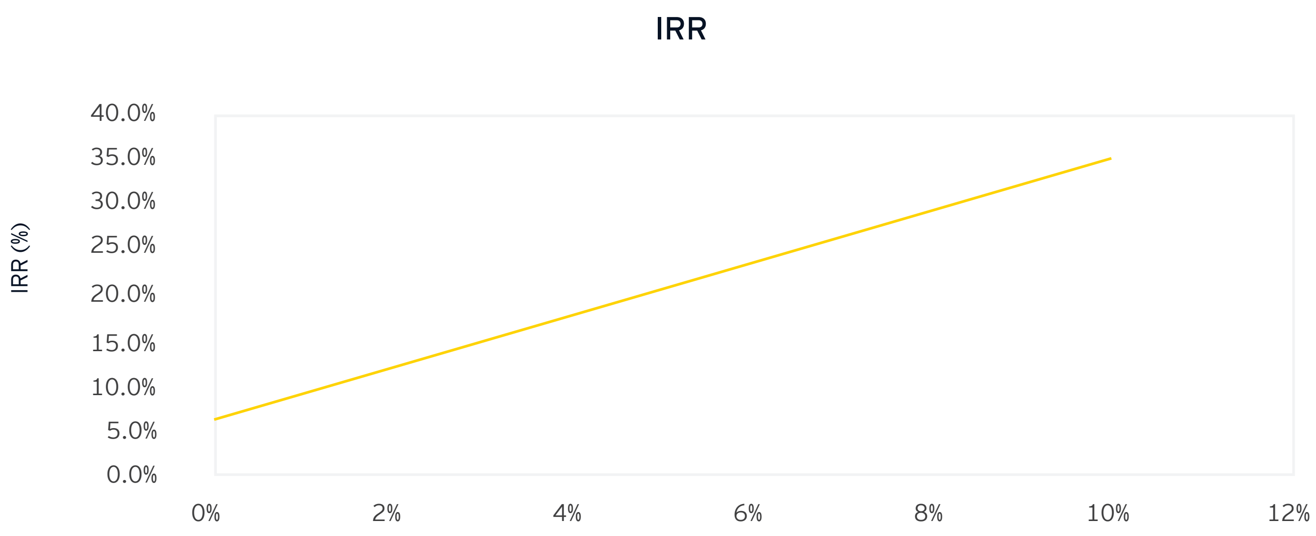


Figure 41: Equity IRR variation with change in mark-up on electricity charged to EV owners[163]

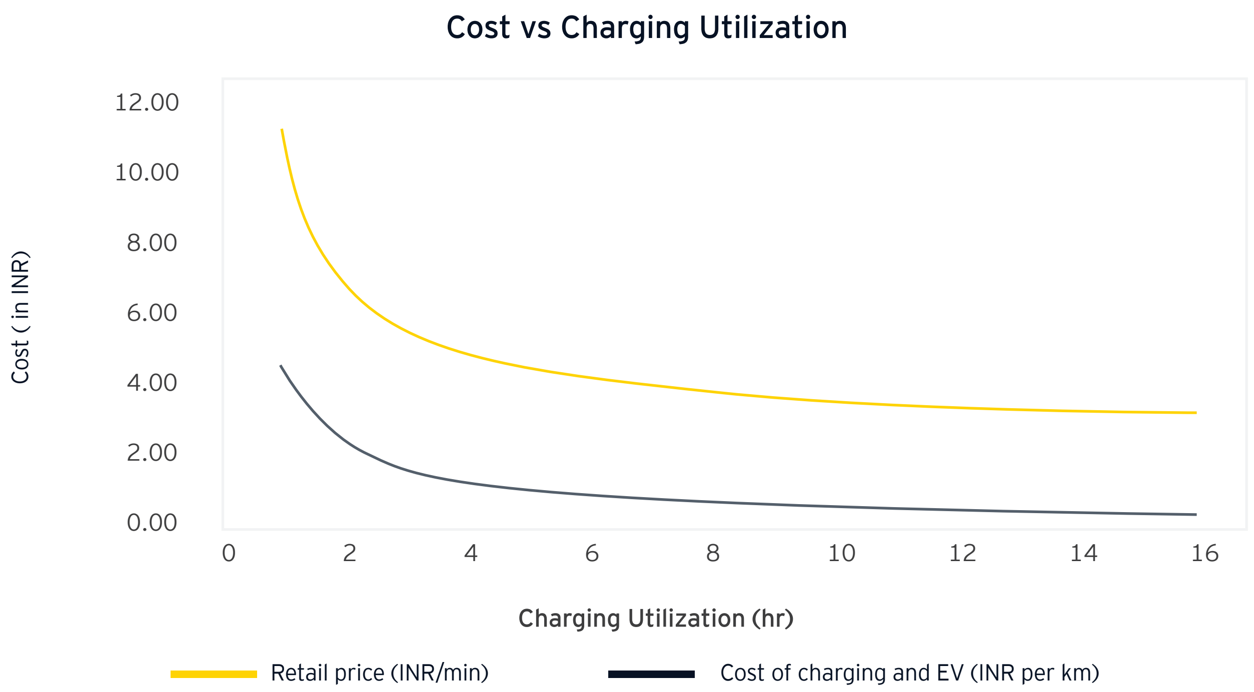


Figure 42: Impact of utilization of DC fast charger on retail price of charging

[163] EY analysis

It has been observed that higher utilization of EVSE results in lower retail per minute pricing that is charged by a charging station's operator. The retail pricing has been determined to be INR4.13 per minute of charging that the operator will charge the EV user considering that utilization of charging station shall be effectively be about six hours in a day and being in operation for 330 days in a year. The model considers that the charging station shall, in an average, be in maintenance for 35 days in a year.

The cost of operation on electric car with a range of 130 km and battery capacity of 18.55 kWh has been determined to be INR1.61 per km. Further, cost of operations of an equivalent diesel and CNG fuel fired internal combustion engine (ICE) car was found to be INR4.20 and INR1.85 per km, respectively. If the tariffs charged by DISCOMs to charging station operators exceeds INR9 per kWh, then it is observed that EVs will lose the advantage of lower operational costs.

Tariff charged by DISCOMs to charging stations

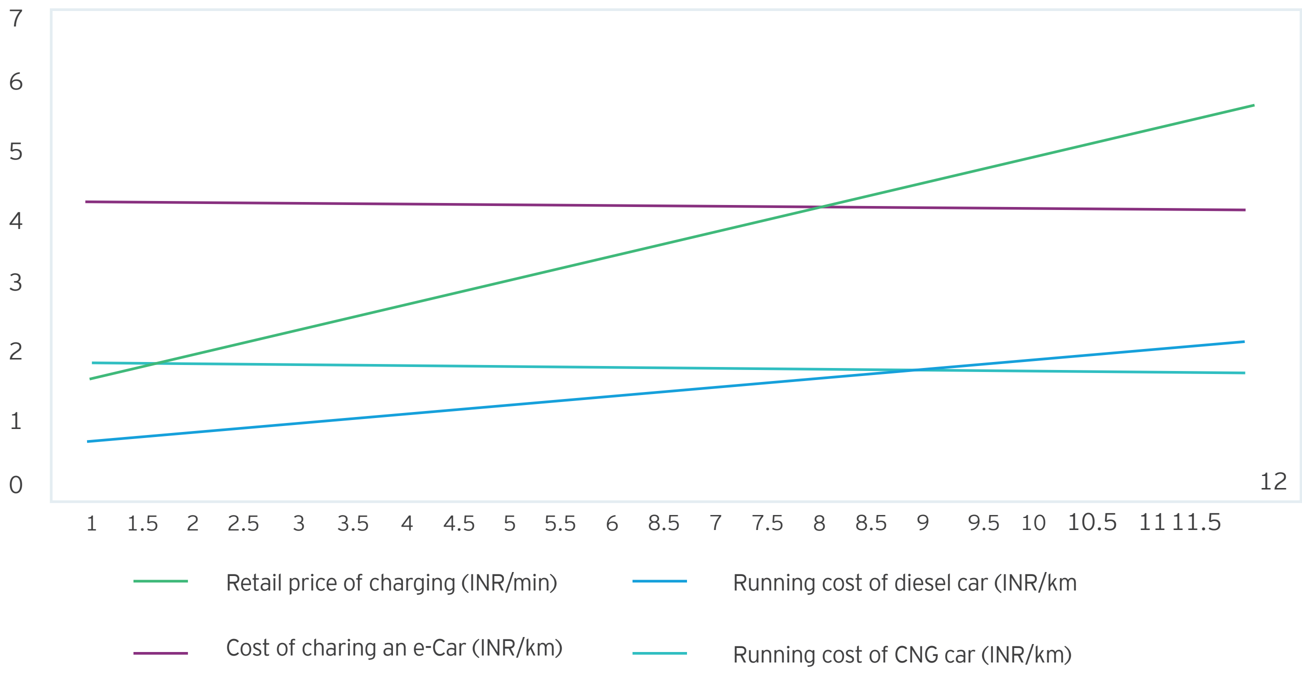


Figure 43: : Tariff charged by discoms to charging stations [164]

[164] EY analysis

4.3.

Assessment of ownership structures for reducing the risks

India's electric mobility sector has seen a rapid transformation. This has been primarily due to policy and regulatory level push both at central and state level. Government of India (GOI) has set an ambitious target of achieving 100% EVs by 2030.

The GOI's FAME scheme, which provides purchase subsidy for EVs, has been revised to further encourage EV adoption. In addition, clarification by the Ministry of Power for considering EV charging as a service has increased the interest of the industry players and investors for charging infrastructure deployment.

However, the EV landscape in India remains a chicken and egg situation. Despite the above-mentioned incentives, investors lack confidence in setting up charging stations due to lack of assured demand. In addition, operational risks related to lower utilization of chargers, financial risks regarding capability to service debt and contractual risks regarding revenue sharing are the key areas of concern for setting up charging stations. Furthermore, land acquisition remains a critical issue for market players.

Thus, it is imperative to design project structures which address these issues through optimal risk allocation. Accordingly, this section in the report aims at assessing two Public Private Partnership (PPP) models and a joint venture set-up between PSUs. The assessment has been done based on inputs from the industry players looking to set charging stations through these modalities.

For each model, a detailed project structure was designed. This included detailed review of cost allocation methodology, contractual obligations, revenue model and risks. In addition, sensitivity analysis was done to identify impact of parameters like charger utilization rate, mark up on cost of electricity as service charge and subsidy on the overall project viability.

4.3.1. Public Private Partnership

India has an opportunity to become the largest nation to achieve 100% electric mobility by 2030 and availability of adequate charging stations and associated infrastructure is imperative to achieve this objective. A PPP model may be one of the most suitable business models to develop such a critical public infrastructure. In addition to the fiscal benefits, the PPP model also gives an opportunity for the utilities to transfer the development and operational risks to private entities. The PPP model can minimize construction costs, implementation timelines and will allow the utilities access to the best practices and state-of-the-art technologies.

For a typical PPP model for charging infrastructure, risks can be broadly categorized as – risks to be managed by public players and risks that shall be transferred to private players. The former shall include policy and regulatory risks while the latter shall include construction, real estate and technology risk.

In order to increase the overall project viability, it is imperative to reduce the risks of private investors. Accordingly, state transport utilities and municipal corporations have been considered as the potential public entities in the PPP structure. Municipal corporations can provide access to land at strategic locations resulting in reduced risk for land acquisition. Also, state transport utilities can assure demand for EV charging apart from providing land available in their depots for installation of charging infrastructure. The following section tries to evaluate the impact of these benefits on the overall project viability.

PPP between private investors and municipal corporations

In this model, municipal corporations shall be giving land to private investors on a lease basis. The public entity shall also be having a revenue sharing mechanism with private investors. Private entities can be players ranging from OEMs to cab aggregators. Apart from revenue from EV charging, the model looks at advertising and co-branding as prospective revenue streams for private entities. In accordance with the PPP requirements, private entity shall be responsible for raising funds and assuring demand for the overall operation and maintenance of the asset. Key obligations for each player have been represented in the figure below

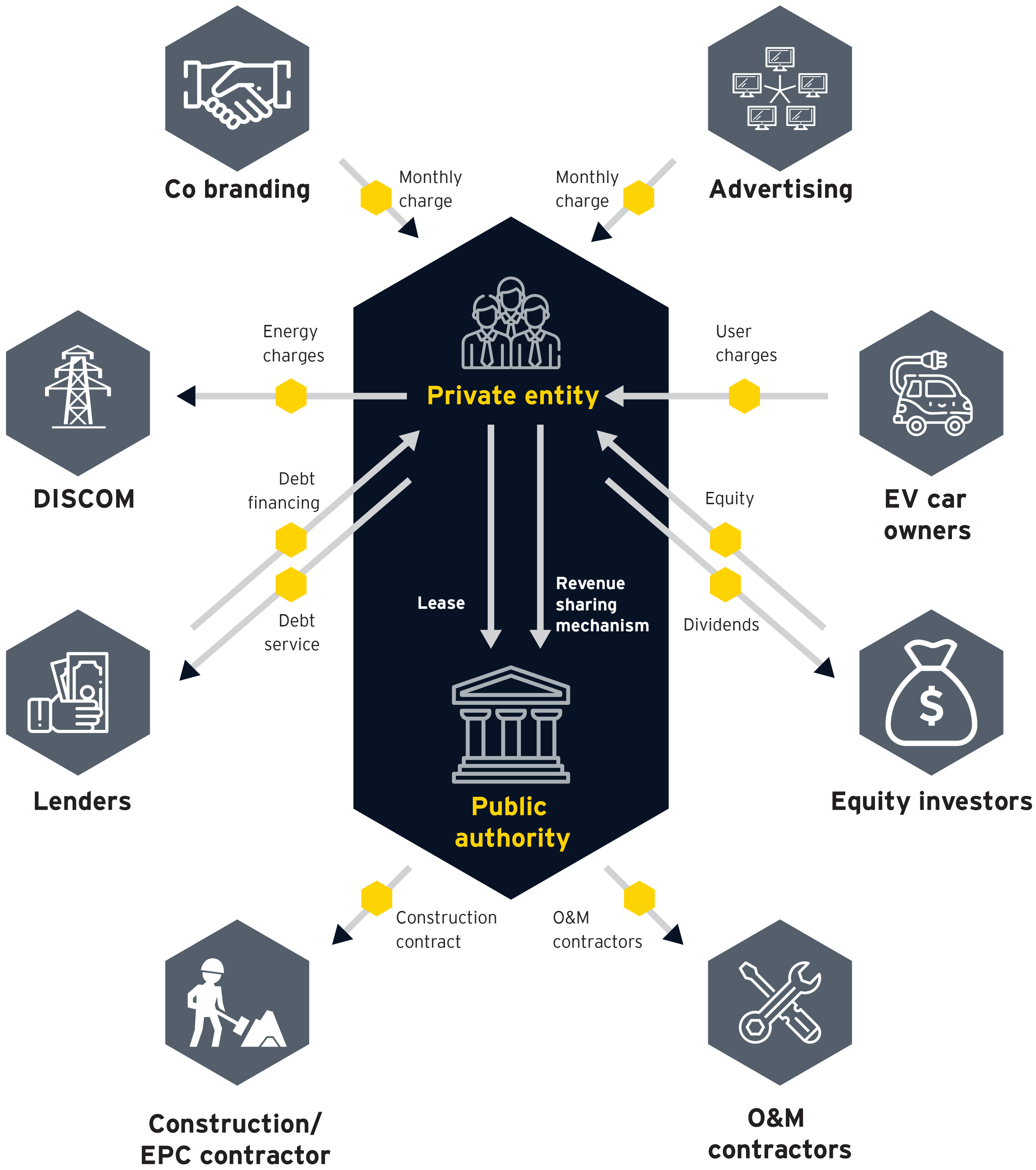


Figure 44: PPP players' key obligation representation [165]

[164]EY analysis

PPP between private investors and municipal corporations:

Deployment scenario

The model developed for the purpose of the study is based on a scenario wherein a fast DC charging station of 50 kW has been deployed. The charging station has a single DC charging point and is used to charge vehicles with an average battery capacity of 18.55 kWh. It has been further assumed, basis the existing electric cars available in Indian market, the vehicle would deliver a range of 130 km on a single full charge. Further, it is assumed that the losses due to conversion in EVSE as well as losses in distribution and consumption due to auxiliary load would be about 20%.

However, as the DC fast charger charges a vehicle to 80% of its capacity in a constant current (CC) mode, the charging station operator shall need to procure 20% extra power to compensate for the power lost in EVSE and shall even load the loses to an EV user.

The DC fast charger deployed by a parking lot operator needs to apply for a separate metered connection for charging EVs as a consumer of a DISCOM. The tariff that the operator needs to pay to the DISCOM is INR7.5 per unit (kWh). The connection that the operator needs to apply shall be for a low-tension commercial category consumer or a special consumer category for charging of EVs. The operator can charge a mark up on electricity as a service charge to derive the final consumer price for EV charging.

Assumptions

Assumptions on location of deployment of a charging station

- The model delves around deployment of one DC fast charger with one fast charging point at a public parking of Municipal Corporation of Delhi.
- Annually, the charging station operation is done for 330 days, considering 30-35 days for preventive and breakdown maintenance.

Assumptions regarding procurement and installation of a charging station

- One charging point is available in a DC fast charging station.
- Power rating of DC fast charger is assumed to be 50 kW.
- Cost of one DC fast charger has been assumed to be INR18 lakh[166] .
- Service life of a charger has been assumed t be 10 years.
- Installation cost has been considered to be 25% of capital cost of a DC fast charger.
- Existing manpower deployed at the location shall be utilized for preliminary admin activities. No additional cost has been considered for the private investor.
- It has been assumed that an electric vehicle shall be charged till 80% of its battery capacity.
- Further, the losses in charger has been assumed to be 20%.
- Utilization of DC fast charger has been assumed to be six hours a day with a yoy improvement of 12%.

Assumptions regarding revenue model

- Public entity shall be getting 10% of the PAT each year as part of the revenue sharing mechanism.
- For this PPP set-up, based on current EV volumes, lease expenses have not been considered.
- For advertising revenue, INR5000 will be charged monthly with an annual escalation of 5%.
- For co-branding, INR5000 will be charged with an annual escalation of 10%.
- In order to assess the investment viability for public utility, land opportunity cost has been calculated, considering 10% yoy improvement in revenue through alternate investments.

The cost of debt has been assumed to be 10% with a repayment period of 10 years and the weighted average cost of capital (WACC) is 13%. The debt to equity ratio for the model has been considered to be 70:30. Duration of installation for a charger ranges from a few days to a month and hence, the moratorium period for repayment has not been considered.

Other assumptions

- For straight line value method (SLM), depreciation is considered to be spread over 10 years (life of charger).
- The written down value method (WDV) assumes 80% depreciation.
- Tax: Basic tax – 30%, MAT – 19%, Surcharge – 12% and Cess – 3%.

Sensitivity analysis

The model tries to capture sensitivity around the mark-up on cost of electricity as service charge and subsidy. However, due to lack of assured demand, the yoy improvement in charger utilization is assumed to be constant.

Scenario 1: No subsidy is provided and mark-up on cost of electricity is variable

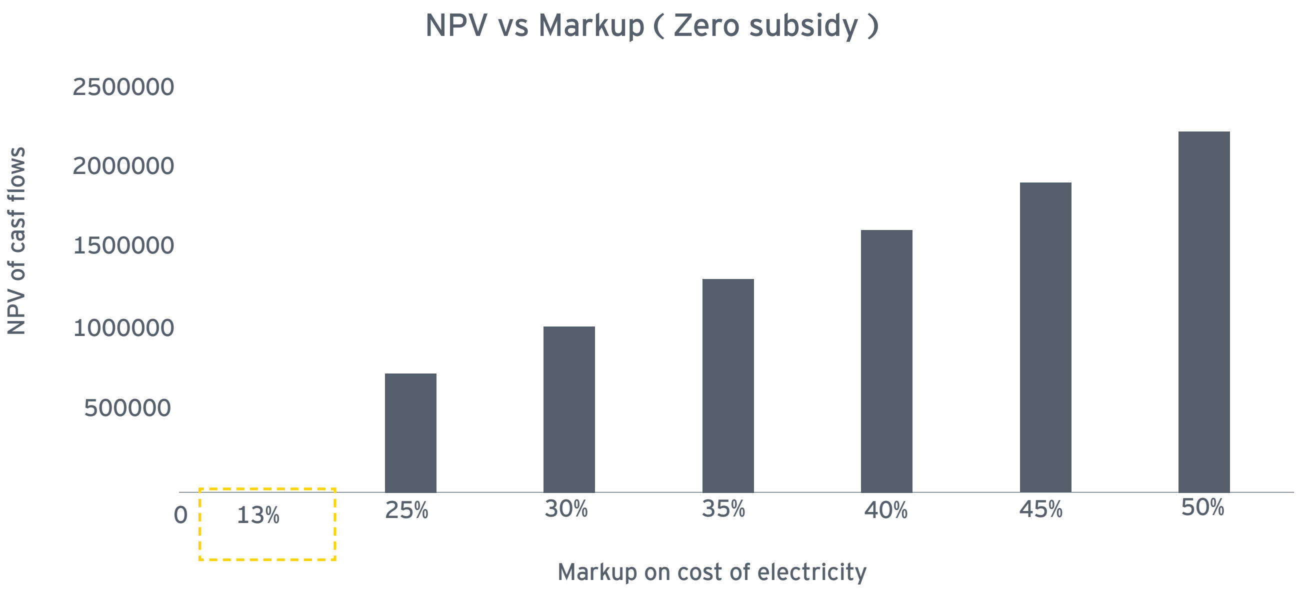


Figure 45: PPP- No subsidy is provided and mark-up on cost of electricity is variable [167]

The above figure captures the sensitivity of NPV with respect to the percentage of mark-up on cost of electricity. It was determined that the project is viable, i.e., NPV is greater than zero, when mark-up is more than 13%. Moreover, as shown in figure, project is feasible if mark-up on cost of electricity is greater than 13%, as NPV becomes greater than zero and equity IRR is greater than WACC.

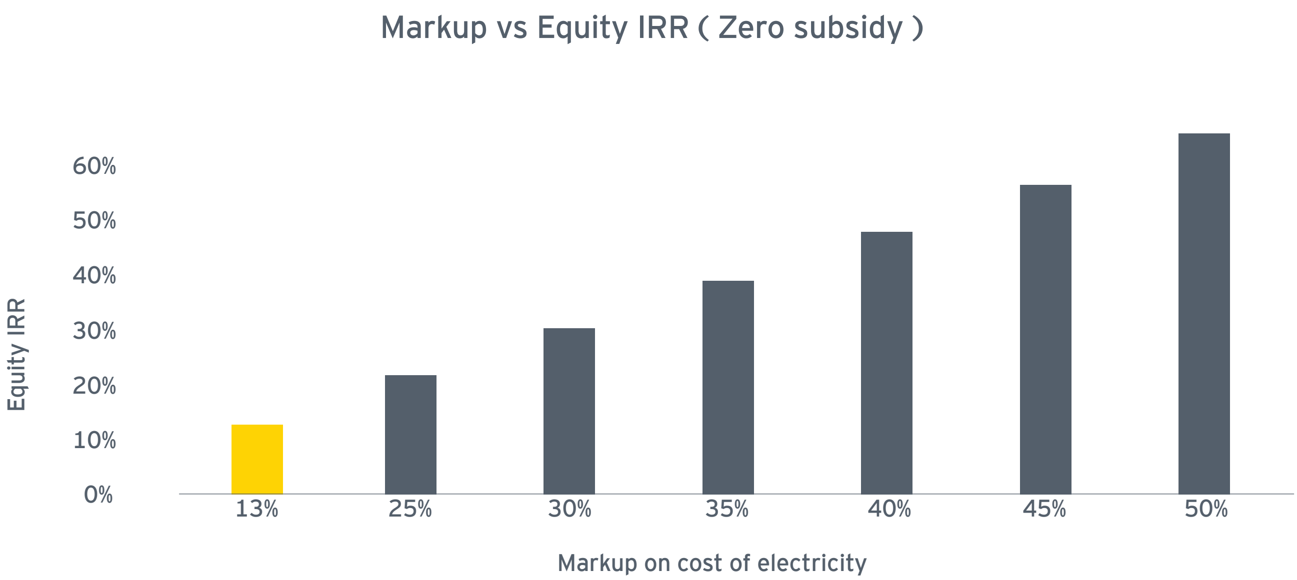


Figure 46: PPP- Mark-up vs. equity IRR (zero subsidy)[168]

[165]EY analysis
[166]Stakeholder inputs
[167]EY analysis
[168]EY analysis

As evident from the figure below, the 5% increase in mark-up results in 4% yoy increase in the charges.

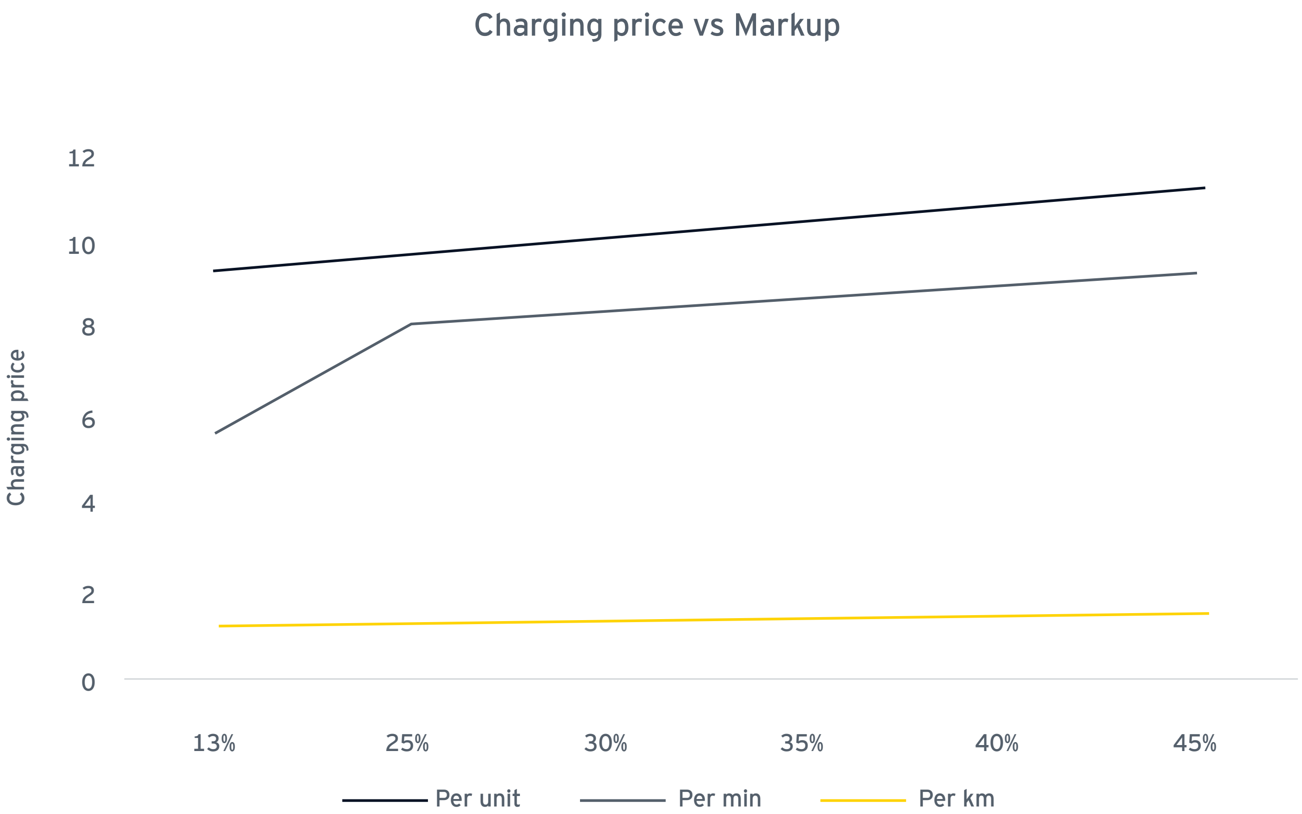


Figure 47: Charging price v. mark-up[169]

Scenario 2: Mark-up is fixed at 10% and subsidy variable

The figure captures the sensitivity of NPV with respect to subsidy. It was determined that the project is viable, i.e., NPV is greater than zero (mark-up is fixed at 10%) when 13% subsidy is provided.

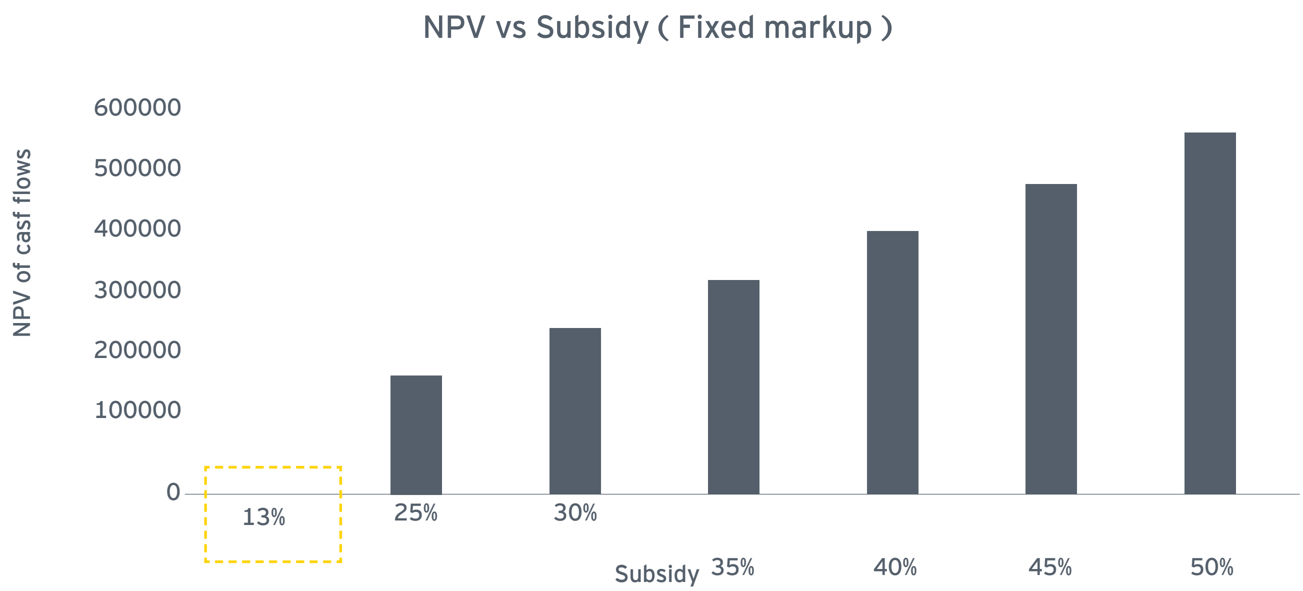


Figure 48: PPP- NPV vs. subsidy (fixed mark-up)[170]

[169]EY analysis
[170]EY analysis

Moreover, as shown in the figure, project is feasible if 13% subsidy is provided as NPV becomes greater than zero and equity IRR is greater than WACC.

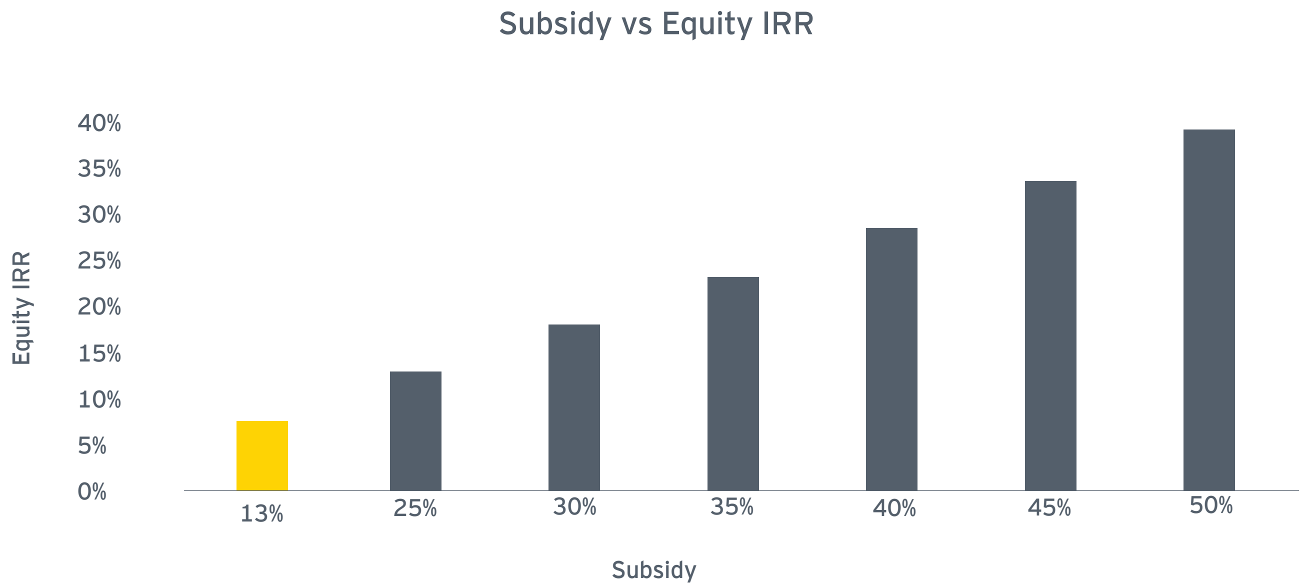


Figure 49: Subsidy vs. equity IRR[171]

Key observations

1. Land opportunity cost for municipal corporations, considering monthly rental of INR20,000 with an annual escalation of 10%, comes out to be 18 lakhs. Even after a 10% revenue sharing arrangement with the private entity, the public entity cannot recover this cost. As observed in mature markets, public entity has to look for additional revenue streams (like advertising and lease rental from restaurants) to increase the viability.

2. Public entities with underutilized land (having low opportunity costs) will be more suitable for this model. For example, distribution companies might utilize their land near existing substations for setting up charging stations which might also require collaboration with a municipality to get clearance to allow vehicles to charge and park. By this, the unutilized piece of land could be monetized by municipality and distribution utility can provide a reliable power directly from a substation of a discom.

3. Assuming no capital subsidy is provided, charging station operator has to charge minimum 13% as mark-up on the cost of electricity tariff as retail price for ensuring project viability.

4.3.2. PPP between private investors and state transport utility for public charging infrastructure

In this model, state transport utility shall be responsible for assuring demand and land. Revenue sharing model has been assumed similar to the model with municipal corporation. However, the sensitivity analysis has been done assuming a constant mark-up on electricity. In addition, the model tries to capture impact of improvement in charging utilization due to assured demand.

For studying viability for a state transport utility, specifications for e buses have been included. Key assumptions are mentioned below:

1. E bus with 300 KM range and 235 kWh of battery capacity has been considered

2. Markup on electricity has been considered to be fixed at 10%

3. Cost of 100 kW charger has been assumed to be INR 26,00,000

4. For a PPP setup, it has been assumed that the private investor will not be charged any lease expense

The assessment has been done for following 2 scenarios:

- Scenario 1: No subsidy is given and charger utilization rate is variable
- Scenario 2: 25 % Subsidy is given and charger utilization rate is variable

Scenario 1: No subsidy is given

The figure captures the sensitivity of NPV with respect to improvement in charger utilization. It was determined that the project is viable, i.e., NPV is greater than zero (mark-up is fixed at 10%) when the yoy improvement is 13.5%.

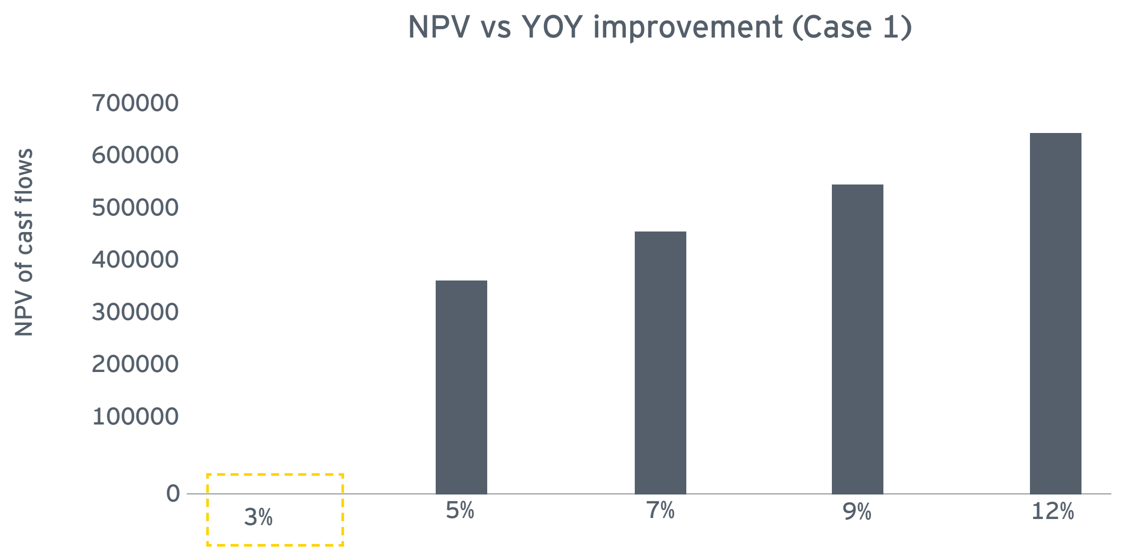


Figure 50: NPV vs. yoy improvement (Case 1)[172]

Moreover, project is feasible if yoy improvement is 13.5% as NPV becomes greater than zero and equity IRR is greater than WACC

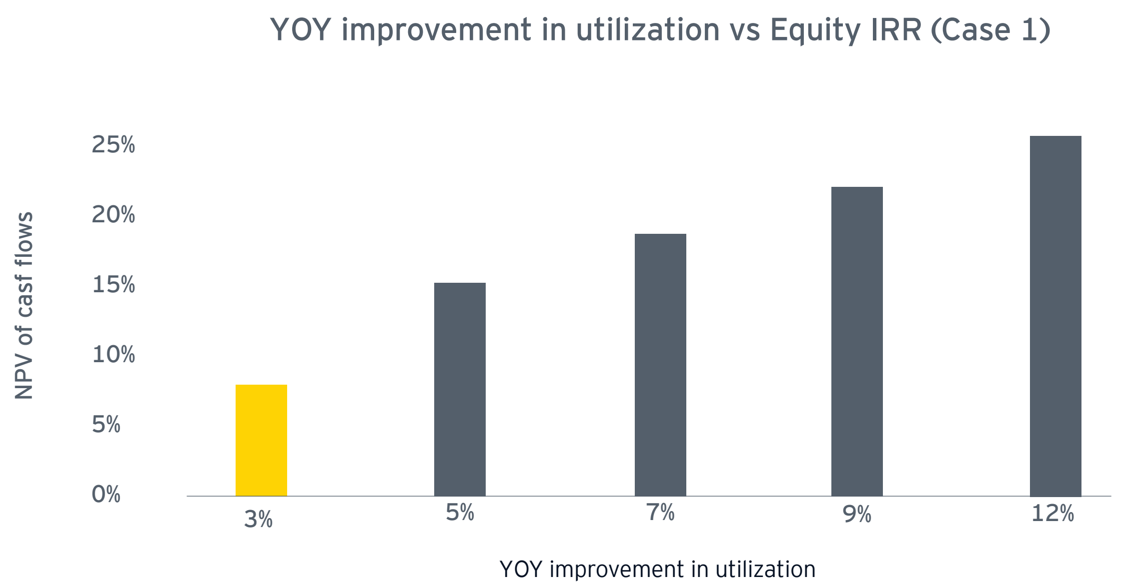


Figure 51: yoy improvement in utilization vs. equity IRR (Case 1)[173]

[171]EY analysis
[172]Stakeholder inputs
[173]EY analysis

Scenario 2: 25% subsidy is given

The figure captures the sensitivity of NPV with respect to improvement in charger utilization considering 25% subsidy.

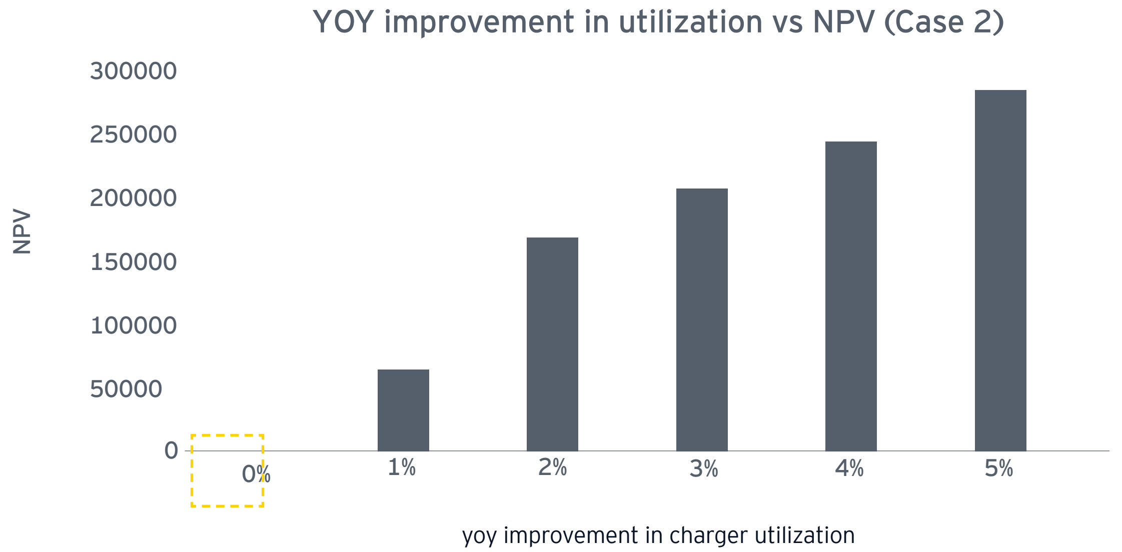


Figure 52: Sensitivity of NPV with respect to improvement in charger utilization considering 25% subsidy[174]

It was determined that the project is viable, i.e., NPV is greater than zero (mark-up is fixed at 10%) when yoy improvement is around 1%.

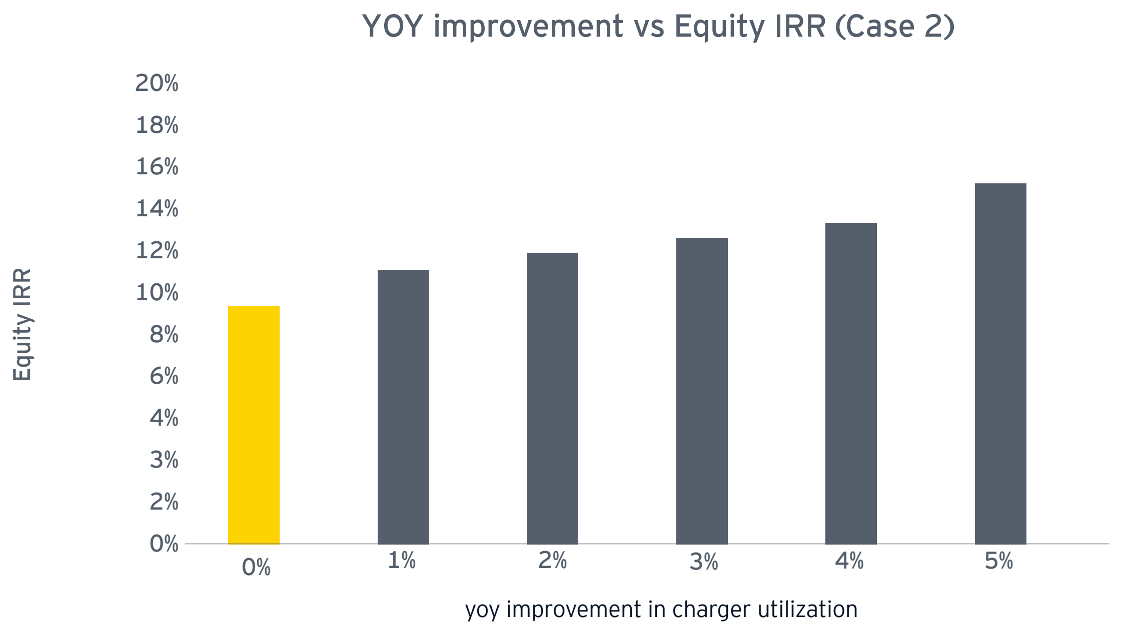


Figure 53: yoy improvement vs. equity IRR (case 2)[175]

Key observations

1. Partnership with state transport utilities can result in a substantial reduction of demand risks for private investor.
2. The 3% annual percentage increase in charger utilization can result in the overall project viability.
3. With 25% subsidy support, the required improvement in charger utilization could be as low as 1%.

[174]Stakeholder inputs
[175]EY analysis

5 City Level Assessment Model for Charging Infrastructure

Distribution infrastructure is a vital spoke in the electric mobility ecosystem. A vibrant ecosystem needs mass scale deployment of charging infrastructure which would be hooked up to the power distribution network. Availability of reliable power for operations of charging infrastructure is essential as its failure may lead to disruption of transport system of a city in scenario where the fleets are electrified.

Hence, assessment of existing distribution and determination of augmentation requirements for enhancing resilience is inadvertent for deployment of sustainable operations of electric powertrains in a city. In the following sections analysis of distribution infrastructure has been done to assess the impact of addition of load due to charging of EVs considering possible charging patterns for different segments of EVs depending on their usage.

It is important to understand following key aspects at city level for good planning of charging infrastructure:

It is important to understand following key aspects at city level for good planning of charging infrastructure:

- EV adoption numbers across different vehicle segments can evolve at a city level (driven through different policy measures)
- Typical battery charging load that can come to the grid (assuming typical battery sizes that will get adopted for different vehicle segments meeting driving range and affordability criterion of the end-users; and also choice of battery ownership – whether integrated or swapping)
- End-user behaviours for choosing EV charging location (between home, office/private, public charging, swapping), charging types (between slow 5 hours or fast 1 hour) and time of the day
- Number of charges can happen yearly across different vehicle segments (given their typical average distance run and assumed electric mileage efficiency) and where (home, office/private, public charging, swapping)
- Peak load can come on to the grid in what time of the day (given different charging behaviours), and how this compare to existing peak load and what time of the day
- Year-on-year increase in peak load from Business-as-usual condition because of EVs assumed adoption scenario
- Grid planning and investment would need to be undertaken to support the assumed EV adoption
- Charger types (individual slow/ fast, centralized bulk charging) and numbers with deployment location (home, office/private, public charging, swapping) would be required over years to meet the charging demand
- Above aspects were studied and modelled for Delhi, Lucknow and Nagpur cities, given their different characteristics. Existing city planning reports and data (Mobility plan, RTO data, power distribution expansion plan), and local stakeholders consultations including and not limited to Discom, Transport, and City officials were undertaken to build and vet the model. The assessment has been done for Nagpur and Delhi as detailed in following sections.

5.1

Delhi

Delhi is the third largest city in India and the most preferred city in terms of Investments, Industrialization, Information Technology, Healthcare, Real Estate, etc. Investment in new projects to develop charging infrastructure such as Quick Pilot on EV Charging Infrastructure has been recently introduced by NITI Aayog in Delhi.

The objective is to provide a structure for EV charging infrastructure rollout in the Gurgaon-IGI-South Delhi-Noida corridor. The plan for the corridor includes 55 locations with 135 charging stations of which 46 are DC fast charging stations and 89 a AC slow charging stations. The actual deployment will rely on co-operation with state governments, selected government authorities, Ministry of Power, grid companies as well as some private enterprises. By early 2018 there were few thousands of electric vehicles already running on the roads of Delhi.

The distribution of power in Delhi is managed by five Discoms named BRPL, BYPL, Tata Power DDL (earlier NPDL), NDMC (a Govt. owned deemed licensee) and MES (deemed licensee under Defence Ministry), with below geographic coverage.

The city is spread over 1484 sq.kms. The number of registered vehicles in city is estimated around 1.02 crore in 2017 with then people population of around 2.04 crore[176] , meaning almost every second person in the city has a vehicle. Some measures have been announced in the wake of 'severe' air quality of Delhi such as Odd-Even Policy on Vehicles, Delhi Metro announcing that its trains will undertake over 180 additional trips and charge four times the prevalent parking rates to discourage use of private vehicles, thereby increasing share of public transport in the city.

The city is expected to grow at a faster rate with companies (Tata Motors, Mahindra, etc.) showing their increasing interests in new projects and investments in EV with the help from the government. It is estimated that Delhi's population shall increase by to 2.98[176] crores by 2030. The number of two-wheelers are expected to continue to form the highest modal share of 67%, followed by individual passenger cars with modal share of 30.3% and rising share of fleet vehicles including four-wheelers and three-wheelers.

Table 46: Delhi's population and vehicle stock[177]

Delhi	Units	2018	2020	2025	2030
City population	no.	2,10,91,418	2,23,54,166	2,58,01,582	2,98,82,065
Total vehicle stock on road	no.	1,08,94,161	1,23,81,046	1,69,85,525	2,34,28,142
2W	%	65.4%	65.9%	66.7%	67.1%
3W – PV	%	1.0%	0.9%	0.8%	0.8%
3W – CV	%	0.6%	0.6%	0.5%	0.4%
4W – PV	%	31.0%	30.8%	30.4%	30.3%
4W – CV	%	1.7%	1.5%	1.3%	1.3%
Bus	%	0.3%	0.3%	0.2%	0.1%
Vehicle per unit 1,000 Population	no.	517	554	658	784

5.1.1. EVs Adoption and Mix

EVs adoption shall be higher in public/fleet vehicles, including buses, three-wheeler autos and fleet cars. Fleet vehicles' higher kilometres run per year and daily certainty in travelled distances, makes EV economics better viable over other personal vehicle segments (including personal two-wheelers and four-wheeler cars). Some 2030 all-India estimates on EV mix and adoption across different vehicle segments are shared below:

Table 47: EV mix and adoption across different vehicle segments[178]

Vehicle category	Scenario-1 (Fast and high adoption at national level) Reference: NITI Aayog RMI Report		Scenario-2 (Medium optimistic adoption at city level)Used in this case study	
	EV mix % of new sales in 2030	EV mix % of total vehicles stock in 2030	EV mix % of new sales in 2030	EV mix % of total vehicles stock in 2030
2-wheeler	100%	~40%	100%	36%
3-wheeler	100% (since 2025)	~100%	100% (since 2025)	40%
4-wheeler PV	100%	~40%	100%	37%
4-wheeler CV	100% (since 2020)	~100%	100% (since 2025)	50%
Buses – public	100% (since 2020)	~100%	100% (since 2025)	26%
Buses – private	100% (since 2020)	~50%	100% (since 2025)	26%

In both the above scenarios, percentage of EV mix of new sales is increased across the years to 100%. NITI Aayog RMI report's assumptions are aggressive with early, faster and higher adoption rate, which seems unlikely, given the current level of EV supply chain and policy readiness in India. Hence **Scenario-2, a medium optimistic scenario,** is modelled with the results shared in the analysis below. This Scenario-2 model estimates 37% EV mix of total stock with 86.28 lakhs EVs on road by 2030. Morgan Stanley research assumed this number at an all-India level to be around 15%[179] , which supports higher mix in fast growing Tier-1 city, Delhi.

[176]Delhi Transport Department - https://delhi.gov.inwps/wcm/connect/doit_transport/Transport/Home/Statistics
[177, 178] EY analysis
[179]Morgan Stanley

5.1.2. EV battery technologies and ownership models

India with its value conscious customers, shall see a mixed adoption of integrated lithium ion battery (LIB) EVs, battery swapping and range extension EVs. Public fleet vehicles are expected to see higher adoption of battery swapping model over years, while personal vehicles are likely to see an increased use of range extension batteries, both driven by establishment of successful operational and economical battery swapping models in India.

From the total EV stock on road in 2030, it is assumed that 60% EVs shall have integrated LIBs, 9% swapping and 31% with range extension battery option.

LIBs are undergoing fast changes in battery chemistries, driven by volumetric size, weight, charging speed, operating temperatures, stability and most important, cost. Lithium manganese cobalt oxide (NMC) batteries with their size and cost advantages are likely to see higher adoption in India, with higher charging performance batteries like LTO getting increasingly adopted due to the fall in their prices. The model assumed following engineering values across different vehicle categories:

Table 48: Technical specifications assumed in the Delhi model[181]

	Avg. battery size (kWh/unit)		Avg. vehicle efficiency	Avg. km run	kms per charge per vehicle		# of charges per year per vehicle		
	If integrated	If swapping	km/kWh	kms/year	If integrated	If swapping only	If integrated	If swapping only	If RE with integrated (RE battery only)
2W	1.5	1.5	50.00	6,600	57.38	57.38	115.03	115.03	23.01
3W PV	4.5	3	20.00	33,000	68.85	45.90	479.30	718.95	143.79
3W CV	6	4.5	14.29	26,400	65.57	49.18	402.61	536.82	107.36
4W PV	15	12	7.69	12,540	88.27	70.62	142.07	177.58	35.52
4W CV	15	12	7.69	69,300	88.27	70.62	785.10	981.37	196.27
Bus	100	60	1.00	66,000	76.50	45.90	862.75	1,437.91	287.58

With above battery sizes and assumed EV stock, it is estimated that in 2030, Delhi shall have some 48.5 GWh of LIBs in the system with approx. 88% as integrated LIBs and the remaining 12% as swappable LIBs. NITI Aayog's report estimated that India shall see some total 3,500 GWh of LIBs in 2030.

Table 49: Cumulative LIB in the system[182]

Delhi		2018	2020	2025	2030	CAGR
Cumulative LIBs in system	MWh	28	707	12,271	48,478	53%
Integrated LIBs	%	91%	95%	92%	88%	-1%
Swapping + RE LIBs	%	9%	5%	8%	12%	8%

5.1.3. EV charging technologies (slow vs. fast) and choice of location

The choice of integrated and/or swappable batteries is likely to influence charging choices of the customers between mix of home charging, office/private charging, public charging and centralized bulk swappable battery charging stations. The analysis assumed mix adoption of charging options between different vehicle categories, and its variation over years with change in battery technology and costs. It is estimated that in 2030, there shall be a total of 12,540 lakh EV charges done in Delhi, with 61% happening via home charging, 8% via office/private charging, 10% via public charging and 21% via centralized bulk charging for swappable batteries.

Additionally, it is assumed that full home charging can be completed in six hours (assuming slow charging), office/private and public charging can be undertaken in an hour (assuming fast charging), and bulk swapping charging can take place in two hours (relative slow charging). Depending on the battery sizes assumed, and full battery charging time specifications, the average peak charging power is likely to vary across vehicle categories and charging options as below:

Table 50: Various charging options as per vehicle categories[183]

	Avg. battery size (kWh/unit)		*Peak charging load (kW) per battery charging			
	If integrated	If swapping	Home charging	Office/Private charging	Public charging	Swapping
			Home chargers	Fast chargers	Fast chargers	Slow chargers
2W	1.5	1.5	0.28	1.65	1.65	0.83
3W PV	4.5	3	0.83	4.95	4.95	2.48
3W CV	6	4.5	1.10	6.60	6.60	3.30
4W PV	15	12	2.75	16.50	16.50	8.25
4W CV	15	12	2.75	16.50	16.50	8.25
Bus	100	60	22.00	132.00	132.00	66.00

*Peak charging load is assumed uniform across charging time, but this may vary with battery chemistry. Hence peak load multiple of 1.1 is used to absorb such variations.

India has developed two charging specifications – AC-001 charger for AC charging, and DC-001 charger for DC charging. Both have a charging voltage level under 100 V and use custom GB/T communication protocol over CAN mode. AC-001 charger can give max 15 A charging current with 3.3 kW power, while DC-001 can give max 200 A current with 15 kW power. Between both the chargers, above charging range for two-wheeler, three-wheeler and four-wheeler can get closely covered. For buses, India has developed another charger (under development) that gives 50 A current and 30 kW power.

There are other two higher voltage/power level charging standards that are under development, to be called AC-002 and DC-002, that can provide further fast charge (within one hour). It will be important for India to define and use the standard chargers across vehicle categories, to witness EVs' scale-up.

Battery chemistry and battery temperature highly influence use of slow vs. fast charging. Low cost NMC battery life is likely to degrade if it charges fast (less than an hour) at higher than 45-degree ambient temperatures, while LTO batteries can support such fast charging.

[180]This is assuming 85% depth of discharge (DOD) in batteries and 90% close to DOD value when charging is initiated.
[181, 182, 183]EY analysis

5.1.4. EVs and impact on the grid

It is estimated that 8,169 MUs/year of electricity consumption is likely to take place from EVs charging alone in 2030, with home charging (at residential tariff) taking a majority of 49% share, followed by charging loads at commercial tariff, including 25% of bulk swappable battery charging, 13% of office/private charging and 13% of public charging. The assumptions for adoptions in charging categories across vehicle and time are changeable in the model and can give new

Table 51: Electricity consumption for EV charging (at network input incorporating distribution losses) [184]

Delhi		2018	2020	2025	2030	CAGR
Electricity consumption for EV charging (at network input incorporating distribution losses)	MUs/year	9	176	2,245	8,169	46.8%
Home charging (residential tariff)	%	54%	50%	51%	49%	-0.2%
Office/private charging (commercial tariff)	%	9%	21%	16%	13%	-4.4%
Public charging (commercial tariff)	%	13%	13%	13%	13%	0.1%
Swapping + RE (commercial tariff)	%	23%	17%	20%	25%	4.1%

Total average connected load from EVs is estimated to grow faster from 346 MVA in 2020 to 15,901 MVA in 2030, with a CAGR of 47% and an average load factor of 6%.

Table 52: Average connected EV charging load to grid across charging segments[185]

Delhi		2018	2020	2025	2030	CAGR
Total avg. connected EV charging load to grid	MVA	16	346	4,321	15,901	47%
Home charging (residential)	%	17%	14%	15%	14%	0.5%
Office/private charging (commercial)	%	17%	34%	27%	23%	-3.8%
Public charging (commercial)	%	25%	22%	24%	23%	0.8%
Swapping + RE (commercial)	%	32%	20%	24%	29%	3.6%

Further, depending upon the four charging location types and time of the day tariff incentives, the EV charging will be spread up in four 6-hour time slots of the day (TS1 – 0:00 to 6:00; TS2 – 6:00 to 12:00; TS3 – 12:00 to 18:00; TS4 – 18:00 to 24:00). The following are the used assumptions for the EV charging load distribution across these time slots:

Table 53: Assumptions on EV charging load distribution[186]

Time slots	Home charging	Office/private	Public	Swapping + RE
TS1	35%	5%	5%	50%
TS2	15%	30%	30%	35%
TS3	15%	40%	30%	15%
TS4	35%	25%	35%	0%
Total	**100%**	**100%**	**100%**	**100%**

[184, 185,186] EY analysis

Using above load-time distribution in a day, peak charging load from EV charging across different locations is estimated to be 72 MVA in 2020, 878 MVA in 2025 and 3024 MVA in 2030, with 10-years CAGR of 45%. This peak from EV load comes in TS2 time slot in the day, compared to the business-as-usual (BAU) peak in grid that occurs in TS4 time slot during summers in Delhi. The BAU peak without EVs for Delhi is assumed to be 7,771 MVA in 2020 and 11,822 MVA in 2030, with a CAGR of about 4.3%. The total system peak with EVs comes out to be 7,844 MVA in 2020, 10,463 MVA in 2025 and 14,845 MVA in 2030, growing at a CAGR of 6.6%. By 2030, peak demand from EVs in TS4 is expected to contribute 20% of the total peak load in Delhi, which is likely to be significant for DISCOMs to plan their preparation. The next three to five years EV additional load may be catered to with existing excess distribution capacity and BAU capital investments in the network by all the DISCOMs (TPDDL, BRPL, BYPL and NDMC) beyond which it will require special planning and interventions.

Table 54: Peak demand across charging types in Delhi [187]

Delhi		2018	2020	2025	2030	CAGR
Peak EV demand for charging (in TS2 6:00 to 12:00 noon slot)	MVA	3	72	878	3,024	45.2%
BAU peak demand of city (in TS4 12 noon to 6pm without EVs)	MVA	7,146	7,771	9,585	11,822	4.3%
Total peak demand of city, including EVs (in TS4)	MVA	7,149	7,844	10,463	14,845	6.6%
% EV contribution to city's peak demand (in TS4)	%	0%	1%	8%	20%	-
BAU peak demand CAGR	%	4.5%	4.3%	4.3%	4.3%	-
EV peak demand CAGR	%	-	123%	46%	22%	-
Combined total peak demand CAGR	%	4.6%	5.0%	7.8%	8.8%	-

The transmission capacity of 13,151 MVA in 2014 also will need higher augmentation with additional investments by 2030. By top estimates, Delhi's current distribution and transmission network capacity (distribution transformers, 11kV feeders, sub-station power transformers, 33kV feeders and EHV sub-station power transformers) is some approx. 1.5 to 1.9 times of its current peak load, and has been grown at a little higher than load growth rate by 5%-6% annually. With the increase in the incremental EV load at faster rates, Delhi distribution and transmission network will need to be augmented at higher 8% annually.

5.1.5. Number of chargers and charging locations

Knowing the total number of charges per day across different charging locations and assuming the operational service hours for each of the charging location types (average 14 service hours per day for each location types), total number of chargers at each location types can be calculated. It is estimated that in 2030, 22.62 lakhs charging points will be required in Delhi, with 93% being home chargers, followed by 5% bulk swappable battery charging points and the remaining 2% at office/ private and public charging stations. This includes all EVs and all charging points, including home chargers that may yield EV to EVSE ratio of 3.81 by year 2030. After removing home charging EVs and also home chargers, the EV to EVSE ratio becomes approx. 17. This ratio for Delhi for public charging is high as compared to the global current best practice ratio of 10-12.

[187] EY analysis

Table 55: Skill development at DISCOMs to minimize impact on grid [188]

Skill development at DISCOMs to minimize impact on grid
DISCOMs are bound to play a critical role in EV ecosystem if India is to achieve it's ambitious target of enhancing EV penetration by 2030. According, capacity building initiatives are required to develop skill sets of DISCOM officials in load estimation and in assessments required for giving clearances for settings up stations

Further assuming the number of charging points to be 5, 10 and 200, respectively for office/private, public and swapping stations, it is estimated that Delhi may need to grow the number of office/private charging stations from 75 in 2020 to 4536 in 2030; public charging stations from 45 in 2020 to 2552 in 2030; and bulk swapping charging stations from 7 in 2020 to 592 in 2030. These numbers may change with sizing of each of these stations. Delhi has around 350 petrol pumps and these can be used to co-locate EV public/swap charging stations. Home chargers need not have communication link and hence may not need full fledge AC-001 chargers. However, cluster EVs charging in the parking lot of a residential locality may use the option of AC-001 chargers, if managed by a third party. Malls, public parking spaces, cinema halls and metro/railway/bus stations are some of the spaces that can be used for deploying mix of slow and fast chargers.

5.1.6. Delhi City's EV projections

Refer to the annexure table 80: Statistics dashboard for Delhi projections for key EVs stats that Delhi city may witness till 2030, under above assumed Scenario-2

The chapter covered analyzed the impact on distribution infrastructure if the projected number of electric vehicles are added to the system. It stresses on the fact that there is no immediate threat on stability of the power system. However, it would be win-win scenario if the deployment of charging infrastructure in a city is done in planned manner so that the operations remain viable as explained in chapter 3 on business models, as well as adding minimum burden on distribution infrastructure. Hence, several city-level assessments are encouraged for sustainable deployment of charging infrastructure.

[188] EY analysis

5.2

Lucknow

Lucknow is the capital of Uttar Pradesh in India. It is the 11th most populous city and the 12th most populous urban cluster of India. The city is spread over an area of 2,528 square kilometers (976 sq. mi.). Lucknow has got an extensive network of roads and railways and it has grown across the radius of 25 km[189] .

Lucknow is a part of the 100-smart city mission and is focusing on citywide solutions envisioned to develop the city as a clean, green, efficient and a citizen centric modern economy. Four key initiatives, namely, Jeevant Lucknow, Swachh Lucknow, Sugam Lucknow and Samruddh Lucknow have been launched under the smart city mission focusing on the aspects of improving living standards, cleanliness, mobility and the economy of the state[190] .

The population of Lucknow in 2018 is estimated to be more than 50 lakhs and the number of registered vehicles in Lucknow is around 20 lakhs. This implies that almost every second person in Lucknow has a vehicle. Further, a CAGR of 7% is being witnessed in the new vehicle additions in the city from 2015.

Lucknow power distribution is managed by Madhyanchal Vidyut Vitaran Nigam Limited (a Government of UP undertaking), catering to around 50 lakhs consumers. Total electricity consumption is estimated to be 17,377 MUs/year with a CAGR of 16% in 2017. Distribution losses have been estimated to be down to 17% compared to 23% distribution losses in 2015[191] .

Table 56: Lucknow and vehicle stock[192]

Lucknow	Units	2018	2020	2025	2030	CAGR
City population	no.	55,58,170	57,82,720	63,84,590	70,49,103	2%
Total vehicle stock on road	no.	21,37,214	24,65,384	34,87,770	49,28,235	7%
2W	%	77.4%	76.0%	73.3%	71.1%	-1%
3W - PV	%	0.4%	0.4%	0.5%	0.5%	2%
3W - CV	%	1.3%	1.9%	2.7%	3.1%	5%
4W - PV	%	13.7%	15.2%	18.1%	20.2%	3%
4W - CV	%	7.0%	6.3%	5.3%	5.0%	-2%
Bus	%	0.2%	0.2%	0.1%	0.1%	-2%
Vehicle per unit 1000 Population	no.	385	426	546	699	5%

[189]Rajiv Gandhi University - http://www.ijhssi.org/papers/v4(5)/Version-2/B0452011020.pdf
[190]Lucknow Smart City - https://www.lucknowsmartcity.com/
[191]Madhyanchal Vidyut Vitaran Nigam Ltd. Lucknow (MVVNL) - http://www.mvvnl.in/post/en-tariff-details
[192,193]EY analysis

5.2.1. EVs adoption and mix

EVs adoption shall be higher in public/fleet vehicles, including buses, three-wheeler autos and fleet cars. Fleet vehicles have higher operational periods and a daily certainty in travelled distances. This makes EV economics much viable over other personal vehicle segments (including personal two-wheelers and four-wheeler cars). All-India estimates on EV mix and adoption across different vehicle segments in 2030 are shared below -

Table 57: Lucknow EV adoption scenarios[193]

	Scenario-1 (fast and high adoption at national level) Reference: NITI Aayog RMI Report		Scenario-2 (medium optimistic adoption at city level) Used in this case study	
Vehicle category	EV mix % of new sales in 2030	EV mix % of total vehicles stock in 2030	EV mix % of new sales in 2030	EV mix % of total vehicles stock in 2030
2-wheeler	100%	~40%	100%	30%
3-wheeler	100% (since 2025)	~100%	100% (since 2025)	50%
4-wheeler PV	100%	~40%	100%	35%
4-wheeler CV	100% (since 2020)	~100%	100% (since 2025)	35%
Buses – public	100% (since 2020)	~100%	100% (since 2025)	60%
Buses – private	100% (since 2020)	~50%	100% (since 2025)	60%

In both the above scenarios, percentage of EV mix of new sales is increased across the years to 100%. NITI Aayog RMI report's assumptions are aggressive with early, faster and higher adoption rate, which seems unlikely, given the current level of EV supply chain and policy readiness in India. Hence Scenario-2, a medium optimistic scenario, is modelled. This Scenario-2 model gives 40% EV mix of total stock in year 2030 with 19.55 lakhs EVs on road.

5.2.2. EV battery technologies and ownership models

India, with its value conscious customers, is likely to see a mix adoption of integrated lithium ion battery (LIB) EVs, battery swapping[194] and range extension[195] EVs. Public fleet vehicles are expected to see a higher adoption of battery swapping model over the years, while personal vehicles shall see an increased use of range extension batteries, with both driven by establishment of successful operational and economical battery swapping models in India. Of the total EV stock on road in 2030, it is assumed that 63% EVs are likely to have an integrated LIBs, 10% swapping only and 28% with a range extension battery option.

LIBs are witnessing a fast change in battery chemistries, driven by volumetric size, weight, charging speed, operating temperatures, stability and most importantly, cost. NMC batteries with their size and cost advantages shall likely see higher adoption in India, with higher charging performance batteries like LTO getting increasingly adopted with lowering of their costs. The model assumed the following engineering values across different vehicle categories:

[194]Swapping batteries: these batteries can be swapped at a swapping station, replacing a discharged battery with a charged one. The vehicles, therefore, do not need to be fast-charged or have very large batteries. Here the batteries can be separated from the vehicle and will not be owned by the vehicle owner. Instead it will be owned by an energy operator (provider of charged battery as a service), who will buy the batteries, charge them and lease it to the vehicle owners at convenient charge-cum-swap centre.

[195]Range extension batteries: a normal integrated LIB will be charged every night. But since the battery is small, the range will not be large. Since most personal vehicles drive small distance in India in a day, this small range may be acceptable on 90% to 95% of the days. But for the remaining 5% to 10% of the days, this could cause a problem. Instead of using a fast-charger and battery life degradation problems, in this option, the vehicles will have a slot for a second battery called range-extension swappable batteries (or RE battery).

[196]This is assuming 85% depth of discharge (DOD) in batteries, and 90% close to DOD value when charging is initiated.

Table 58: Technical specifications assumed in Lucknow model[197]

	Avg. battery size (kWh/unit)		Avg. vehicle efficiency	Avg. km run	kms per charge per vehicle[196]		# of charges per year per vehicle		
	If integrated	If swapping	km/kWh	kms/year	If integrated	If swapping only	If integrated	If swapping only	If RE with integrated (below counts for RE battery only)
2W	1.5	1.5	50.00	6,600	57.38	57.38	115.03	115.03	23.01
3W PV	4.5	3	20.00	33,000	68.85	45.90	479.30	718.95	143.79
3W CV	6	4.5	14.29	26,400	65.57	49.18	402.61	536.82	107.36
4W PV	15	12	7.69	12,540	88.27	70.62	142.07	177.58	35.52
4W CV	15	12	7.69	69,300	88.27	70.62	785.10	981.37	196.27
Bus	100	60	1.00	66,000	76.50	45.90	862.75	1,437.91	287.58

With above battery sizes and assumed EV stock, it is estimated that in 2030, Lucknow shall have some 13.7 GWh of LIBs in the system with approximately 70% as integrated LIBs and remaining 30% as swappable LIBs.

Table 59: Cumulative LIBs in system[198]

Lucknow		2018	2020	2025	2030	CAGR
Cumulative LIBs in system	**MWh**	150	387	3,305	13,669	43%
Integrated LIBs	%	87%	87%	80%	70%	-2%
Swapping + RE LIBs	%	13%	13%	20%	30%	9%

5.2.3. EV charging technologies (slow vs. fast) and location choices

The choice of integrated and/or swappable batteries will influence the charging choices of the customers choosing a range of options such as home charging, office/private charging, public charging and centralized bulk swappable battery charging stations. The analysis assumed mixed adoption of charging options between different vehicle categories, and its variation over the years with change in battery technology and costs. It is estimated that in 2030, there shall be some total 3,703 lakh EV charges done in Lucknow, with 56% happening through home charging, 10% through office/private charging, 11% through public charging and 23% through centralized bulk charging for swappable batteries.

Additionally, it is assumed that full home charging can be completed within five hours, while office/private and public charging can be undertaken within an hour, and bulk swapping charging within two hours. Depending on the battery sizes assumed, and full battery charging time specifications, the average peak charging power may vary across the vehicle categories and charging options as given below:

[197]EY analysis
[198]EY analysis

Table 60: Various charging options as per vehicle categories[199]

	Avg. battery size (kWh/unit)		*Peak charging load (kW) per battery charging			
	If integrated	If swapping	Home charging	Office/private charging	Public charging	Swapping
			Home chargers	Fast chargers	Fast chargers	Slow chargers
2W	0.33	1.65	1.65	0.83	0.33	1.65
3W PV	0.99	4.95	4.95	2.48	0.99	4.95
3W CV	1.32	6.60	6.60	3.30	1.32	6.60
4W PV	3.30	16.50	16.50	8.25	3.30	16.50
4W CV	3.30	16.50	16.50	8.25	3.30	16.50
Bus	22.00	110.00	110.00	55.00	22.00	110.00

*Peak charging load is assumed uniformly across the charging times, but this may vary according to battery chemistry. Hence peak load multiple of 1.1 is used to absorb such variations.

India has developed two charging standards – one called AC-001 charger for AC charging, and another DC-001 charger for DC charging. DC-001 has charging voltage level under 100 V, and uses custom GB/T communication protocol over CAN mode. AC-001 has three charging points that can deliver maximum 15 A charging current at 3.3 kW power, while DC-001 can deliver maximum 200 A current at 15 kW power. Between these chargers, the above charging range for 2-wheeler, 3-wheeler and 4-wheeler can get closely covered. For buses, India has developed another charger (under development) that gives 50 A current and 30 kW power. There are other two higher voltage/power level charging standards that are under development, to be called AC-002 and DC-002, which can further provide faster charge (below one hour). Therefore, it may be important for India to define and use such standard chargers across vehicle categories, to see a scale-up of EVs.

Battery chemistry and battery temperature highly influence use of slow vs. fast charging. Cycle life of low cost NMC batteries degrades if they are fast charged (charged in less than an hour) at ambient temperatures higher than 45 °C, while LTO batteries supports such fast charging.

5.2.4. EVs and impact on the grid

It is estimated that 2864 MUs/year electricity consumption shall happen from EVs charging by 2030, with home charging (at residential tariff) taking a majority of 44% share, followed by charging loads at commercial tariff including 28% of bulk swappable battery charging, 16% of office/private charging and 12% of public charging. The assumptions for adoption of charging options across vehicle categories and time are changeable in the model and can give new scenarios to simulate and study.

[199, 200, 201] EY analysis

Table 61: Electricity consumption for EV charging (at network input incorporating distribution losses)[200]

Lucknow		2018	2020	2025	2030	CAGR
Electricity consumption for EV charging (at network input incorporating distribution losses)	MUs/year	40	120	867	2,864	37%
Home charging (RESIDENTIAL TARIFF)	%	63%	56%	51%	44%	-2%
Office/Private charging (COMMERCIAL TARIFF)	%	12%	17%	14%	16%	-1%
Public charging (COMMERCIAL TARIFF)	%	16%	14%	14%	12%	-2%
Swapping + RE (COMMERCIAL TARIFF)	%	10%	13%	21%	28%	8%

Total **average connected** load from EVs is expected to grow fast from 224 MVA in 2020 to 6000 MVA in 2030, with a CAGR of 39% and an average load factor of 6%.

Table 62: Total avg connected EV charging load to grid[201]

Lucknow		2018	2020	2025	2030	CAGR
Total avg connected EV charging load to grid	MVA	65	224	1,707	6,000	39%
Home charging (residential)	%	24%	19%	17%	14%	-3%
Office/private charging (commercial)	%	23%	30%	25%	27%	-1%
Public charging (commercial)	%	31%	25%	23%	19%	-2%
Swapping + RE (commercial)	%	12%	16%	25%	30%	7%

Further, depending upon the four charging location types and the time of the day tariff incentives, the EV charging will be spread up in four six-hour time slots of the day (TS1 – 0:00 to 6:00; TS2 – 6:00 to 12:00; TS3 – 12:00 to 18:00; TS4 – 18:00 to 24:00). The following are the assumptions that have been used for the EV charging load distribution across these time slots:

Table 63: Assumptions on EV charging load distribution[202]

Time slots	Home charging	Office/private	Public	Swapping + RE
TS1	35%	5%	5%	50%
TS2	15%	30%	30%	35%
TS3	15%	40%	30%	15%
TS4	35%	25%	35%	0%
Total	**100%**	**100%**	**100%**	**100%**

[201, 202, 203] EY analysis

Using the above load-time distribution in a day, **peak charging load** from EV charging across different locations is estimated to be 18 MVA in 2020, 486 MVA in 2025 and 1755 MVA in 2030, with 10 years CAGR of 40%. This compared to BAU scenario (i.e., without EVs) for Lucknow is assumed to be 496 MVA in 2020 and 703 MVA in 2030, with a CAGR of 3%. By 2030, peak demand from EVs is expected to contribute 70% of total peak load in Lucknow, which shall be a significant addition for DISCOMs to start preparing upfront. In the next three to five years, EV additional load may be catered with existing excess distribution capacity and BAU capital investments in the network by the DISCOM, beyond which it may require special planning and interventions.

Table 64: Lucknow peak demand assessment[203]

Lucknow		2018	2020	2025	2030	CAGR
Peak EV demand for charging	MVA	18	62	486	1,755	40%
BAU peak demand of city (without EVs)	MVA	496	526	608	703	3%
Total peak demand of city including EVs	MVA	514	587	1,094	2,458	15%
% EV contribution to peak demand	%	4%	11%	44%	71%	-
BAU peak demand CAGR	%	13%	3%	3%	3%	-
EV peak demand CAGR	%	54.7%	61%	44%	20%	-
Combined total peak demand CAGR	%	14%	7%	18%	15%	-

5.2.5. Number of chargers and charging locations

Knowing the total number of charges per day across different charging locations and assuming the operational service hours for each charging location type (average 14 service hours per day for each location type), the total number of chargers at each location type can be calculated. It is estimated that in 2030, Lucknow will require 6.27 lakhs charging points, with 37% being home chargers.

All the EVs and charging points (including home chargers), will yield EV to EVSE ratio of 3.12 by 2030. After removing home charging EVs and also home chargers, the EV to EVSE ratio becomes 11.48.

Further assuming the number of charging points to be 5, 10 and 200, respectively for office/private, public and swapping stations, it is estimated that Lucknow shall need to grow the number of office/private charging stations from 58 in 2020 to 1634 in 2030; public charging stations from over five in 2020 to 775 in 2030; and bulk swapping charging stations from three in 2020 to 393 in 2030. These numbers may change with sizing of each of these stations. Lucknow's petrol pumps may be used to co-locate EV public/swap charging stations, provided that necessary safety standards for such co-locations are developed. Home chargers need not have communication link and hence may not need full fledge AC-001 chargers. However, cluster EV charging in parking lots of residential localities is an option that can use AC-001 chargers, if managed by a third-party. Malls, public parking spaces, cinema halls, metro/railway/bus stations are some of the spaces that can be used for deploying mix of slow and fast chargers.

5.2.6. Lucknow City's EV projections

Dashboard of key EVs stats that Lucknow city may witness till 2030, under above assumed Scenario-2,
Table 81: Statistics dashboard for Lucknow City projections

[203]EY analysis

5.3

Nagpur

Nagpur is the third largest city in Maharashtra. It is located at exact geographical centre of India giving it an advantage and easy access of commuting to any part of the country. It is one of the smart cities in making. It hosts country's one of the biggest multi modal logistics hub "MIHAN".

It became the first city in India to pilot electric mass mobility in partnership with Ola with a total fleet size of 200 consisting of four-wheeler cars, three-wheeler autos, two-wheeler scooters and buses. Ola invested in four charging stations with some 50 charging points. By early 2018, it has 60 e-cars and 20 e-autos operational with two charging stations.

The city has SNDL, an Essel Group company, as a power distribution franchisee of MSEDCL in three out of four zones with MSEDCL operating the 4th zone. The city is spread across some 218 sq. kms with some 2,295 km of roads. The number of registered vehicles in Nagpur is estimated around 15 lakhs in 2017 with then population of around 27 lakhs, meaning almost every second person in the city has a vehicle. New initiative like Metro is being taken up at fast pace in the city, with completion time line of 2019. The metro proposed will run on two lines covering a total distance of 40 km, thereby increasing the share of public transport in the city. It will also pave the way for increased fleet vehicles share of four-wheelers, three-wheelers and two-wheelers for first and last mile commute to and from metro stations.

The city is expected to grow at a faster rate with supporting ecosystem including smart city, Metro, MIHAN and EVs heads-up. By two projections, city population is expected to double-up in next 15 and 25 years, respectively. We assumed this to happen in 20 years, with population CAGR of 3.5%, giving some 41.5 lakhs population in 2030. Total vehicles on-road are expected to rise to 28 lakhs, with estimated 680 vehicles per 1000 population. Two-wheelers are expected to continue forming highest modal share of 87%, followed by passenger cars and rising share of fleet vehicles including 4-wheelers and 3-wheelers.

Table 65: Nagpur population and vehicle stock[204]

Nagpur	Units	2018	2020	2025	2030
City population	no.	27,50,000	29,45,869	34,98,768	41,55,439
Total vehicle stock on road*	no.	15,77,721	17,17,519	21,66,936	28,19,481
2W	%	88.0%	88.1%	88.0%	87.7%
3W - PV	%	1.4%	1.4%	1.4%	1.5%
3W - CV	%	0.6%	0.6%	0.6%	0.5%
4W - PV	%	8.3%	8.3%	8.3%	8.4%
4W - CV	%	1.5%	1.5%	1.6%	1.8%
Bus	%	0.1%	0.1%	0.1%	0.1%
Vehicle per unit 1000 population	no.	574	583	619	679

[204] EY analysis

5.3.1. EVs adoption and mix

EVs adoption is likely to be higher in public/fleet vehicles, including in buses, three-wheeler autos and fleet cars. Fleet vehicles' higher kilometers run per year and daily certainty in travelled distances, makes EV economics better viable over other personal vehicle segments (including personal two-wheelers and four-wheeler cars). Nearly 2030 all-India estimates on EV mix and adoption across different vehicle segments are shared below:

Table 66: EV adoption scenarios[205]

Vehicle category	Scenario-1 (Fast and high adoption at national level) Reference: NITI Aayog RMI Report		Scenario-2 (Medium optimistic adoption at city level)Used in this case study	
	EV mix % of new sales in 2030	EV mix % of total vehicles stock in 2030	EV mix % of new sales in 2030	EV mix % of total vehicles stock in 2030
2-wheeler	100%	~40%	100%	30%
3-wheeler	100% (since 2025)	~100%	100% (since 2025)	50%
4-wheeler PV	100%	~40%	100%	35%
4-wheeler CV	100% (since 2020)	~100%	100% (since 2025)	35%
Buses – public	100% (since 2020)	~100%	100% (since 2025)	60%
Buses – private	100% (since 2020)	~50%	100% (since 2025)	60%

In both the above scenarios, %EV mix of new sales is increased across years till 100%. NITI Aayog RMI report's assumptions are aggressive with early, faster and higher adoption rate, which seems unlikely, given the current level of EV supply chain and policy readiness in India. Hence **Scenario-2, a medium optimistic scenario** is modelled and results shared in below analysis. This modelled Scenario-2 gives 33% EV mix of total stock in 2030 with 9.18 lakhs EVs on road then. Morgan Stanley research assumed this number at all-India level to be 15%[206] , which supports higher mix at fast growing Tier-2 Nagpur.

5.3.2. EV battery technologies and ownership models

India with its value conscious customers, shall see a mix adoption of integrated lithium ion battery (LIB) EVs vs. battery swapping[207] and range extension[208] EVs. Public fleet vehicles are expected to see a higher adoption of battery swapping model over years, while personal vehicles are likely to see an increased use of range extension batteries, both driven by establishment of successful operational and economical battery swapping models in India. Of the total EV stock on road in 2030, it is assumed that 64% EVs shall have integrated LIBs, 8% swapping only and 29% with range extension battery option.

The model assumed following engineering values across different vehicle categories:

[206]http://www.autocarpro.in/news-international/-global-ev-miles-penetration-2040-requires-rs-055-900-crore-investment-morgan-stanley-26582

[207]Swapping batteries: these batteries can be swapped at a swapping station by replacing a discharged battery with a charged one. The vehicles therefore do not need to be fast-charged or have very large batteries. Here, the battery can be separated from the vehicle and will not be owned by the vehicle owner. Instead it will be owned by an energy operator (provider of charged battery as a service), who will buy the batteries, charge them and lease it to the vehicle owners at convenient charge-cum-swap centre.

[208]Range extension batteries: a normal integrated LIB gets charged every night. But since the battery is small, the range will not be large. Since most personal vehicles drive small distance in India in a day, this small range may be acceptable on 90% to 95% of the days. But for the remaining 5% to 10%, this could cause a problem. Instead of using fast-charger and face with downgrade battery life problems, in this option, the vehicles will have a slot for a second battery called range-extension swappable batteries (or RE battery).

Table 67: Technical specifications assumed in Nagpur model[210]

	Avg. battery size (kWh/unit)		Avg. vehicle efficiency	Avg. km run	kms per charge per vehicle[196]		# of charges per year per vehicle		
	If integrated	If swapping	km/kWh	kms/year	If integrated	If swapping only	If integrated	If swapping only	
2W	1.5	1.5	50.00	6,600	57.38	57.38	115.03	115.03	23.01
3W PV	4.5	3	20.00	33,000	68.85	45.90	479.30	718.95	143.79
3W CV	6	4.5	14.29	26,400	65.57	49.18	402.61	536.82	107.36
4W PV	15	12	7.69	12,540	88.27	70.62	142.07	177.58	35.52
4W CV	15	12	7.69	69,300	88.27	70.62	785.10	981.37	196.27
Bus	100	60	1.00	66,000	76.50	45.90	862.75	1,437.91	287.58

With above battery sizes and assumed EV stock, it is estimated that in 2030, Nagpur shall have 3.7 GWh of LIBs in the system with approximately 70% as integrated LIBs and remaining 30% as swappable LIBs. NITI Aayog's report estimated that India is likely to see a total of 3,500 GWh of LIBs in 2030, which is almost 100 times of the total LIB capacity that Nagpur will account in 2030.

Table 68: Cumulative LIBs in system[211]

Lucknow		2018	2020	2025	2030	CAGR
Cumulative LIBs in system	**MWh**	2	55	875	3,729	52%
Integrated LIBs	%	89%	85%	78%	70%	-2%
Swapping + RE LIBs	%	11%	15%	22%	30%	7%

[210] EY analysis
[211] EY analysis

5.3.3. EV charging technologies (slow vs. fast) and location choices

The choice of integrated and/or swappable batteries is likely to influence charging choices of customers between a mix of home charging, office/private charging, public charging and centralized bulk swappable battery charging stations. The analysis assumed a mix of charging options' adoption between different vehicle categories, and their variation over years with change in battery technology and costs. It is estimated that in 2030, a total of 1,434 lakh EV charges are likely to be done in Nagpur, with 61% happening via home charging, 8% via office/private charging, 9% via public charging and 22% via centralized bulk charging for swappable batteries.

Additionally, it is assumed that full home charging may be completed in five hours, while office/private and public charging may take one hour to complete and bulk swapping charging, two hours. Depending on the battery sizes assumed and time specifications taken to fully charge the battery, the average peak charging power may vary across vehicle categories and charging options as below:

Table 69: Battery size and types of charging across the vehicle segments[212]

	Avg. battery size (kWh/unit)		*Peak charging load (kW) per battery charging			
	If integrated	If swapping	Home charging	Office/private charging	Public charging	Swapping
			Home chargers	Fast chargers	Fast chargers	Slow chargers
2W	1.5	1.5	0.33	1.65	1.65	0.83
3W PV	4.5	3	0.99	4.95	4.95	1.65
3W CV	6	4.5	1.32	6.60	6.60	2.48
4W PV	15	12	3.30	16.50	16.50	6.60
4W CV	15	12	3.30	16.50	16.50	6.60
Bus	100	60	22.00	110.00	110.00	33.00

*Peak charging load is assumed to be uniform across charging times, but this may vary according to battery chemistry. Hence peak load multiple of 1.1 is used to absorb such variations.

India has developed two charging standards – the first being AC-001 charger for AC charging, and other being DC-001 charger for DC charging. Both have charging voltage levels under 100V and use custom GB/T communication protocol over CAN mode. AC-001 charger can give maximum 15 A charging current with 3.3 kW power, while DC-001 can give maximum 200 A current with 15 kW power. Between both the chargers, above charging ranges for two-wheelers, three-wheelers and four-wheelers can get closely covered. For buses, India has already started developing another charger that gives 50 A current and 30 kW power. There are other two higher voltage/power level charging standards that are under development, to be called AC-002 and DC-002 that has the potential to further improve fast charging (i.e., below one hour). It will be important for India to define and use the standard chargers across vehicle categories, to see scale-up of EVs.

Battery chemistry and battery temperature highly influence use of slow vs. fast charging. The life of low cost NMC batteries is likely to degrade if its charges fast (less than an hour) at higher 45°C ambient temperatures, while LTO batteries can support such fast charging.

[212]EY analysis

5.3.4. EVs and impact on the grid

It is estimated that a total of 798 MUs/year **electricity consumption** is likely to happen from EVs charging in 2030, with home charging (at residential tariff) taking majority 39% share, followed by charging loads at commercial tariff including 31% of bulk swappable battery charging, 20% of office/private charging and 9% of public charging -

Table 70: Electricity consumption for EV charging (at network input incorporating distribution losses)[213]

Nagpur		2018	2020	2025	2030	CAGR
Electricity consumption for EV charging (at network input incorporating distribution losses)	MUs/year	1	22	240	798	43%
Home charging (residential tariff)	%	60%	43%	43%	39%	-1%
Office/private charging (commercial tariff)	%	14%	26%	20%	20%	-3%
Public charging (commercial tariff)	%	14%	10%	10%	9%	-1%
Swapping + RE (commercial tariff)	%	11%	20%	27%	31%	5%

Total average connected load from EVs is likely to grow faster from 44 MVA in 2020 to 1600 MVA in 2030 with a CAGR of 43% and an average load factor of 6%. This average connected load share is highest with 35% in office/private charging stations, followed by 26% in bulk swappable battery charging stations, 16% in public charging stations and 13% in home charging.

Table 71: Total average connected EV charging load to grid[214]

Nagpur		2018	2020	2025	2030	CAGR
Total avg. connected EV charging load to grid	MVA	2	44	467	1,600	43%
Home charging (residential)	%	24%	14%	15%	13%	-1%
Office/private charging (commercial)	%	28%	43%	34%	35%	-2%
Public charging (commercial)	%	28%	17%	18%	16%	-1%
Swapping + RE (commercial)	%	11%	16%	23%	26%	5%

[213]EY analysis
[214]EY analysis

Further, depending upon the four charging location types and time of the day tariff incentives, the EV charging will spread up in four six-hour time slots of the day (TS1 – 0:00 to 6:00; TS2 – 6:00 to 12:00; TS3 – 12:00 to 18:00 and TS4 – 18:00 to 24:00). The following are the assumptions for the EV charging load distribution across these time slots:

Table 72: EV charging load distribution across time slots[215]

Time slots	Home charging	Office/private	Public	Swapping + RE
TS1	35%	5%	5%	50%
TS2	15%	30%	30%	35%
TS3	15%	40%	30%	15%
TS4	35%	25%	35%	0%
Total	100%	100%	100%	100%

Using the above load-time distribution in a day, the peak charging load from EV charging across different locations is estimated to be 13 MVA in 2020, 134 MVA in 2025 and 468 MVA in 2030, with 10 years CAGR of 43%. This peak from EV load comes in TS2 time slot in the day, as compared to the business-as-usual (BAU) peak in grid today that occurs in TS4 time slot. The BAU peak without EVs for Nagpur is estimated to be 526 MVA in 2020 and 703 MVA in 2030, with a CAGR of 3%. The total system's peak with EVs comes out to be 536 MVA in 2020, 712 MVA in 2025 and 1038 MVA in 2030, growing at a CAGR of 6.8%. By 2030, the peak demand from EVs in TS4 is expected to contribute 32% of total peak load in Nagpur, which may be a significant addition for DISCOMs to plan their preparation. The next three to five years of EV additional load can be catered to using the existing excess distribution capacity and BAU capital investments in the network by the two DISCOMs (MSEDCL and SNDL), beyond which special planning and interventions may be required.

Table 73: Assessment of Lucknow's peak demand[216]

Nagpur		2018	2020	2025	2030	CAGR
Peak EV demand for charging (TS2)	MVA	1	13	134	468	43%
Peak EV demand for charging (TS4)	MVA	1	11	104	335	41%
BAU peak demand of city (without EVs, in TS4)	MVA	496	526	608	703	2.9%
Total peak demand of city including EVs (TS4)	%	497	536	712	1,038	6.8%
% EV contribution to peak demand (TS4)	%	0%	2%	15%	32%	32%
BAU peak demand CAGR	%	13%	3%	3%	3%	0%
EV peak demand yearly CAGR	%	-	137%	47%	20%	-18%
Combined total peak demand CAGR		13%	4%	8%	8%	7%

[215] EY analysis
[216] EY analysis

The 335 MVA peak load addition from EV charging in 2030 is close to Nagpur today's peak demand of 446 MVA, and this is sizeable as it requires an estimate of INR837.5 crores of incremental investments in augmenting the distribution network, including sub-station capacity. The current transmission capacity of 806 MVA may also need higher augmentation with additional investments by 2030.

5.3.5. Number of chargers and charging locations

After understanding the total number of charges per day across different charging locations and assuming operational service hours for each charging location types (average 14 service hours per day for each location types), total number of chargers at each location types can be calculated. It is estimated that in 2030, 2.6 lakhs charging points requirements may exist in Nagpur, with 93% being home chargers, followed by 5% bulk swappable battery charging points, and remaining 2% at office/private and public charging stations. This includes all EVs and all charging points, including home chargers, which may yield EV to EVSE ratio of 3.53 by 2030. After removing home charging EVs as well as home chargers, the EV to EVSE ratio may become 20. This ratio for Nagpur for public charging is high compared to global current best practice of 10-12 ratio.

Further assuming the number of charging points to be 5, 10 and 200, respectively for office/private, public and swapping stations, it is estimated that Nagpur may need to grow the number of office/private charging stations from 11 in 2020 to 545 in 2030; public charging stations from 5+ in 2020 to 243 in 2030; and bulk swapping charging stations from 1 in 2020 to 71 in 2030. These numbers are likely to change with the sizing of each of these stations. Nagpur has 80 petrol pumps and these may be used to co-locate EV public/swap charging stations. Home chargers do not need communication link and hence may not need full-fledge AC-001 chargers. However, cluster EV charging in residential locality in parking lot is an option that can use AC-001 chargers, if managed by a third party. Malls, public parking spaces, cinema halls, metro/railway/bus stations are some of spaces that can be used for deploying a mix of slow and fast chargers.

5.3.6. Nagpur City's EV projections

Refer Table 82: Statistics dashboard for Nagpur projections. for key EVs stats that Nagpur city may witness till 2030, under above assumed Scenario-2:

6 City level implementation plan

India has emerged as one of the key automotive markets globally with a dominant position across several vehicle segments. The country is actively exploring cost-effective and viable solutions to tackle poor air quality in many of its cities as well as reducing its excessive dependence on oil imports. A blossoming EV market must be accompanied by adequate electric vehicle supply equipment (EVSE) installations, also known as EV charging points. In 2017, the total installed publicly accessible chargers grew to 222 .

The growth dependency of EV adoption and charging stations is often described as the chicken and egg problem, i.e., the need for ample EV penetration as a prerequisite for EV charging infrastructure deployment vs. the need for abundant EV charging infrastructure as a prerequisite for EVs' adoption. However, recent studies confirm that availability and accessibility of reliable public charging infrastructure must precede dense EV penetration. In the absence of a robust charging infrastructure, EV growth may be difficult to sustain.

Below enumerated Table 70: Charging options identified for various vehicle categories and Table 71: Specifications of charging options identified highlights optimal charging solutions identified for various vehicle segments and their respective power and charge time specifications

Table 74: Charging options identified for various vehicle categories[219]

<table>
<tr><th colspan="8">Charging locations</th></tr>
<tr><th></th><th>Home</th><th>Society</th><th>On-street/ Parking</th><th>Work</th><th>Private (dedicated fleet)</th><th>Public charging station</th><th>Commercial[218]</th></tr>
<tr><td>2W</td><td>Slow AC</td><td>Slow AC</td><td>Slow AC
Battery Swap</td><td>Slow AC</td><td>Slow AC
Slow DC</td><td rowspan="3">Intracity:
Slow AC
Fast AC
Slow DC
Fast DC
Battery swap

Intercity/ highways:
Slow AC
Fast AC
Slow DC
Fast DC
High power fast DC
Battery swap</td><td>Slow AC</td></tr>
<tr><td>3W</td><td>Slow AC</td><td>NA</td><td>Slow AC
Battery swap</td><td>NA</td><td>Battery swap</td><td>Slow AC
Fast AC
Slow DC</td></tr>
<tr><td>4W</td><td>Slow AC</td><td>Slow AC</td><td>Slow AC
Fast AC
Slow DC
Battery swap</td><td>Slow AC
Fast AC
Slow DC</td><td>Slow AC
Fast AC
Slow DC
Fast DC Battery swap</td><td>NA</td></tr>
</table>

[217]International Energy Agency (IEA) - https://webstore.iea.org/global-ev-outlook-2018

[218]E.g. e-commerce delivery fleets

Table 75: Specifications of charging options identified[220]

	Standard		Power Level		Typical Charging Time	
			2W	3W	4W	Bus
			1.25 kWh	3 kWh	15 kWh	100 kWh
Slow AC	Bharat Charger AC-001	3.3 kW	1-5 hour	1-5 hour	5-8 hour	NA
Fast AC	Type-2 AC	Min 22 kW	NA	NA	~35 minutes	NA
Slow DC	Bharat Charger DC-001	15 kW	0.5-1 hour	~45 mins	~50 minutes	NA
Fast DC	CCS-2/CHAdeMO	Min 50 kW	NA	NA	~15 minutes	1-2 hour
High Power Fast DC	CCS-2/CHAdeMO	Min 100 kW	NA	NA	NA	0.5-1 hour

EVs and supporting ecosystem is still evolving in the Indian context. Home charging is expected to emerge as the primary option mainly due to the lack of public charging facilities. It is expected that the share of public charging will grow, however, home charging would continue to be the dominant source with a share of nearly 70% in 2030.

Public charging infrastructure deployment is expected to face a major challenge of land unavailability. Government and public-sector agencies are ideally placed to mitigate this risk through collaborations with private players. Market players, such as municipal corporations and transport utilities, shall be anchoring infrastructure deployment at the city level. Accordingly, electric mobility is expected to be a city-led development wherein various city level players shall be collaborating to reduce risks and improve overall operational efficiency.

Thus, city-level initiatives will hold the key for reducing risks of supply and demand side stakeholders. To boost demand, there is a need to address the issue of range anxiety through deployment of charging stations at strategic locations in a city. This shall be based on pre-assessments of land, availability of power, civil works for pedestal and foundations, installation of transformers, line, terminations and packaged substations constituting of distribution boards, isolators, protection devices and metering equipment. In addition, a phase-wise city level deployment plan has to be made. Deployment can begin with installation at the existing fuel retail stations. Additionally, fast charging stations shall be set up at the bus depots, workshops, etc. and swapping stations shall be set up at the intermittent halts for intracity and intercity buses as well as to meet the fast charging requirements for other four-wheelers. Charging/swapping stations for Heavy-Duty Vehicle (HDVs) shall be deployed at intermittent halts such as food joints on highways, transport nagars and places where they are parked.

The sections below assess the role of strategic collaborations at city level, key assessments required and phased-wise approach for developing a city level implementation plan.

[219] Stakeholder consultations http://electric-vehicles-in-india.blogspot.com/
[220] Stakeholder consultations http://electric-vehicles-in-india.blogspot.com/

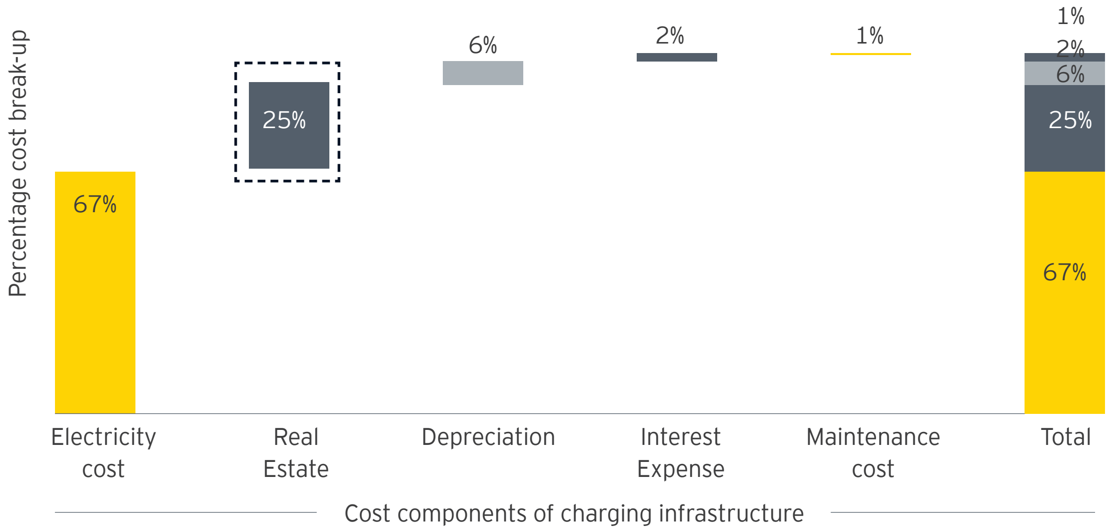


Figure 54: Cost components of charging infrastructure

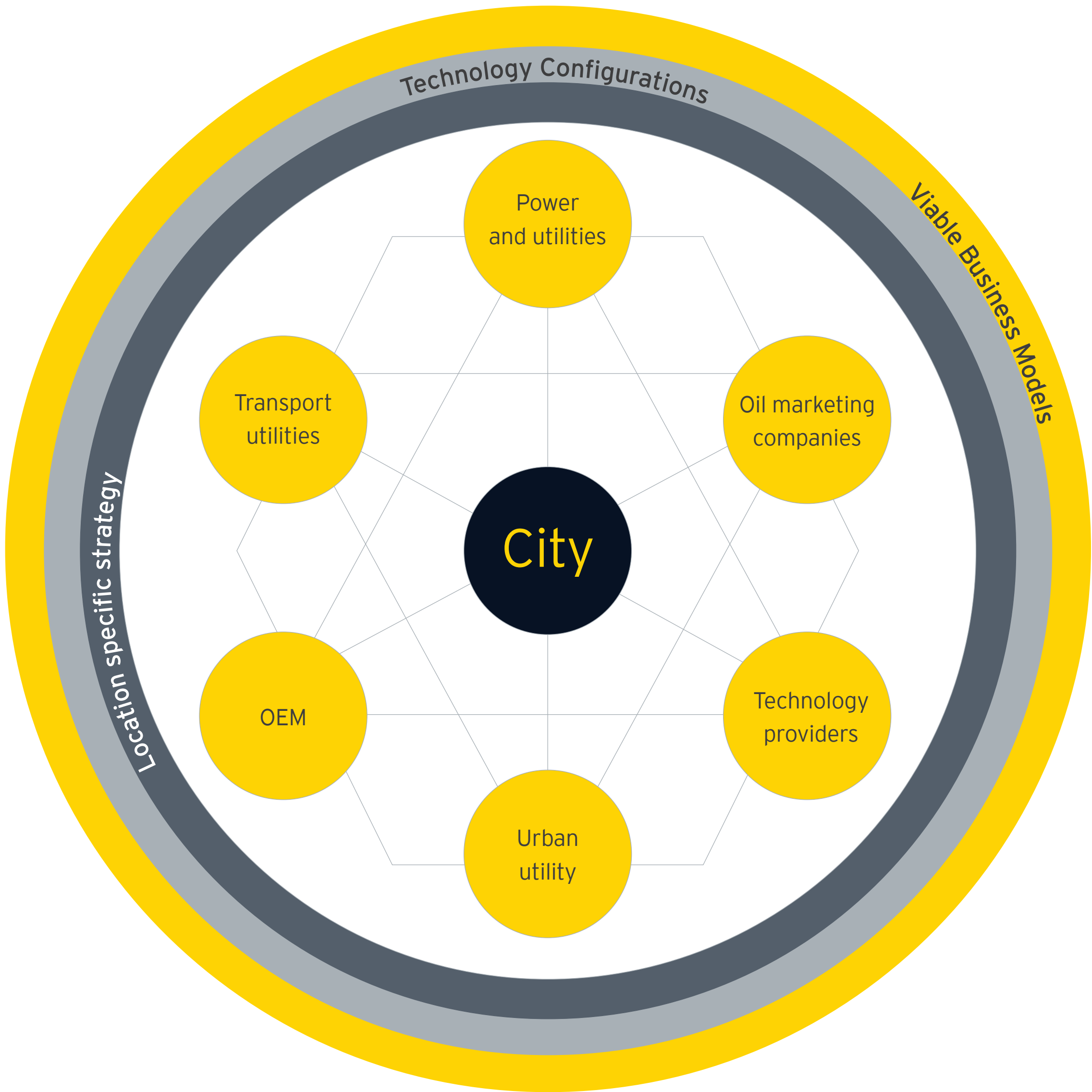


Figure 55: City-level collaborations to enhance overall business viability and timeliness of deployment


Van Ness Ave., California
60
& Market
Streets
GRANT
Kearny
Quincy

6.2

Key assessments required for developing the implementation plan

For an effective roll-out of electric mobility program in a city, several assessments need to be done to determine the ease of deployment and prepare a transition plan. As per several stakeholder interactions and secondary research done during the study, a list of such assessments was made that could help an implementing agency develop a plan before the roll-out of electric mobility deployment programs.

6.2.1. Assessment of demographic aspects and consumer behavior

One of the key assessments is that of demographic aspects. It is the demography of a city that reflects the acceptance of end users/customers for transitioning to electric mobility.

The following assessments need to be undertaken to determine the demographic aspects of a city.

- Literacy levels of residents and daily commuters

It is a fair assumption to consider that people with higher literacy level have greater acceptance to new technology and they easily adopt to changing socio-economic conditions as per the need of hour. Moreover, due to their reach, access to information and aspiration of better living conditions, they make efforts to participate in supporting greener initiatives.

- Economic level to understand the market for different types of electric vehicle

Apart from literacy levels, economic level of residents plays an important role in acceptance and adoption. Economic level assessment will determine the affordability of end users. Sustainability of transitioning to electric powertrains will largely depend on the viability of operations. Hence, the price point at which the services could be charged to end users will depend on the purchasing power of daily commuters and residents who should be comfortable to afford such services.

- Preference for the medium of transport for inter/intra-city commutation

Depending on the robustness of public transport in a city, commuters decide their mode of transport. This greatly varies across cities due to economic considerations and quality of services rendered by transport authorities. Hence, such an assessment is inevitable to determine footfall and enhance utilization of public infrastructure.

- Preference of medium of transport for first and last mile connectivity

In several occasions of interaction with the stakeholders and end users, concerns regarding provision of first and last mile connectivity rose. Even if a robust transport infrastructure might exist, unavailability of reliable and efficient first and last mile connectivity could be a major deterrent for shift to public transport, especially in smaller cities where average commutation distance is less as compared to metropolitan cities.

- Commuters preference for ride sharing services

Awareness, affordability and technology have supported proliferation of ride sharing services offered by fleet aggregators which were offered by last mile service providers such as three-wheelers. The timeliness of availability of such service at doorsteps and their quality has led to an increase in aspiration of commuters and their preference for ride sharing services.

6.2.2. Assessment of existing transportation system

In order to understand the availability of dominant mode of transport in a city, the entire available transport system needs to be studied. Such an assessment will help in preparing a transition plan for a city to shift to electric powertrains. The following assessments might be required to be done to achieve the intended objective of reducing vehicular emissions.

- GIS assessment and mapping

It is necessary to map routes of prevalent options of transport such as three-wheelers and buses across the entire city for developing a deployment an transitioning plan.

- **Medium of transport for commuting within the city**

The options for commutation that a city offers to its residents to commute, needs to be considered to determine the most viable segment of vehicles that could be transformed to electric.

- **Identification of routes with highest commutation**

For a viable operation of infrastructure that needs to be deployed, assessment of routes needs to be done. Higher utilization of infrastructure to achieve lower marginal operational costs which could bring the fare at par or lesser than what users are being charged.

- **Distance of routes with highest commutation**

Planning for deployment of charging infrastructure in the identified routes with high commutation needs to assess the length of routes and even the type of vehicles being deployed. This is likely to aid in determination in the selection and sizing of the requisite charging infrastructure enroute.

- **Route planning**

For a complete implementation plan, it is important to optimize the locations of charging infrastructure so that it could cater to maximum vehicles. It is ideal, if the deployed infrastructure , can be at the intersection of multiple routes that in-turn could ensure higher asset utilization and lower pricing for charging the services.

6.2.3. Infrastructure assessment for electric buses

- **Number of buses plying in and around the city**

To build a transition and implementation plan, determination of the number of buses that are catering to the entire population of a city is necessary. Adequacy of buses to meet the growing demands of urbanization needs to be assessed as well.

- **Number of buses plying on routes of highest commutation**

As the cities develop heterogeneously, assessment of profitable routes of operation for fleet operators, such as transport undertakings, is essential. Frequency of operation of buses apart from number of buses plying on such routes is essential in assessing the type of charging infrastructure that needs to be deployed.

- **Number of bus depots available in and around the city**

Considering the ease of deployment of charging infrastructure, depots seem a simple and conducive proposition. Availability of land and access to power infrastructure can lead to viable deployment models of charging infrastructure that could be both owned and operated by transport undertaking or by a charge point operator.

- **Assessment of route plan and schedule**

Existing plans and schedules of buses and their methodology might need to be tweaked, considering the technical capability of an electric bus. It will largely depend on capacity of battery and ability to charge in a shorter duration depending on the chemistry of battery used in prevalent models of electric buses available in a market. Moreover, while accessing the schedule, the enroute charging time should also be considered, if required in certain cases.

- **Average number of trips in routes of highest commutation**
- **Assessment of average number of trips is essential** to determine the specification of electric buses and charging infrastructure for catering to the requirements of a city. Scheduling of electric buses depends on flexibility of charging enroute and load factors in high commutation routes.Average distance between the depots

As already mentioned, depots are suitable locations for deployment of charging infrastructure due to access to infrastructure in terms of both land and power. However, distance between depots needs be assessed as the availability of space and grid infrastructure to charge the entire fleet in a few locations of a city might be inadequate to cater to the demands.

- **Average number of buses parked in a depot**

Determination of the number of buses parked shall give an urban planner a sense of number of charging stations that are needed to be deployed enroute. This is because the infrastructure available in a depot may or may not be able to charge the entire volume of fleet parked.

- **Availability of space in a depot for the setup of charging stations for e-buses**

Any additional deployment of infrastructure in a depot is possible either by sacrificing the space utilized for some other purpose, such as maintenance bays or utilization of space, that is readily available. Hence, assessment of availability of space for parking and charging of electric buses across depots needs to be undertaken so that the load could be distributed across depots to avoid any immediate infrastructure augmentation.

- **Availability of alternate spaces in the route**

Assessment of specific routes, where feasibility of plying electric buses is possible, needs to be assessed for the availability of spaces for emergency charging where an electric bus can park and charge for a while without creating any traffic congestion.

- **IT and automation for metering, billing and data related to utilization and handling of electric bus**

To improve operational efficiency, the implementing agencies need to assess the right technology platforms that help the transport service provider maintain a seamless connect with end users as well as charging infrastructure operators. Further, such platforms could encompass technology for automated metering, billing and usage of vehicle. The data that would be collected regarding usage of electric buses in this case could be used to monitor performance and aid in enhancing operational efficiency.

6.2.4. Assessment of operations of first and last mile commuting vehicles in a city

First and last mile connectivity are provided by three-wheelers in India. India has witnessed a natural transition to electric powertrains by three wheeler service providers. This is mainly because of the favourable economies due to shorter trip lengths and lower upfront purchase costs. Charging of such vehicles has been mostly noticed to be unauthorized. Assessment of operating clusters for such vehicles needs to be conducted to plan the infrastructure requirement towards a sustainable growth.

- **Number of rickshaws plying in the clusters of a city**

The demand of power from this category of vehicle needs to be assessed and projections have been made considering a large variety of offerings available in the market, most of which with lower efficiency. The demand would largely depend on average capacity of battery used and the number of vehicles plying in those cluster and routes.

- **Number of rickshaws plying on routes of highest** commutation

Certain target clusters need to be identified after determining the routes that witness high commutation and ridership. However, to prepare a transition plan, the current fleet of rickshaws plying in those routes and the number of such vehicle that could transition to electric need to be determined.

- **Average distance commuted by a rickshaw in a day**

Similar to infrastructure implementation planning for electric buses, average distance commuted needs to be assessed to determine the number of charging points that needs to be deployed to charge the vehicles and to sustain their operations.

- **Average number of trips taken by e-rickshaws in a day**

Average number of trips done by e-rickshaws also needs to be assessed along with distance travelled by them to optimize the number of charging points in clusters.

- **Free space availability for parking and access to reliable power for charging**

Post assessment of routes, access to land and power infrastructure needs to be assessed to identify the places for setting up authorized parking and charging without hampering the regular operations and business.

6.2.5. infrastructure assessment for public chargers

Assessment for deployment of public chargers for private fleet and individual private electric vehicle owners is essential to boost the transition to electric powertrains. The assessments of this category of vehicles (mostly car and commercial vehicle) will encompass forecasting exercises of vehicle stocks, EV penetration projections and possible locations of deployment of charging infrastructure in a city.

- **Existing vehicle stock and growth trends**

Assessment of existing vehicle stocks on road and their growth trends need to be assessed to project the growth for the following years. Though several other parameters also need to be considered, this projection will aid in determining the annual transitioning targets.

- **Forecast vehicle stock and EV penetration**

The EV transition mix can be determined as per the EV targets and market uptake through correction factors build into the sizing model.

- **Determine y-o-y growth rates of electric vehicles in the city**

Year-on-year growth rates that a city needs to target can be determined and incorporated into the implementation plan for target penetration levels by undertaking the above-mentioned assessments.

- **Determine the number and type of chargers/ number of battery swapping stations**

Assessment for deployment of charging infrastructure to cater to the forecasted number of EVs benchmarking with the countries with high EV penetration as well as considering local geographical factors such as ambient temperature.

- **Number of parking lots in shopping malls, railway station, office complexes, etc.**

The location of deployment of charging infrastructure needs to be assessed critically, considering that land should be available at affordable costs to have a viable business model for sustainable operations. Cost of real estate along with availability of power are another key considerations. However, parking lots in shopping malls, railway stations and office complexes that may allow public charging also needs to be assessed for their deployment potential as per the infrastructure and need as per the estimates.

- **Number of fuel retail stations (sharing of space for distribution/retail of battery) for installation of DC fast chargers or setting up battery swapping stations.**

Assessment for the possibility of deploying charging stations in fuel stations as per the available space and safety regulations should be determined. Oil marketing companies (OMC) may aid by sharing their available space for the installation of fast charging stations or small battery swapping outlets.

- **GIS assessment**

GIS assessments for locations to set up the charging infrastructure needs to be done by mapping transportation geographic information system (GIS) assessment with power infrastructure. GIS assessment will be described in grid infrastructure availability assessment.

6.2.6. Infrastructure assessment for the availability and resilience of power distribution infrastructure

Electric mobility can be sustainably implemented if issues in transport and power sectors are judiciously taken care of. Assessment for the availability of power distribution infrastructure and augmentation plan needs to be in place as part of the city-level implementation plan as both, transition of vehicles to electric powertrains and augmentation of distribution infrastructure, need to happen in tandem.

- **Assessment of existing margins in distribution transformer levels**

This assessment will help determine if any immediate augmentation is necessary. Further, it could help in determining the readiness of network to cater to the demand of EVs that a city is planning to deploy. Further, there is a need to need to assess the voltage levels, availability of dedicated feeders, redundancy of supply and metering infrastructure.

- **Load flow analysis**

Load flow simulation studies need to be conducted to analyze the impact of addition of load as per the target number of EVs. Further, it will also help to understand the load consumption pattern at any given location of the city.

- **GIS assessment**

GIS mapping of flow of distribution utility network will be useful to determine their proximity to transport routes that would have been GIS mapped as mentioned earlier. This could help in optimizing the number and size of deployment of the charging infrastructure.

- **Access to reliable power**

Charging infrastructure will be at the heart of operations of the entire electric mobility implementation plan in a city. Uninterrupted supply is necessary else failure in electric supply is likely to disrupt the transport service of entire city. Hence, assessment of reliable sources of power for charging infrastructure is inevitable.

- **Existing type of point of connection**

As per the type of charger to be deployed in a location determined from the assessments done earlier, the point of connection needs to be looked for. However, these are guided by principles laid down in safety regulations.

- **Applicable tariff structure**

Assessment of an applicable EV charging tariff is necessary to determine the applicable connections in the right consumer category, such that business viability of charging infrastructure operators can be increased.

- **Grid integration for vehicle-to-grid (V2G) implementation**

This assessment needs to be done to test for grid resilience. Though CEA has defined the standards for connectivity in its draft distributed generation resource regulation, power flow simulations needs to be done and clearance from the distribution utility might be necessary for obtaining the permission to install a charging station.

It needs to be assessed if a city could bundle state renewable power purchase obligation targets to meet the additional load of EVs. Considering the load curve of EVs to peak in afternoon and nights, power procured from renewable sources could be used to cater their demand.

- Renewable power purchase obligation

It needs to be assessed if a city could bundle state renewable power purchase obligation targets to meet the additional load of EVs. Considering the load curve of EVs to peak in afternoon and nights, power procured from renewable sources could be used to cater their demand.

6.2.7. Phase-wise implementation plan

Implementation at a city level can be based upon a phase-wise procurement of EVs. In the initial phase, public fleet providing last mile connectivity is expected to be introduced. This shall be followed by an adoption by fleet service providers and private players in subsequent phases. Below mentioned diagram details out the activities envisaged in each phase of the plan.

Figure 56: Phase-wise implementation plan[221]

Phase 1

a) Activity 1: Assessments for identifying strategic locations:

this shall be based upon the review of existing public transport infrastructure, route planning and load analysis on distribution grid infrastructure at substation and DT level. Key sub activities for each of these are mentioned below:

1. Reviewing the existing public transport infrastructure: this shall include review of the existing bus depots and metro stations to estimate inter-station distance.

2. Route level assessment: route level assessment shall be done which shall factor in parameters such as expected number of vehicles at each route, route length and average daily run.

3. Distribution grid infrastructure availability assessment: this shall include review of the existing cable networks at city level.

4. Identification of intersecting nodes: based on route assessment and grid infrastructure availability assessment, strategic locations corresponding to intersecting nodes shall be shortlisted.

5. Feeder level assessment for identifying locations and grid augmentation requirements: this shall include assessment of expected load patterns at feeder level for identified nodes. Accordingly, percentage of the availability of DT capacity for different durations in a day shall be estimated.

a) Activity 2: Developing DPR: DPR for city level deployment shall be developed highlighting the following areas:

1. Operating models based on gap assessment from mature markets

2. Phase-wise adoption targets for each vehicle segment

3. CAPEX requirements for each phase

4. Expected grid infrastructure augmentation requirement

Business models

b) Activity 3: Pilot projects: based on the findings on strategic locations and targets defined in DPR, a pilot project shall be designed. The project shall factor in collaborations amongst government agencies for reducing the supply side, demand side and financing risks.

[221]EY analysis

[220]Stakeholder consultations http://electric-vehicles-in-india.blogspot.com/

Phase 2

a) Activity 1: Developing procurement plan for e-buses and public fleets providing last mile connectivity. The plan shall include:

1. Number of buses to be procured
2. Capping of permit requirements for internal combustion engine (ICE)
3. Bid process management for selecting right partners for program implementation

b) Activity 2: Developing transition plans for small commercial and private vehicles based on:

1. Supply and demand mechanics in the city
2. Life cycle cost
3. Asset utilization

Phase 3

a) Improvement of operational efficiency for the deployed buses and public fleet: this shall be based on:

1. Review of impact of technical inefficiencies on operating parameters such as charge time, halt time, expected range, number of trips and average trip length.
2. Developing transition plans for inter-city commuting services.

6.2

Conclusions

Electric mobility is expected to be a city-led development wherein various city-level stakeholders will collaborate to reduce risks (such as land availability) through viable and sustainable business models. An ideal city-level implementation plan shall be based on a phase-wise approach of procurement factoring in techno-commercial considerations specific to the city.

Implementation plan needs to factor in the following critical areas:

1. Route planning and electric load analysis at feeder level for identifying strategic locations.
2. Assessment of transport infrastructure.
3. Viability analysis to structure pilots and explore options for PPP models.

Accordingly, there is a need to develop a detailed DPR and a detailed implementation plan factoring in phase-wise adoption targets, CAPEX requirements and infrastructure augmentation assessments for both transport and power. This shall also include learnings from use cases such as pilot programs run in other parts of the country and globally.

7 Annexure

7.1

Regulatory treatment of Setting-up Electric Vehicle Charging Infrastructure

Draft circular on explanation for EV charging not being considered as resale of electricity

National Context

1. India, at 1.7 metric tonnes of CO2e per capita[222] , has one of the highest per capita carbon-di-oxide emissions globally. A major contributor of these emissions is transport fuel, constituting about 125 Mt of CO2e[223] (2007). Further, towards this, India has an annual oil import bill of around INR 5 lakh[224] crores (2015-2016).

2. As part of the Intended Nationally Determined Contributions (INDCs), under the United Nations Framework Convention on Climate Change (UNFCCC), India has committed to reduce the emissions intensity of its GDP by 33 to 35 percent from 2005 level and to achieve 40% of the cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030.

3. Electrification of surface transport, especially roads, can improve the carbon emissions while drastically reducing the oil import bill and hence improving the Current Account deficit (CAD). The NITI Aayog[225] , in 2017, estimated that India can reduce 37% of its carbon emissions and USD 60 billion in the imported oil bill for the year 2030 by pursuing a shared and electric mobility future.

4. Towards this objective, the Government of India (GoI) has been concentrating its focus on propagating road electric mobility. On one hand, to incentivise the supply of Electric Vehicles (EVs)[226] in the market, the GoI is implementing the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme. On the other hand, one of the most important aspect for global uptake of EVs is ubiquitous presence of reliable charging infrastructure[227], both at personal and public levels.

[222]The World Bank
[223]The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth – Planning Commission of India
[224]Indian petroleum & natural gas statistics (2015-2016)
[225]India Leaps Ahead: Transformative Mobility Solutions For All – Niti Aayog
[226]This circular covers all road-based electric vehicles, namely e-2Ws, e-rickshaws, e-4Ws, and e-buses.
[227]The circular covers only public charging, both live plugged-in charging as well as battery swapping. Further, the circular covers all types of battery technologies used in charging and does not discriminate or prefer one technology over another. Lastly, it covers only conductive charging and not wireless / inductive charging technologies or methods.

Background to the Circular

5. The Forum of Regulators (FOR) had conducted a study on impact of electric vehicles (EV) on the grid that was published on September 2017. The report considers the service of charging electric vehicles as distribution or supply of electricity as per the Electricity Act, 2003 (hereinafter called EA or EA 2003 or the Act).

6. It further mentions that specific amendments to the Act are to be made to allow electric vehicle charging business to resell electricity without license.

7. Further, the report states as per the current regulation following three models of operation of charging infrastructure could be allowed,

   a. Distribution licensee owned charging infrastructure, which suggests the distribution licensee to own and operate charging infrastructure at retail supply tariffs determined by state electricity regulatory commission (SERC).

   b. Distribution licensee franchised charging infrastructure, which suggests that a third party can be authorized by distribution licensee in its area of supply to install and operate the charging infrastructure. Public private partnerships model could also be encouraged. The single point bulk supply tariff as well as the retail tariff is to be determined by SERC. Moreover, it suggests that franchisee could purchase power through open access without application of any cross subsidy surcharge (CSS).

   c. Privately owned battery swapping stations that shall not be considered as reselling of electricity and third parties can set up the infrastructure by intimating about the same to distribution licensee in that are to avail special category tariff. It suggests the charging infrastructure can procure power in bulk from distribution licensee of that area or through open access, as per the provisions of the act. The bulk supply tariff to procure power from distribution licensee shall be determined by SERC.

Analysis of EV Charging Infrastructure with Respect to Regulatory Aspects

8. The hypothesis, behind this circular, is that the models developed in the FOR's analysis have been framed taking a conservative approach to the interpretation of EA 2003 itself. The charging of electric vehicles is just not supply of electricity but value added services as well such as condition monitoring of battery while charging in a safe and reliable manner. The user shall not come to a charging station to buy electricity but to charge its battery for a certain period of time and hence can be inferred to avail services rendered by the charging infrastructure operator.

9. This circular aims to analyse the role of a typical public EV charging station, corresponding role of a utility, and evaluate how other countries have treated setting up of such a public infrastructure under the regulatory ambit, and how should it be treated under the prevalent regulation in India.

10. A public EV charging station is expected to provide the following, if not all, to the end consumer[228] :

a. infrastructure for electrical charging of battery, viz., step down transformer for high capacity charging station;
b. Electric Vehicle Supply Equipment (EVSE) to keep the electric car safe while charging, converter for DC charging;

c. Connectors and space for parking of car with appropriate lighting;

d. basic waiting arrangement for customers and vehicles in queue; and

e. web-based real time charging station database to show the location of charging station, charging facilities available, rate, availability and occupancy of charging bays, etc.

11. An EV with partially discharged/discharged battery comes to a Charging Station where it is provided parking space and service of charging of battery by electricity through EVSE. In the charging process carried out at the premises of Charging Station, the electrical energy is converted into chemical energy in the battery. During the charging, the EVSE installed at the charging station monitors the status of the battery and regulates the electricity supply to ensure safe charging. The EV leaves the charging station with change in the status of the battery condition from low chemical energy to high level of chemical energy.

12. EV is not coming to a Charging Station for purchase of electricity but for getting its battery charged in a safe and reliable manner and to know the condition of its battery from the diagnostic tools of the EV charging station. The whole gamut of tasks a charging station has to essentially perform clearly shows that it will be a simplification to equate it with the sale of raw electrical energy at standard voltage done by a DISCOM or a distribution licensee to a consumer.

Global Precedence

13. Globally, EV charging business has been either exempted from regulatory business of utilities or allowed as pure commercial service business, paving way for its mass roll out[229] :

a. State of New York Public Service Commission (NYPSC)[230] removed a potential impediment to investment into the electric vehicle charging infrastructure space by announcing that it did not have jurisdiction over publicly available electric vehicle charging stations. The commission mentioned that charging stations do not fall under the definition of an "electric plant" since charging stations simply provide a service which requires the use of specialized equipment and allows the customer to perform only one thing i.e. charging.

b. The Missouri Public Service Commission (MPSC) announced that it does not have jurisdiction over EV charging stations since EV charging stations are not "electric plant" as defined in the statute. It concluded that EV charging stations are facilities that use specialized equipment, such as a specific cord and vehicle connector, to provide the service of charging a battery in an electric vehicle. The battery is the sole source of power to make the vehicle's wheels turn, the heater and air conditioner operate, and the headlights shine light. To rule otherwise would conceivably assert jurisdiction over other similar battery-charging services, such as smart phone charging stations or kiosks, RV parks that allow vehicles to connect to the park's electricity supply, or airports that connect planes to a hangar's electricity supply while parked etc.

c. The Ontario Energy Board (OEB) released a staff bulletin mentioning that the ownership or operation of an EV charging station, and the selling of EV charging services from that facility, do not constitute distribution or retailing. In OEB staff's view, an electrical apparatus or infrastructure owned or operated for the sole intended purpose of charging EVs is not a system for distributing electricity. Providers of EV charging services to the public do not simply sell or offer to sell a commodity. They provide customers with a complete service, a "vehicle refuelling" service, including, at a minimum, the use of a parking space and a charging device, and which may also involve information technology letting EV drivers know where charging stations are located, whether they are occupied or available for use, and how fast a charge they can expect to receive (e.g. level 2 or level 3 charging).

[228] Source: Private sector consultations
[229] Source: private sector consultations
[230] Source: 13080/13-E-0199 PSC Removes Obstacle to New Investments in Charging Stations

d. Finnish Energy Agency has not seen the requirement to justify or mention its position on whether charging infrastructure business be considered under the scope of electricity distribution. It has been the general consensus in Finland that charging infrastructure service should not be covered under the electricity distribution regulation, and that the distribution company remains responsible till the electricity connection to the charging station. The charging station operation is not covered under the distribution regulations and is left to the market for sale of service.

Conclusion

14. Thus, the charging process of an EV at a public charging station is not a simple transmission, distribution or trade of electricity, as prohibited to be freely undertaken, under Section 12 of the EA 2003.

Section 12:

No person shall
a. transmit electricity; or
b. distribute electricity; or
c. undertake trading in electricity, unless he is authorised to do so by a licence issued under section 14, or is exempt under section 13.

It should be considered to treat public EV charging as a sale of service where some value addition is provided through the premises of charging station operator.

15. Setting up a public EV charging infrastructure should not be restricted only within the purview of a DISCOM or its franchisee, as prescribed under Section 14 of the EA 2003:

Section 14:

The Appropriate Commission may, on an application made to it under section 15, grant a licence to any person

a. to transmit electricity as a transmission licensee;
b. to distribute electricity as a distribution licensee; or
c. to undertake trading in electricity as an electricity trader, in any area as may be specified in the licence:

As setting-up and operation of EV charging infrastructure falls outside of purview of a DISCOM or its licensee, any other government or a private sector entity, in addition to a DISCOM or its licensee, should be allowed to set up EV charging infrastructure.

16. The EA 2003 only deals with Generation, Transmission, Distribution, Trading and Use of electricity as specified in the Preamble of the Act.

Preamble:

An Act to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all

Hence, as setting up and operating EV charging infrastructure falls under a service aspect, there is no requirement to undertake any amendment of the EA 2003

17. The EA 2003 specifies under Section 176 sub-section 2 (z) that the Central Government can make rules for any matter which is required, that

Section 176:

2. In particular and without prejudice to the generality of the foregoing power, such rules may provide for all or any of the following matters, namely:--
z. any other matter which is required to be, or may be, prescribed.

Section 75: Directions by Central Government to Authority:

1. In the discharge of its functions, the Authority shall be guided by such directions in matters of policy involving public interest as the Central Government may give to it in writing.

2. If any question arises as to whether any such direction relates to a matter of policy involving public interest, the decision of the Central Government thereon shall be final

[231]Source: https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=ET-2016-0246&attach_id=2017016053 Tariff No. YE-2017-0052
[232]Source: https://www.oeb.ca/oeb/_Documents/Documents/OEB_Bulletin_EV_Charging_20160707.pdf

Section 107: Directions by Central Government:

1. In the discharge of its functions, the Central Commission shall be guided by such directions in matters of policy involving public interest as the Central Government may give to it in writing.

2. If any question arises as to whether any such direction relates to a matter of policy involving public interest, the decision of the Central Government thereon shall be final.

Section 62. (Determination of tariff): The Appropriate Commission shall determine the tariff in accordance with provisions of this Act for –

3. The Appropriate Commission shall not, while determining the tariff under this Act, show undue preference to any consumer of electricity but may differentiate according to the consumer's load factor, power factor, voltage, total consumption of electricity during any specified period or the time at which the supply is required or the geographical position of any area, the nature of supply and the purpose for which the supply is required.

The Central Government henceforth directs this circular to be notified as per the the provisos of the EA 2003 under Section 75 to the Central Electricity Authority (CEA) and under Section 107 of the EA 2003 to the Central Commission and Appropriate Commissions to give preferential tariff category to EV charging service providers/operators by capping the tariff to a maximum of +...% for the purpose of EV charging as specified under Section 62 sub-section 3 of the EA 2003.

18. Moreover, it has directed to the Bureau of Energy Efficiency (BEE) to specify norms and energy standards for appliances under Section 14 (a) and (b) of the Energy Conservation Act 2001,

    Energy Conservation Act, 2001, Section 14. Power of Central Government to enforce efficient use of energy and its conservation -

    The Central Government may, by notification, in consultation with the Bureau,-

    a. specify the norms for processes and energy consumption standards for any equipment, appliance which consumes, generates, transmits o supplies energy;
    b. specify equipment or appliance or class of equipments or appliances, as the case may be, for the purposes of this Act;

    Hence, BEE is hereby directed to specify energy consumption standards for charging equipment of EV, also referred to as Electric Vehicle Supply Equipment (EVSE).

19. A vibrant EV charging infrastructure market will provide revenue augmentation opportunities to DISCOMS, opportunity to upgrade the distribution network, expand the business, and as well as encourage private sector to set up and operate a reliable network of charging points. Amongst the developing nations, India should take a lead in developing a forward-looking framework towards encouraging electric mobility.

7.2

Detailed charging standards adopted in the studied countries

7.2.1. U.S.A.

Table 76: Standards adopted in USA

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
TS 21.101	3rd Generation Partnership Project (3GPP)	Technical Specifications and Technical Reports for a UTRAN-based 3GPP system	●		●
TS 21.201	3GPP	Technical Specifications and Technical Reports for an Evolved Packet System (EPS) based 3GPP system	●		●
TS 41.101	3GPP	Technical Specifications and Technical Reports for a GERAN-based 3GPP system	●		●
ANSI/AIHA Z10	American Industrial Hygiene Association- AIHA (ASC Z10)	American National Standard for Occupational Health and Safety Management Systems	●		●
189.1	American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)	Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings			●
ANSI/ASHRAE/ IESNA 90.1	ASHRAE	Energy Standard for Buildings Except Low-Rise Residential Buildings, I-P Edition			●
ANSI/ASSE Z244.1	ASSE (ASC Z244)	Control of Hazardous Energy - Lockout/Tag-out and Alternative Methods		●	
F496	ASTM	Standard Specification for In-Service Care of Insulating Gloves and Sleeves			●
F711	ASTM	Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools		●	
F1506-10a	ASTM	Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
F2249-03	ASTM	Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment			●
F2413	ASTM	Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear			●
2070	Advanced Transportation Controller (ATC)	Advanced Transportation Controller (ATC) Standard for the type 2070 Controller	●		
	Auto Alliance	Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems	●		
Title 13, California Code Regulations, Section 1968.2	California Environmental Protection Agency Air Resources Board (CARB)	Malfunction and Diagnostic System Requirements for 2004 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines (OBD II);	●		
Title 13, California Code of Regulations, Section 1968.5	CARB	Enforcement of Malfunction and Diagnostic System Requirements for 2004 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines	●		
	Environmental Protection Agency (EPA/NHTSA)	Revisions and Additions to Motor Vehicle Fuel Economy Label	●		
	Electric Power Research Institute (EPRI)	Common Functions for Smart Inverters, Version 3	●		
	G3-PLC Alliance	G3 MAC Layer Specification	●		●
	G3-PLC Alliance	G3 Physical Layer Specification	●		●
	G3-PLC Alliance	G3 Profile Specification	●		●
GreenPHY1.1	HomePlug Powerline Alliance	HomePlug GreenPHY Specification, 1.1	●		●
AV2	HomePlug Powerline Alliance	HomePlug AV2 – The Specification for Next-Generation Broadband Speeds over Powerline Wires	●		●
IBC	International Code Council (ICC)	International Building Code			●
IECC	ICC	International Energy Conservation Code	●	●	●
IFC	ICC	International Fire Code			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
IgCC	ICC	International Green Construction Code			●
IMC	ICC	International Mechanical Code			●
IRC	ICC	International Residential Code			●
IZC	ICC	International Zoning Code			●
ICC A117.1	ICC (ASC A117)	Accessible and Usable Buildings and Facilities			●
60038	International Electro technical Commission (IEC)	IEC standard voltages			●
60050-482	IEC	International Electro-technical Vocabulary (IEV) - Part 482: Primary and secondary batteries		●	
60059	IEC	IEC standard current ratings	●	●	●
60068-1	IEC	Environmental testing. Part 1: General and guidance	●	●	●
60068-2	IEC	Environmental testing - Part 2: Tests	●	●	●
60068-3	IEC	Environmental testing - Part 3: Background information	●	●	●
60068-4	IEC	Environmental testing. Part 4: Information for specification writers - Test summaries	●	●	●
60068-5-2	IEC	Environmental testing. Part 5: Guide to drafting of test methods - Terms and definitions	●		●
60204-1	IEC	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	●		●
60269-1	IEC	Low-voltage fuses - Part 1: General requirements	●		●
60309 series	IEC	Plugs, socket-outlets and couplers for industrial purposes			●
60364 series	IEC	Low-voltage electrical installations	●		●
60364-1	IEC	Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions	●	●	●
60417	IEC	Graphical symbols for use on equipment	●		●
60445	IEC	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors	●		●
60481	IEC	Coupling devices for power line carrier systems			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
60529	IEC	Degrees of protection provided by enclosures (IP Code)	●	●	●
60622	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes Sealed nickel-cadmium prismatic rechargeable single cells		●	
60623	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes Vented nickel-cadmium prismatic rechargeable single cells		●	
60664-1	IEC	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	●	●	●
TR 60664-2-1	IEC	Insulation coordination for equipment within low-voltage systems - Part 2-1: Application guide - Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing	●	●	●
60721-1	IEC	Classification of environmental conditions - Part 1: Environmental parameters and their severities	●		
60721-2	IEC	Classification of environmental conditions - Part 2: Environmental conditions appearing in nature	●		
60721-3	IEC	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities	●		
TR 60721-4	IEC	Classification of environmental conditions - Part 4-0: Guidance for the correlation and transformation of the environmental condition classes of IEC 60721-3 to the environmental tests of IEC 60068	●		
TR 60755	IEC	General requirements for residual current operated protective devices	●		●
TR 60783	IEC	Wiring and connectors for electric road vehicles	●		●
TR 60784	IEC	Instrumentation for electric road vehicles	●		
TR 60785	IEC	Rotating machines for electric road vehicles	●		
TR 60786	IEC	Controllers for electric road vehicles	●		
60811 series	IEC	Common test methods for insulating and sheathing materials of electric cables and optical cables - Part 1: Methods for general application - Measurement of thickness and overall dimensions	●		●
60870-2-1	IEC	Telecontrol equipment and systems - Part 2: Operating conditions - Section 1: Power supply and electromagnetic compatibility	●	●	●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
60884	IEC	Plugs and socket-outlets for household and similar purposes	●		●
60947-1	IEC	Low-voltage switchgear and controlgear - Part 1: General rules			●
60947-2	IEC	Low-voltage switchgear and controlgear - Part 2: Circuit-breakers			●
60947-3	IEC	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units			●
60947-6	IEC	Low-voltage switchgear and controlgear - Part 6-1: Multiple function equipment			●
60950 series	IEC	Information technology equipment - Safety	●		●
TR 61000-1	IEC	Electromagnetic compatibility (EMC) - Part 1: General	●	●	●
61000-2	IEC	Electromagnetic compatibility (EMC) - Part 2: Environment	●	●	●
61000-3	IEC	Electromagnetic compatibility (EMC) - Part 3: Limits	●	●	●
61000-4	IEC	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques	●	●	●
61000-5	IEC	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines	●	●	●
61000-6	IEC	Electromagnetic compatibility (EMC) - Part 6: Generic standards	●	●	●
61140	IEC	Protection against electric shock - Common aspects for installation and equipment	●	●	●
61204-3	IEC	Low voltage power supplies, d.c. output - Part 3: Electromagnetic compatibility (EMC)			●
61316	IEC	Industrial cable reels			●
61429	IEC	Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135	●		
61434	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes Guide to the designation of current in alkaline secondary cell and battery standards	●		
TS 61438	IEC	Possible safety and health hazards in the use of alkaline secondary cells and batteries and health hazards in the use of alkaline secondary cells and batteries Guide to equipment manufacturers and users		●	

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
61508	IEC	Functional safety of electrical/electronic/programmable electronic safety-related systems	●		●
61850-7-420 Ed. 1.0	IEC	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes	●		●
TR 61850-90-7 Ed.1.0	IEC	Communication networks and systems for power utility automation - Part 90-7: IEC 61850 object models for power converters in distributed energy resources (DER) systems	●		●
TR 61850-90-8 Ed. 1.0	IEC	IEC 61850 object models for electrical mobility	●		
TR 61850-90-9 Ed. 1.0	IEC	Use of IEC 61850 for electrical storage systems		●	
61851-1 Ed. 2.0	IEC	Electric vehicle conductive charging system - Part 1: General requirements			●
61851-3-1 Ed. 1.0	IEC	Electric Vehicles conductive power supply system - Part 3-1: General Requirements for Light Electric Vehicles (LEV) AC and DC conductive power supply systems			●
61851-3-2 Ed. 1.0	IEC	Electric Vehicles conductive power supply system - Part 3-2: Requirements for Light Electric Vehicles (LEV) DC off-board conductive power supply systems			●
61851-3-3 Ed. 1.0	IEC	Electric Vehicles conductive power supply system - Part 3-3: Requirements for Light Electric Vehicles (LEV) battery swap systems		●	●
61851-3-4 Ed 1.0	IEC	Electric Vehicles conductive power supply system - Part 3-4: Requirements for Light Electric Vehicles (LEV) communication	●		●
61851-21 Ed. 1.0	IEC	Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply			●
61851-21-1 Ed. 1.0	IEC	Electric vehicle conductive charging system - Part 21-1 Electric vehicle onboard charger EMC requirements for conductive connection to an a.c./d.c. supply			●
61851-21-2 Ed. 1.0	IEC	Electric vehicle conductive charging system - Part 21-2: EMC requirements for off-board electric vehicle charging systems			●
61851-22 Ed. 1.0	IEC	Electric vehicle conductive charging system - Part 22: AC electric vehicle charging station			●
61851-23 Ed. 1.0	IEC	Electric vehicle conductive charging system- Part 23: DC electric vehicle charging station			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
61851-24 Ed. 1.0	IEC	Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging			●
61947-1	IEC	Electronic projection - Measurement and documentation of key performance criteria - Part 1: Fixed resolution projectors	●	●	●
61947-2	IEC	Electronic projection - Measurement and documentation of key performance criteria - Part 2: Variable resolution projectors	●	●	●
61959	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes Mechanical tests for sealed portable secondary cells and batteries		●	
61960	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications		●	
61980-1 Ed. 1.0	IEC	Electric vehicle wireless power transfer systems (WPT) - Part 1: General requirements			●
TS 61980-2 Ed. 1.0	IEC	Electric vehicle wireless power transfer (WPT) systems - Part 2 specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems			●
TS 61980-3 Ed. 1.0	IEC	Electric vehicle wireless power transfer (WPT) systems - Part 3 specific requirements for the magnetic field power transfer systems			●
61981	IEC	On board electric power equipment for electric road vehicles		●	
61982	IEC	Secondary batteries (except lithium) for the propulsion of electric road vehicles- Part 1: Test parameters		●	
62040-1	IEC	Uninterruptible power systems (UPS) - Part 1: General and safety requirements for UPS			●
62040-2	IEC	Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements			●
62040-3	IEC	Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements			●
62133	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications		●	

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
TR 62188	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Design and manufacturing recommendations for portable batteries made from sealed secondary cells		●	
62196-1 Ed. 3.0	IEC	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements			●
62196-2 Ed. 1.0	IEC	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories			●
62196-3 Ed. 1.0	IEC	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers			●
62196-4 Ed. 1.0	IEC	Future IEC 62196-4: Plugs, socket-outlets, and vehicle couplers - Conductive charging electric vehicles - Part 4: Dimensional compatibility and interchangeability requirements for a.c., d.c. and a.c./d.c. vehicle couplers for Class II or Class III light e			●
62259	IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes Nickel-cadmium prismatic secondary single cells with partial gas recombination			●
62281	IEC	Safety of primary and secondary lithium cells and batteries during transport		●	
62335	IEC	Circuit breakers - Switched protective earth portable residual current devices for class I and battery powered vehicle applications		●	
TS 62351	IEC	Power systems management and associated information exchange - Data and communications security		●	
62485-3	IEC	Safety requirements for secondary batteries and battery installations. Traction batteries		●	
62576 Ed. 1.0	IEC	Electric Double-Layer Capacitors for Use in Hybrid Electric Vehicles -Test Methods for Electrical Characteristics		●	
62660-1	IEC	Secondary batteries for the propulsion of electric road vehicles - Performance testing for lithium-ion cells and batteries		●	
62660-2	IEC	Secondary batteries for the propulsion of electric road vehicles - Reliability and abuse testing for lithium-ion cells		●	

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
62752	IEC	In cable control and protective device for mode 2 charging of electric road vehicles -- (IC-RCD)	●		
62831 Ed. 1.0	IEC	User identification in Electric Vehicle Service Equipment using a smartcard			●
62840-1 Ed. 1.0	IEC	Electric vehicle battery swap system Part 1: System description and general requirements		●	●
62840-2 Ed. 1.0	IEC	Electric Vehicles Battery Swap System - Part 2: Safety requirements		●	●
80416-1	IEC	Basic principles for graphical symbols for use on equipment - Part 1: Creation of graphical symbols for registration	●		●
80416-3	IEC	Basic principles for graphical symbols for use on equipment Part 3: Guidelines for the application of graphical symbols	●		●
CISPR 11	IEC	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	●		●
CISPR 12	IEC	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers	●		●
CISPR 16 Series	IEC	Specification for radio disturbance and immunity measuring apparatus and methods	●		●
CISPR 22	IEC	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement	●		●
CISPR 25	IEC	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers	●		●
C63.4	Institute of Electrical and Electronics Engineers (IEEE)	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz	●		●
450	IEEE	Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications		●	
484	IEEE	Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications		●	
485	IEEE	Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications		●	
519	IEEE	IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems	●	●	●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
802	IEEE	Standard for Local and Metropolitan Area Networks: Overview and Architecture			●
802.1AB	IEEE	Standard for Local and metropolitan area networks -- Station and Media Access Control Connectivity Discovery			●
802.1AE	IEEE	Standard for Local and Metropolitan Area Networks: Media Access Control (MAC) Security			●
802.1AR	IEEE	Standard for Local and Metropolitan Area Networks - Secure Device Identity			●
802.1AS	IEEE	Standard for Local and Metropolitan Area Networks - Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks			●
802.1AX	IEEE	Standard for Local and Metropolitan Area Networks - Link Aggregation			●
802.1D	IEEE	Standard for Local and Metropolitan Area Networks: Media Access Control (MAC) Bridges			●
802.1Q	IEEE	Standard for Local and Metropolitan Area Networks--- Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks			●
802.1X	IEEE	Standard for Local and metropolitan area networks - Port-Based Network Access Control			●
802.3.1	IEEE	Standard for Management Information Base (MIB) Definitions for Ethernet			●
802.3as	IEEE	Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Phy			●
802.11	IEEE	Standard for Information Technology - Telecommunications and information exchange between systems - Local and Metropolitan networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications			●
802.11ac	IEEE	IEEE Standard for Information technology-- Telecommunications and information exchange between systems Local and metropolitan area networks-- Specific requirements--Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications--			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
802.11n	IEEE	IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput	●		●
802.11p	IEEE	IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments			●
802.15.2	IEEE	Recommended Practice for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks specific requirements - Part 15.2: Coexistence of Wireless Personal Area Networks with Other Wireless Devi			●
802.15.5	IEEE	Recommended Practice for mesh topology capability in Wireless Personal Area Networks (WPANs)			●
802.15.7	IEEE	Standard for Short-Range Wireless Optical Communication Using Visible Light			●
802.16	IEEE	Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Broadband Wireless Access Systems			●
802.16.2	IEEE	Recommended Practice for Local and Metropolitan Area Networks - Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems			●
802.16.C04	IEEE	Conformance to IEEE 802.16 - Part 4: Protocol Implementation Conformance Statement (PICS) Proforma for Frequencies below 11 GHz.			●
802.17	IEEE	Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 17: Resilient Packet Ring (RPR) Access Method and Physical Layer Specifications			●
802.2	IEEE	Standard for Local and Metropolitan Area Networks - Standard Air Interface for Mobile Broadband Wireless Access Systems Supporting Vehicular Mobility - Physical and Media Access Control Layer Specification			●
802.20.2	IEEE	Standard for Conformance to IEEE P802.20 Systems - Protocol Implementation Conformance Statement(PICS) Proforma			●
802.20.3	IEEE	Standard for Minimum Performance Characteristics of IEEE P802.20 Terminals and Base Stations/Access Nodes			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
802.21	IEEE	Standard for Media Independent Handover Services			●
937	IEEE	Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems		●	
1106	IEEE	Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications		●	
1375	IEEE	Guide for the Protection of Stationary Battery Systems		●	
1547 Series*	IEEE	Standard for Interconnecting Distributed Resources with Electric Power Systems	●		●
1584	IEEE	Guide for Performing Arc Flash Hazard Calculations	●		
P1609.0	IEEE	Guide for Wireless Access in Vehicular Environments (WAVE) - Architecture			●
P1609.2	IEEE	IEEE Draft Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages			●
1609.3	IEEE	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services			●
1609.4	IEEE	IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation			●
P1609.5	IEEE	Standard for Wireless Access in Vehicular Environments (WAVE) - Communication Manager			●
1609.11	IEEE	IEEE Standard for Wireless Access in Vehicular Environments (WAVE)-- Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)			●
P1609.12	IEEE	IEEE Draft Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations			●
1657	IEEE	Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries			●
1815	IEEE	Standard for Electric Power Systems Communications - Distributed Network Protocol (DNP3)			●
1901-2010	IEEE	Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications			●
P1901.2	IEEE	IEEE Standard for Low Frequency (less than 500kHz) Narrowband Power Line Communications for Smart Grid Applications			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
2030	IEEE	IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads			●
P2030.1	IEEE	Guide for Electric-Sourced Transportation Infrastructure	●		
P2030.1.1	IEEE	Standard Technical Specifications of a DC Quick Charger for Use with Electric Vehicles			●
P2030.2	IEEE	Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure		●	
P2030.3	IEEE	Standard for Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications		●	
2030.5	IEEE	IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard	●	●	●
C2	IEEE (ASC C2)	National Electrical Safety Code	●	●	●
ANSI/ISA 61010-1	International Society of Automation (ISA)	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements	●	●	●
6469-1	International Organization for Standardization (ISO)	Electric road vehicles - Safety specifications - Part 1: On-board rechargeable energy storage system (RESS)		●	
6469-2	ISO	Electric Road Vehicles—Safety specifications—Part 2: Functional safety means and protection against failures.	●	●	●
6469-3	ISO	Electric road vehicles—Safety Specifications—Part 3: Protection of users against electrical hazards.	●	●	●
6469-4.2	ISO	Electrically propelled road vehicles -- Safety specifications -- Part 4: Post crash electrical safety requirements	●	●	●
7637-1	ISO	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 1: Definitions and general considerations	●		
7637-2	ISO	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 2: Electrical transient conduction along supply lines only			●
7637-3	ISO	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines			●
8713	ISO	Electric road vehicles -- Vocabulary			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
8714	ISO	Electric road vehicles -- Reference energy consumption and range -- Test procedures for passenger cars and light commercial vehicles			●
8715	ISO	Electric road vehicles – Road operating characteristics	●	●	
8820-1	ISO	Road vehicles -- Fuse-links -- Part 1: Definitions and general test requirements	●		
8820-2	ISO	Road vehicles -- Fuse-links -- Part 2: User's guide	●		
8820-3	ISO	Road vehicles -- Fuse-links -- Part 3: Fuse-links with tabs (blade type) Type C (medium), Type E (high current) and Type F (miniature)	●		
8820-4	ISO	Road vehicles -- Fuse-links -- Part 4: Fuse-links with female contacts (type A) and bolt-in contacts (type B) and their test fixtures	●		
8820-5	ISO	Road vehicles -- Fuse-links -- Part 5: Fuse-links with axial terminals (Strip fuse-links) Types SF 30 and SF 51 and test fixtures	●		
8820-6	ISO	Road vehicles -- Fuse-links -- Part 6: Single-bolt fuse-links	●		
8820-7	ISO	Road vehicles -- Fuse-links -- Part 7: Fuse-links with tabs (Type G) with rated voltage of 450 V	●		
10605	ISO	Road vehicles -- Test methods for electrical disturbances from electrostatic discharge	●	●	
11451-1	ISO	Road vehicles -- Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 1: General principles and terminology	●		
11451-2	ISO	Road vehicles -- Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 2: Off-vehicle radiation sources	●		
11451-3	ISO	Road vehicles -- Electrical disturbances by narrowband radiated electromagnetic energy -- Vehicle test methods -- Part 3: On-board transmitter simulation	●		
11451-4	ISO	Road vehicles -- Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 4: Bulk current injection (BCI)	●		
11452 series	ISO	Road vehicles -- Component test methods for electrical disturbances from narrowband radiated electromagnetic energy	●		
TR 11954	ISO	Hybrid-electric road vehicles -- Guidelines for charge balance measurement	●		

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
12405-1	ISO	Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 1: High power applications		●	
12405-2	ISO	Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 2: High energy application		●	
12405-3	ISO	Electrically propelled road vehicles - Test specification for Lithium-ion traction battery packs and systems -- Part 3: Safety performance requirements		●	
13064-1	ISO	Battery-electric mopeds and motorcycles -- Performance -- Part 1: Reference energy consumption and range		●	
13064-2	ISO	Battery-electric mopeds and motorcycles -- Performance -- Part 2: Road operating characteristics		●	
14001	ISO	Environmental management systems - Requirements with guidance for use			
15118-1	ISO	Road vehicles -- Vehicle to grid communication interface -- Part 1: General information and use-case definition	●		
15118-2	ISO	Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 2: Network and application protocol requirements	●		●
15118-3	ISO	Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 3: Physical and data link layer requirements	●		●
15118-4	ISO	Road vehicles -- Vehicle to grid communication interface -- Part 4: Network and application protocol conformance test	●		●
15118-5	ISO	Road vehicles -- Vehicle to grid communication interface -- Part 5: Physical layer and data link layer conformance test	●		●
15118-6	ISO	Road vehicles -- Vehicle to grid communication interface -- Part 6: General information and use-case definition for wireless communication	●		●
15118-7	ISO	Road vehicles -- Vehicle to grid communication interface -- Part 7: Network and application protocol requirements for wireless communication	●		
15118-8	ISO	Road vehicles -- Vehicle to grid communication interface -- Part 8: Physical layer and data link layer requirements for wireless communication	●		●
16254	ISO	Measurement of minimum noise emitted by road vehicles	●		
16750-1	ISO	Environmental conditions and testing for electrical and electronic equipment – Part 1: General	●		

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
16750-2	ISO	Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 2: Electrical loads	●		
16750-3	ISO	Environmental conditions and testing for electrical and electronic equipment – Part 3: Mechanical loads	●		
16750-4	ISO	Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 4: Climatic loads	●		
16750-5	ISO	ISO 16750-5 Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 5: Chemical loads	●		
17409.2	ISO	Electrically propelled road vehicles - Connection to an external electric power supply - Safety requirements			●
18300	ISO	Electrically propelled road vehicles -- Specifications for lithium-ion cell and battery coupled with other types of battery and capacitor			●
PAS 19363	ISO	Electrically propelled road vehicles -- Magnetic field wireless power transfer -- Safety and interoperability requirements			●
19092	ISO	Financial services -- Biometrics -- Security framework	●	●	●
20653	ISO	Road Vehicles – Degrees of Protection (IP-Code) – Protection of electrical equipment against foreign objects, water and access.	●		
23273-1	ISO	Hybrid-electric road vehicles — Exhaust emissions and fuel consumption measurements — Part 2:Externally chargeable vehicles	●		
23274-2	ISO	Hybrid-electric road vehicles -- Exhaust emissions and fuel consumption measurements -- Part 2: Externally chargeable vehicles	●		
26262	ISO	Road vehicles -- Functional safety	●		
80416-2	ISO	Basic principles for graphical symbols for use on equipment - Part 2: Form and use of arrows			
80416-4	ISO	Basic principles for graphical symbols for use on equipment -- Part 4: Guidelines for the adaptation of graphical symbols for use on screens and displays (icons)			
TR 11581-1	ISO/IEC	Information technology - User interface icons - Part 1: Introduction to and overview of icon standards	●		●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
12139-1	ISO/IEC	Information technology -- Telecommunications and information exchange between systems -- Powerline communication (PLC) -- High speed PLC medium access control (MAC) and physical layer (PHY) -- Part 1: General requirements	●		●
PAS 16898	ISO/IEC	Electrically propelled road vehicles -- Dimensions and designation of secondary lithium-ion cells		●	
27001	ISO/IEC	Information technology -- Security techniques -- Information security management systems -- Requirements	●		●
Guide 74	ISO/IEC	Graphical symbols - Technical guidelines for the consideration of consumers' needs	●		●
ESPI 1.0	North American Energy Standards Board (NAESB)	Energy Services Provider Interface			●
413	National Electrical Contractors Association (NECA)	Standard for Installing and Maintaining Electric Vehicle Supply Equipment (EVSE)			●
250	National Electrical Manufacturers Association (NEMA)	Enclosures for Electrical Equipment	●	●	●
EVSE 1.1	NEMA	EV Charging Network Interoperability Standards Framework			●
EVSE 1.2	NEMA	A Contactless RFID Credential for Authentication (UR Interface)	●		●
EVSE 1.3	NEMA	QR Code and NFC Tags for EV Charging Station Identification (UT Interface)	●		●
EVSE 1.4	NEMA	Data Model and Protocols for Distributing Station Directories (ID Interface)			●
EVSE 1.5	NEMA	Authentication and Authorization Across EV Charging Networks (IA Interface)	●		●
EVSE 1.6	NEMA	Charging Session Status and Accounting Data Exchange (IC Interface)			●
C12.11	NEMA (ASC/C12)	Instrument Transformers For Revenue Metering, 10 Kv Bil Through 350 KV (0.6 KV NSV Through 69 KV NSV)			●
ANSI/NEMA Z535.4	NEMA (ASC Z535)	Product safety signs and labels	●		●
ANSI/NETA MTS	International Electrical Testing Association (NETA)	Standard for Maintenance Testing Specifications for Electrical Distribution Equipment and Systems			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
1	National Fire Protection Association (NFPA)	Fire Code (chapter 52)	●	●	●
13	NFPA	Standard for the Installation of Sprinkler Systems			●
30A	NFPA	Code for Motor Fuel Dispensing Facilities and Repair Garages	●		●
70®	NFPA	National Electrical Code	●	●	●
70B	NFPA	Recommended Practice for Electrical Equipment Maintenance	●	●	●
70E	NFPA	Standard for Electrical Safety in the Workplace	●	●	●
88A	NFPA	Standard for Parking Structures			●
730	NFPA	Guide for Premises Security			●
900	NFPA	Building Energy Code			
1001	NFPA	Standard for Fire Fighter Professional Qualifications			
1006	NFPA	Standard for Technical Rescuer Professional Qualifications			
1026	NFPA	Standard for Incident Management Personnel Professional Qualifications			
1091	NFPA	Traffic Control Management Professional Qualifications			
1521	NFPA	Standard for Fire Department Safety Officer			
1561	NFPA	Standard on Emergency Services Incident Management System			●
1851	NFPA	Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting			●
1855	NFPA	Standard for Selection, Care and Maintenance of Protective Ensembles for Technical Rescue Incidents			●
1936	NFPA	Standard on Powered Rescue Tools			●
1951	NFPA	Standard on Protective Ensembles for Technical Rescue Incidents			●
1971	NFPA	Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting			●
1999	NFPA	Standard on Protective Clothing for Emergency Medical Operations			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
5000	NFPA	Building Construction and Safety Code			●
49 CFR Part 575	National Highway Traffic Safety Administration (NHTSA)	Fuel economy and environment label			●
FMVSS 101	NHTSA	Controls and Displays	●		
FMVSS 305	NHTSA	Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection	●		
	NHTSA	Vehicle Sound for Pedestrians	●		
	NHTSA	Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices: Notice Of Federal Guidelines	●		
	NHTSA	Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices: Notice Of Federal Guidelines; Clarifications	●		
Handbook 44	NIST	Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices	●		
Handbook 130	National Institute of Science and Technology (NIST)	Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality	●		
NISTIR 7628	NIST	Guidelines for Smart Grid Cyber Security, Volume 2: Privacy and the Smart Grid			●
OpenADR v2.0	OpenADR Alliance	Open Automated Demand Response Communications Specification Version 2.0			●
OpenADE 1.0	OpenSG	Business and User Requirements			●
1910.305	Occupational Safety and Health Administration (OSHA)	Storage Batteries		●	
1926.441	OSHA	Batteries and battery charging General requirements		●	
29CFR 1910	OSHA	Subpart S Electrical			●
29CFR 1926	OSHA	Subpart K Electrical			●
PCI-DSS	PCI Security Standards Council (PCI SSC)	PCI Data Security Standard	●		●
PRIME	PRIME Alliance	Draft Standard for Powerline Intelligent Metering Evolution, Version 1.3.6			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
2000-05-0356	Society of Automotive Engineers (SAE)	Design and Safety Considerations for Automated Battery Exchange Electric Vehicles		●	
J240	SAE	Life Test for Automotive Storage Batteries		●	
J537	SAE	Storage Batteries		●	
J551-1	SAE	Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m) and Machines (16.6 Hz to 18 GHz	●	●	●
J551-5	SAE	Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz to 30 MHz	●		
J1113 series	SAE	EMC measurements	●	●	●
J1495	SAE	Test Procedure for Battery Flame Retardant Venting Systems		●	
J1634	SAE	Battery Electric Vehicle Energy Consumption and Range Test Procedure	●		
J1654	SAE	High Voltage Primary Cable	●		
J1673	SAE	High Voltage Wiring	●		
J1711	SAE	Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles	●		
J1715	SAE	Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology	●		
J1715/2 V1	SAE	Battery Terminology		●	
J1718	SAE	Measurement of Hydrogen Gas Emission from Battery-Powered Passenger Cars and Light Trucks During Battery Charging		●	
J1739	SAE	Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Design FMEA)	●		
J1742	SAE	Connections for High Voltage On-Board Road Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements	●		
J1766	SAE	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing	●		
J1772™	SAE	SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
J1773	SAE	Electric Vehicle Inductively Coupled Charging			●
J1797	SAE	Recommended Practice for Packaging of Electric Vehicle Battery		●	
J1798	SAE	Recommended Practice for Performance Rating of Electric Vehicle	●		
J1850	SAE	Class B Data Communications Network Interface	●		●
J2183	SAE	60 V and 600 V Single-Core Cables	●	●	●
J2185	SAE	Life Test for Heavy-Duty Storage Batteries		●	
J2288	SAE	Life Cycle Testing of Electric Vehicle Battery Modules		●	
J2289	SAE	Vehicle Sound Measurement at Low Speeds	●		
J2293/1	SAE	Energy Transfer System for Electric Vehicles--Part 1: Functional Requirements and System Architectures		●	
J2293/2	SAE	Energy Transfer System for Electric Vehicles - Part 2: Communication Requirements and Network Architecture	●		●
J2344	SAE	Guidelines for Electric Vehicle Safety	●		
J2380	SAE	Vibration Testing of Electric Vehicle Batteries	●		
J2464	SAE	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing		●	
J2497	SAE	Power Line Carrier Communications for Commercial Vehicles		●	
J2501	SAE	Round, Screened and Unscreened, 60 V and 600 V Multi-Core Sheathed Cables	●	●	●
J2711	SAE	Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle		●	
J2735	SAE	Dedicated Short Range Communications (DSRC) Message Set Dictionary	●		●
J2758	SAE	Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle		●	
J2801	SAE	Comprehensive Life Test for 12 V Automotive Storage Batteries		●	
J2836/1™ V1	SAE	Use Cases for Communication Between Plug-in Vehicles and the Utility Grid	●		●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
J2836/2™ V1	SAE	Use Cases for Communication between Plug-in Vehicles and the Supply Equipment (EVSE)	●		●
J2836/3™ V1	SAE	Use Cases for Plug-in Vehicle Communication as a Distributed Energy Resource	●	●	
J2836/4™ V1	SAE	Use Cases for Diagnostic Communication for Plug-in Vehicles	●		
J2836/5™ V1	SAE	Use Cases for Communication between Plug-in Vehicles and their customers	●		
J2836/6™ V1	SAE	Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles	●		●
J2841	SAE	Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using Travel Survey Data	●		
J2847/1 V4	SAE	Communication for Smart Charging of Plug-in Electric Vehicles using Smart Energy Profile 2.0	●		
J2847/2 V2	SAE	Communication between Plug-in Vehicles and Off-Board DC Chargers	●		●
J2847/3 V1	SAE	Communication for Plug-in Vehicles as a Distributed Energy Resource	●		
J2847/4 V1	SAE	Diagnostic Communication for Plug-in Vehicles	●		
J2847/5 V1	SAE	Communication between Plug-in Vehicles and Their Customers	●		●
J2847/6 V1	SAE	Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid	●		●
J2889-1	SAE	Measurement of Minimum Noise Emitted by Road Vehicles	●		
J2894/1	SAE	Power Quality Requirements for Plug In Electric Vehicle Chargers			●
J2894/2	SAE	Power Quality Requirements for Plug In Vehicle Chargers - Part 2: Test Methods			●
J2907	SAE	Hybrid Motor Ratings	●		
J2908	SAE	Hybrid Electric Powertrain Power Test Methods and Definitions	●	●	
J2910	SAE	Design and Test of Hybrid Electric Trucks and Buses for Electrical Safety	●	●	
J2929	SAE	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells	●	●	

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
J2931/1 V2	SAE	Digital Communications for Plug-in Electric Vehicles	●		
J2931/2	SAE	In-band Signaling Communication for Plug-in Electric Vehicles	●		
J2931/3	SAE	PLC Communication for Plug-in Electric Vehicles	●		●
J2931/4 V3	SAE	Broadband PLC Communication for Plug-in Electric Vehicles	●		●
J2931/5 V1	SAE	Telematics Smart Grid Communications between Customers, Plug-In Electric Vehicles (PEV), Energy Service Providers (ESP) and Home Area Networks (HAN)	●		●
J2931/6 V1	SAE	Digital Communication for Wireless Charging Plug-in Electric Vehicles			●
J2931/7 V1	SAE	Security for Plug-in Electric Vehicle Communications			●
J2936	SAE	Vehicle Battery Labeling Guidelines		●	
J2946	SAE	Battery Electronic Fuel Gauging Recommended Practices		●	
J2950	SAE	Recommended Practices (RP) for Shipping Transport and Handling of Automotive-Type Battery System - Lithium Ion		●	
J2953/1 V1	SAE	Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)		●	
J2953/2 V1	SAE	Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)			●
J2954	SAE	Wireless Charging of Electric and Plug-in Hybrid Vehicles			●
J2974	SAE	Technical Information Report on Automotive Battery Recycling			●
J2984 V2	SAE	Identification of Transportation Battery Systems for Recycling Recommended Practice		●	
J2990	SAE	Hybrid and EV First and Second Responder Recommended Practice	●		
J3009	SAE	Stranded Energy -- Reporting and Extraction from Vehicle Electrochemical Storage Systems		●	
J3040	SAE	EV Crash Testing Safety Guidelines	●		
J3068	SAE	Electric Vehicle Power Transfer System Using a Three-phase Capable Coupler	●		
J3072	SAE	Interconnection Requirements for Onboard, Utility-Interactive, Inverter Systems			●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
J3073	SAE	Battery Thermal Management			●
2	SAE/USCAR	Performance Specification for Automotive Electrical Connector Systems	●		
37	SAE/USCAR	High Voltage Connector Performance Supplement to SAE/ USCAR-2	●		●
50E	Underwriters Laboratories, Inc. (UL)	Enclosures for Electrical Equipment, Environmental Considerations			
62	UL	Flexible Cords and Cables	●	●	●
355	UL	Cord Reels	●	●	●
458A	UL	Safety of Power Converters/Inverters for Electric Land Vehicles	●		
991	UL	Tests for Safety-Related Controls Employing Solid-State Devices	●		
1004-1	UL	Safety of On-board Electric Vehicle Equipment Traction Motors	●		
1642	UL	Safety of Lithium-Ion Batteries – Testing		●	
1703	UL	Standard for Flat-Plate Photovoltaic Modules and Panels		●	
1741	UL	Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy	●		
1974	UL	Repurposed and Refurbished Batteries for Use in Stationary and Other Applications		●	
1998	UL	Standards for software in programmable components		●	
2202	UL	Safety of Electric Vehicle (EV) Charging System Equipment	●		●
NMX-J-668/1-ANCE / CSA C22.2 No. 281.1 / UL 2231-1	UL	Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements	●		●
NMX-J-668/2-ANCE / CSA C22.2 No. 281.2 / UL 2231-2	UL	Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems	●		●
NMX-J-678-ANCE/ CSA C22.2 No. 282-13/UL 2251	UL	Standard for Plugs, Receptacles, and Couplers for Electric Vehicles	●		●

Standard	Developer	Title	Vehicle	Energy Storage	Charging infrastructure
2271	UL	Batteries and Battery Packs for Use in Light Electric Vehicles		●	
2580	UL	Batteries for Use in Electric Vehicles		●	
NMX-J-677-ANCE/ CSA C22.2 NO. 280-13/UL 2594	UL	Standard for Electric Vehicle Supply Equipment		●	
2733	UL	Surface Vehicle and On-Board Cable			●
2734	UL	Safety of Connectors for Use with On-Board Electrical Vehicle (EV) Charging Systems	●		●
2735	UL	Electric Utility (Smart) Meters			●
2748	UL	Electric Vehicle Power Supplies			●
2750	UL	Standard for Safety for Electric Vehicle Wireless Charging Equipment	●		●
9741	UL	Outline of Investigation for Bidirectional Electric Vehicle (EV) Charging System Equipment			●
3090	United Nations Regulation (UN)	Lithium Metal Batteries		●	
3091	UN	Lithium Metal Batteries Contained In Equipment		●	
3480	UN	Lithium Ion Cells and Batteries		●	
3481	UN	Lithium Ion Cells and Batteries Installed in or Packed with Equipment		●	
UN/SCETDG/38/ INF.22	UN	Transport of waste lithium batteries and damage/defective lithium batteries		●	
38	United States Department of Transportation (US DOT)	Lithium batteries during shipping		●	
	WP.29 EVS-IWG	Proposal to Develop a Global Technical Regulation Concerning Electrical Vehicle Safety	●		
	World Forum for Harmonization of Vehicle Regulation (WP.29 Working Party on Noise (GRB))	Proposal to Develop a Global Technical Regulation Concerning Quiet Vehicles	●		
	WP.29 Working Party on Pollution and Energy (GRPE)	Proposal to Develop a Global Technical Regulation Concerning Pollution and Energy Efficiency	●		

7.2.2. Germany

Table 77: Standards adopted in Germany

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
EN 50160	UK 767.1	Voltage characteristics of electricity supplied by public distribution networks			●
EN 55012 (05»: 12)	K 767	Vehicles. motorboats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers			●
EN 55025 (0591: 25)	K 767	Vehicles. motorboats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers			●
IEC 6036‘5-53 Edition 3.] DIN VDE 0100-530	K 221	Vehicles. motorboats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers			●
IEC 603645-54 Edition 3 DIN VDE 0300-540	UK 221 .1	Low voltage installations- Part 554: Selection and erection of electrical equipment- Earthing arrangements protective conductors and protective bonding conductors			●
IEC 603647-722	AK221.1.11	Low voltage electrical installations- Part 7-722: Requirements for special installations or locations- Supply of electric vehicles			●
ND 60364-1722/ DIN VDE 0100-722	AK 221.1..11	Low voltage electrical installations- Part 7-722: Requirements for special installations or locations - Supply of electric vehicle			●
EC 60364-441 Edition 5 DINVDE 0100-410	UK 221.1	Low-voltage electrical installations- Part 441: Protection for safety - Protection against electric shock			●
EQTS 60479-1 Edition 4 (VDE 0140-479-1)	UK 221.1	Effects of current on human beings and live-stock- Part 1: General aspects	●	●	●
IEC 60529 Amendment 2 Edition 2	K 212	Degrees of protection provided by enclosures(IP code)	●		●
IEC 61000-6-2 Edition 3	UK 767.3	Electromagnetic compatibility (EMC) Part 6-2: Generic standards- Immunity standard for industrial environments			●
IEC 61000-6-3 Edition 2	K 767	Electromagnetic compatibility (EMC) Part 6-3: Generic standards– Emission standard for residential. commercial and light-industrial environments			●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC 61140 Edition 4 VDE 0140-1	UK 221.1	Protection against electric shock - Common aspects for installations and equipment	●	●	
IEQTS 61439−7	AK 431.1	Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares. electric vehicles charging stations			●
IIEC 61508 Part 1-7 Edition 2	GK 914	Functional safety of electrical} electronic} programmable electronic safety-related systems	●	●	●
IEC 61850-7420 Edition 2	K 952	Communication networks and systems for power utility automation- Part 7420: Basic communication structure - Distributed energy resources logical nodes			●
IEC 61851-1 Edition 3	GAK 353.0.4	Electric vehicle conductive charging system -Part 1: General requirements	●		●
IEC 61851 -21 Edition 2	AK 353.0.6	Electric vehicle conductive charging system -Part 21: Electric vehicle requirements for conductive connection to an a.c.3d.c. supply	●		●
IEC 61851 -21-1	AK 353.0.6	Electric vehicle conductive charging system -Part 21-1: Electric vehicle on board charger EMC requirements for conductive connection to ac/dc supply	●		●
IEC 61851 -21-2	AK 353.06	Electric vehicle conductive charging system -Part 21-2: EMC requirements for OFF board electric vehicle charging a; stems	●		●
IEC 61851-22	K 353	Electric vehicle conductive charging system Part 22: AC electric vehicle charging station	●		●
IEC 61851-23	GAK 353.0.2	Electric vehicle conductive charging system -Part 23: DC electric vehicle charging station	●		●
IEC 61851 -24 Edition 2	GAK 353.0.2	Electric vehicle conductive charging system − Part 24: Digital communication between a dc EV charging station and an electric vehicle for control of do charging	●		●
IEQTS 61351-3-1	GAK 353.0.9	Electric Vehicles conductive power supply C system- Part 3-1: General Requirements for Light Electric Vehicles [LEVI AC and DC conductive power supply systems	●		●
IECJTS 61851-3-2	GAK 353.0.9	Electric Vehicles conductive power supply CD system- Part 3-2: Requirements for Light Electric Vehicles ILEVI DC offboard conductive power supply systems	●		●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC/TS 61851-3-1	GAK 353.0.9	Electric Vehicles conductive power supply A NW system- Part 3-1: Requirements for Light Electric Vehicles ILEVI battery swap systems	●		●
ECJTS 61851-34	GAK 353.03	Electric Vehicles conductive power supply system- Part 34: requirements for Light Electric Vehicles I'LEVI communication	●		●
IEC 619801	GAK 353.0.1	Electric vehicle wireless power transfer systems (WPT)- Part I general requirements			●
IEQTS 61900-2	GAK 353.0.1	Electric vehicle wireless power transfer (WPT) systems- Part 2: Specific requirements for communication between electric road vehicle(EV) and infrastructure with respect to wireless power transfer (WPT)l systems			●
IECJYS 61990-3	GAK 353.0.1	Electric vehicle wireless power transfer (WPT) systems- Part 3: Specific requirements for the magnetic field power transfer systems			●
IEC 621961 Edition 3	OAK 54.2.4.1	Plugs. Socket outlets, vehicle connectors and vehicles in lets - Conductive charging of electric vehicles - Part 1 general requirements		●	●
IEC 621962 Edition 2	OAK 54.2.4.1	Plugs. Socket outlets. vehicle connectors and CD vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for ac pin and contact-tube accessories		●	●
IEC 62196-3	GAK 542.4]	Plugs. Socket outlets. vehicle connectors and IS vehicle inlets- Conductive charging of electric vehicles - Part 3: Dimensional compatibility and Interchangeability requirements for d.c and a.c.,/d.c. pin and contact-tube vehicle couplers		●	●
IEC/TS 62196-4	GAK 542.4.1	Plugs. Socket outlets. and vehicle couplers - Conductive charging of electric vehicles- Part 4: Dimensional compatibility and interchangeability requirements for ac. d.c. and a.c/ d.c. vehicle couplers for Class II or Class III light electric vehicles ILEVI		●	●
IEC 62351 Parts 1-8	K 952	Power systems management and associated information exchange- Data and communications security			●
IEC 62351 Part-0	K 952	Power systems management and associated information exchange- Data and communications security - Part 10: Security architecture guidelines			●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC 61140 Edition 4 VDE 0140-1	UK 221.1	Protection against electric shock - Common aspects for installations and equipment	●	●	
IEQTS 61439–7	AK 431.1	Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares. electric vehicles charging stations			●
IIEC 61508 Part 1-7 Edition 2	GK 914	Functional safety of electrical} electronic} programmable electronic safety-related systems	●	●	●
IEC 61850-7420 Edition 2	K 952	Communication networks and systems for power utility automation- Part 7420: Basic communication structure - Distributed energy resources logical nodes			●
IEC 61851-1 Edition 3	GAK 353.0.4	Electric vehicle conductive charging system -Part 1: General requirements	●		●
IEC 61851 -21 Edition 2	AK 353.0.6	Electric vehicle conductive charging system -Part 21: Electric vehicle requirements for conductive connection to an a.c.3d.c. supply	●		●
IEC 61851 -21-1	AK 353.0.6	Electric vehicle conductive charging system -Part 21-1: Electric vehicle on board charger EMC requirements for conductive connection to ac/dc supply	●		●
IEC 61851 -21-2	AK 353.06	Electric vehicle conductive charging system -Part 21-2: EMC requirements for OFF board electric vehicle charging a; stems	●		●
IEC 61851-22	K 353	Electric vehicle conductive charging system Part 22: AC electric vehicle charging station	●		●
IEC 61851-23	GAK 353.0.2	Electric vehicle conductive charging system -Part 23: DC electric vehicle charging station	●		●
IEC 61851 -24 Edition 2	GAK 353.0.2	Electric vehicle conductive charging system – Part 24: Digital communication between a dc EV charging station and an electric vehicle for control of do charging	●		●
IEQTS 61351-3-1	GAK 353.0.9	Electric Vehicles conductive power supply C system- Part 3-1: General Requirements for Light Electric Vehicles [LEVI AC and DC conductive power supply systems	●		●
IECJTS 61851-3-2	GAK 353.0.9	Electric Vehicles conductive power supply CD system- Part 3-2: Requirements for Light Electric Vehicles ILEVI DC offboard conductive power supply systems	●		●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC/TS 61851-3-1	GAK 353.0.9	Electric Vehicles conductive power supply A NW system- Part 3-1: Requirements for Light Electric Vehicles ILEVI battery swap systems	●		●
ECJTS 61851-34	GAK 353.03	Electric Vehicles conductive power supply system- Part 34: requirements for Light Electric Vehicles I'LEVI communication	●		●
IEC 619801	GAK 353.0.1	Electric vehicle wireless power transfer systems (WPT)- Part I general requirements			●
IEQTS 61900-2	GAK 353.0.1	Electric vehicle wireless power transfer (WPT) systems- Part 2: Specific requirements for communication between electric road vehicle(EV) and infrastructure with respect to wireless power transfer (WPT)I systems			●
IECJYS 61990-3	GAK 353.0.1	Electric vehicle wireless power transfer (WPT) systems- Part 3: Specific requirements for the magnetic field power transfer systems			●
IEC 621961 Edition 3	OAK 54.2.4.1	Plugs. Socket outlets, vehicle connectors and vehicles in lets - Conductive charging of electric vehicles - Part 1 general requirements	●		●
IEC 621962 Edition 2	OAK 54.2.4.1	Plugs. Socket outlets. vehicle connectors and CD vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for ac pin and contact-tube accessories	●		●
IEC 62196-3	GAK 542.4]	Plugs. Socket outlets. vehicle connectors and IS vehicle inlets- Conductive charging of electric vehicles - Part 3: Dimensional compatibility and Interchangeability requirements for d.c and a.c.,/d.c. pin and contact-tube vehicle couplers	●		●
IEC/TS 62196-4	GAK 542.4.1	Plugs. Socket outlets. and vehicle couplers - Conductive charging of electric vehicles- Part 4: Dimensional compatibility and interchangeability requirements for ac. d.c. and a.c/ d.c. vehicle couplers for Class II or Class III light electric vehicles ILEVI	●		●
IEC 62351 Parts 1-8	K 952	Power systems management and associated information exchange- Data and communications security			●
IEC 62351 Part-0	K 952	Power systems management and associated information exchange- Data and communications security - Part 10: Security architecture guidelines			●
IEC TR 6240-34	AK 931.1	Industrial communication networks- Network and system security - Part 3-1: Security technologies for industrial automation and control systems			●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC 62576 Edition 2	K 331	electric double-layer capacitors for use in hybrid A MW electric vehicles- Test methods for electrical characteristics			
IEC 626601	K 371	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1 : Performance nesting		●	
IEC 62660-2	K 371	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing		●	
IEC 626603	K 371	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements of cells and modules		●	
IEC 62752	AK 541.36	In cable Control and Protection Device for mode 2 charging of electric road vehicles (IC-CPD)			●
IEC 6283'	AK 353.0.8	User identification in Electric vehicle Service Equipment using a smartcard			●
IEC 62840-1	AK 353.0.7	Electric vehicle battery swap system – Part 1: System description and general Requirements			●
IEC 62840-2	AK 353.0.7	Electric vehicle battery swap system –Part 2: Safety requirements			●
IEC 62893	UK 411.2.8	Charging cables for electric vehicles			●
23E/853/NP	AK 541.3.7	Residual Direct Current Monitoring Device to be used for Mode 3 charging of Electric Vehicle (RDC-MD)			●
VDE 0105-100	K 224	Operation of electrical installations – Part 100: General requirements			●
ISO 6469-1 Edition 2	052-01-21 AA	Electric propelled road vehicles – Safety specifications– Part 1: On-board rechargeable energy storage system (RESS)		●	
ISO 6469-2 Edition 2	052-01-21 AA	Electric propelled road vehicles – Safety specifications– Part 2: Vehicle operational safety means and protection against failures	●		
ISO 6469-3 Edition 2	052-01-21 AA	Electric propelled road vehicles – Safety specifications – Part 3: Protection of persons against electric shock	●		
ISO 6469-4	052-01-21 AA	Electrically propelled road vehicles – Safety specifications – Part 4: Post crash electrical safety	●		
ISO 6722-1 Edition 4	052-01-03-04 AK	Road vehicles – 60 V and 600 V single-core cables – Part 1: Dimensions, test methods and requirements for copper conductor cables (Ed. 2.0)	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC/TS 61851-3-1	GAK 353.0.9	Electric Vehicles conductive power supply A NW system- Part 3-1: Requirements for Light Electric Vehicles ILEVI battery swap systems	●		●
ECJTS 61851-34	GAK 353.03	Electric Vehicles conductive power supply system- Part 34: requirements for Light Electric Vehicles I'LEVI communication	●		●
IEC 619801	GAK 353.0.1	Electric vehicle wireless power transfer systems (WPT)- Part I general requirements			●
IEQTS 61900-2	GAK 353.0.1	Electric vehicle wireless power transfer (WPT) systems- Part 2: Specific requirements for communication between electric road vehicle(EV) and infrastructure with respect to wireless power transfer (WPT)I systems			●
IECJYS 61990-3	GAK 353.0.1	Electric vehicle wireless power transfer (WPT) systems- Part 3: Specific requirements for the magnetic field power transfer systems			●
IEC 621961 Edition 3	OAK 54.2.4.1	Plugs. Socket outlets, vehicle connectors and vehicles in lets - Conductive charging of electric vehicles - Part 1 general requirements	●		●
IEC 621962 Edition 2	OAK 54.2.4.1	Plugs. Socket outlets. vehicle connectors and CD vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for ac pin and contact-tube accessories	●		●
IEC 62196-3	GAK 542.4]	Plugs. Socket outlets. vehicle connectors and IS vehicle inlets- Conductive charging of electric vehicles - Part 3: Dimensional compatibility and Interchangeability requirements for d.c and a.c.,/d.c. pin and contact-tube vehicle couplers	●		●
IEC/TS 62196-4	GAK 542.4.1	Plugs. Socket outlets. and vehicle couplers - Conductive charging of electric vehicles- Part 4: Dimensional compatibility and interchangeability requirements for ac. d.c. and a.c/ d.c. vehicle couplers for Class II or Class III light electric vehicles ILEVI	●		●
IEC 62351 Parts 1-8	K 952	Power systems management and associated information exchange- Data and communications security			●
IEC 62351 Part-0	K 952	Power systems management and associated information exchange- Data and communications security - Part 10: Security architecture guidelines			●
IEC TR 6240-34	AK 931.1	Industrial communication networks- Network and system security - Part 3-1: Security technologies for industrial automation and control systems			●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
IEC 62576 Edition 2	K 331	electric double-layer capacitors for use in hybrid A MW electric vehicles- Test methods for electrical characteristics			
IEC 626601	K 371	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1 : Performance nesting		●	
IEC 62660-2	K 371	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing		●	
IEC 626603	K 371	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements of cells and modules		●	
IEC 62752	AK 541.36	In cable Control and Protection Device for mode 2 charging of electric road vehicles (IC-CPD)			●
IEC 6283'	AK 353.0.8	User identification in Electric vehicle Service Equipment using a smartcard			●
IEC 62840-1	AK 353.0.7	Electric vehicle battery swap system – Part 1: System description and general Requirements			●
IEC 62840-2	AK 353.0.7	Electric vehicle battery swap system –Part 2: Safety requirements			●
IEC 62893	UK 411.2.8	Charging cables for electric vehicles			●
23E/853/NP	AK 541.3.7	Residual Direct Current Monitoring Device to be used for Mode 3 charging of Electric Vehicle (RDC-MD)			●
VDE 0105-100	K 224	Operation of electrical installations – Part 100: General requirements			●
ISO 6469-1 Edition 2	052-01-21 AA	Electric propelled road vehicles – Safety specifications– Part 1: On-board rechargeable energy storage system (RESS)		●	
ISO 6469-2 Edition 2	052-01-21 AA	Electric propelled road vehicles – Safety specifications– Part 2: Vehicle operational safety means and protection against failures	●		
ISO 6469-3 Edition 2	052-01-21 AA	Electric propelled road vehicles – Safety specifications – Part 3: Protection of persons against electric shock	●		
ISO 6469-4	052-01-21 AA	Electrically propelled road vehicles – Safety specifications – Part 4: Post crash electrical safety	●		
ISO 6722-1 Edition 4	052-01-03-04 AK	Road vehicles – 60 V and 600 V single-core cables – Part 1: Dimensions, test methods and requirements for copper conductor cables (Ed. 2.0)	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
ISO 6722-2 Edition 4	052-01-03-04 AK	Road vehicles – 60 V and 600 V single-core cables – Part 2: Dimensions, test methods and requirements for aluminium conductor cables	●		
ISO 7637-1 Edition 3	052-01-03-03 GAK UK 767.13	Road vehicles – Electrical disturbances by conduction and coupling – Part 1: Definitions and general considerations	●		
ISO 7637-2 Edition 3	052-01-03-03 GAK UK 767.13	Road vehicles – Electrical disturbances by conduction and coupling – Part 2: Electrical transient conduction along supply lines only	●		
ISO 7637-3 Edition 3	052-01-03-03 GAK UK 767.13	Road vehicles – Electrical disturbances by conduction and coupling – Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines	●		
ISO TR 8713	052-01-21 AA	Electrically propelled road vehicles Vocabulary	●		
ISO 10924-5	052-01-03-05 AK	Road vehicles – Circuit breakers – Part 5: Circuit breakers with tabs with rated voltage of 450 V	●		●
ISO 11451-1 Edition 4	UK 767.13	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology	●		
ISO 11451-2 Edition 4	UK 767.13	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Off-vehicle radiation sources	●		
ISO 11451-3 Edition 3	UK 767.13	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 3: On-board transmitter simulation	●		
ISO 11452-1 Edition 4	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology	●		
ISO 11452-2 Edition 2	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Absorber lined shielded enclosure	●		
ISO 11452-3 Edition 3	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 3: Transverse electromagnetic mode (TEM) cell			
ISO 11452-4 Edition 4	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Harness excitation methods	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
ISO 11452-5 Edition 2	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiate electromagnetic energy – Part 5: Strip line	●		
ISO 11452-7 Edition 2	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 7: Direct radio frequency (RF) power injection	●		
ISO 11452-8 Edition 2	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 8: Immunity to magnetic fields	●		
ISO 11452-9	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 9: Portable transmitters	●		
ISO 11452-10	UK 767.13	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 10: Immunity to conducted disturbances in the extended audio frequency range	●		
ISO 12405-1	052-01-21-03 GAK	Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 1: High-power applications		●	
ISO 12405-2	052-01-21-03 GAK	Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 2: High-energy applications	●		
ISO 12405-3	052-01-21-03 GAK	Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 3: Safety performance requirements	●		
ISO 14572 Edition 3	052-01-03-04 AK	Road vehicles – Round, sheathed, 60 V and 600 V screened and unscreened single- or multicore cables – Test methods and requirements for basic and high-performance cables	●		
ISO 15118-1	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 1: General information and use case definition	●		●
ISO 15118-2	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 2: Network and application protocol requirements	●		●
ISO 15118-3	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 3: Physical and data link layer requirements	●		●

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
ISO 15118-4	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 4: Network and application protocol conformance test	●		●
ISO 15118-5	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 5: Physical layer and data link layer conformance test	●		●
ISO 15118-6	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 6: General information and use-case definition for wireless communication	●		●
ISO 15118-7	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 7: Network and application protocol requirements for wireless communication	●		●
ISO 15118-8	052-01-03-17 AK	Road vehicles – Vehicle to grid communication interface – Part 8: Physical layer and data link layer requirements for wireless communication	●		●
ISO/IEC 15408-1 Edition 3	043-01-27-03 AK	Information technology – Security techniques – Evaluation criteria for IT security – Part 1: Introduction and general model	●		●
ISO 16750, Parts 1–5	052-01-03-13 AK	Road vehicles – Environmental conditions and testing for electrical and electronic equipment	●		
ISO/IEC PAS 16898	052-01-21-03 GAK	Electrically propelled road vehicles – Dimensions and designation of secondary lithium-ion cells	●	●	
ISO 17409	052-01-21 AA	Electrically propelled road vehicles – Connection to an external electric power supply – Safety requirements	●		
ISO 17840	052-01-12 AA	Road vehicles – Information for first and second responders – Rescue sheet for passenger cars and light commercial vehicles	●		
ISO 18243	052-01-23 AA	Electrically propelled mopeds and motorcycles- Specifications and safety requirements for lithium-ion traction battery systems		●	
ISO 18300	052-01-21-03 GAK	Electrically propelled road vehicles – Specifications for lithium-ion battery systems combined with lead acid battery or capacitor		●	
ISO PAS 19295	052-01-21-01 GAK	Electrically propelled road vehicles – Specification of voltage sub-classes for voltage class B	●		
ISO PAS 19363	052-01-21 AA	Electrically propelled road vehicles – Magnetic field wireless power transfer – Safety and interoperability requirements	●		
ISO 19453-1	052-01-03-13AK	Road vehicles – Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles – Part 1: General	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
ISO 19453-2	052-01-03-13 AK	Road vehicles – Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles – Part 2: Electrical loads	●		
ISO 19453-3	052-01-03-13 AK	Road vehicles – Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles – Part 3: Mechanical loads	●		
ISO 19453-4	052-01-03-13 AK	Road vehicles – Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles – Part 4: Climatic loads	●		
ISO 19642 Parts 1–10	052-01-03-04 AK	Road vehicles – Automotive cables	●		
ISO 23273	052-01-21 AA	Fuel cell road vehicles – Safety specifications – Protection against hydrogen hazards for vehicles fueled with compressed hydrogen	●		
ISO 23274-1	052-01-21 AA	Hybrid-electric road vehicles – Exhaust emissions and fuel consumption measurements – Part 1: Non-externally chargeable vehicles	●		
ISO 23274-2	052-01-21-02 AK	Hybrid-electric road vehicles – Exhaust emissions and fuel consumption measurements – Part 2: Externally chargeable vehicles	●		
ISO 26262 Part 1–10	052-01-26 AA	Road vehicles – Functional safety	●		
ISO/IEC 27000 Edition 3	043-01-27-01 AK	Information technology – Security techniques – Information security management systems – Overview and vocabulary	●		
ISO/IEC 27001 Edition 2	043-01-27-01 AK	Information technology – Security techniques – Information security management systems – Requirements	●		
DIN SPEC 70121	DIN SPEC 70121	Electric Mobility – Digital communication between a DC EV charging station and an electric vehicle for control of DC charging in the Combined Charging	●		
SAE J 1773		Electric Vehicle Inductively Coupled Charging	●		
SAE J 1797		Recommended Practice for Packaging of Electric Vehicle Battery Modules	●		
SAE J 1798		Recommended Practice for Performance Rating of Electric Vehicle Battery Modules	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
ISAE J 2288		Life Cycle Testing of Electric Vehicle Battery Modules	●		●
SAE J 2289		Electric-Drive Battery Pack System: Functional Guidelines	●	●	
SAE J 2464		Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing	●	●	
SAE J 2929		Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium based Rechargeable Cells		●	

7.2.3. Japan

Table 78: Standards adopted in Japan

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
C601:2000	JEVS	Plugs and receptacles for EV charging			
D001-1995	JEVS	Dimensions and Construction of Valve Regulated Lead-Acid Batteries for EVs		●	
D002:1999	JEVS	Dimensions and Construction of sealed nickel-metal hydride batteries for EVs		●	
D701-1994	JEVS	Capacity test procedure of lead-acid batteries for EVs		●	
D702-1994	JEVS	Energy density test procedure of lead-acid batteries for EVs		●	
D703-1994	JEVS	Power density test procedure of lead-acid batteries for EVs		●	
D704-1997	JEVS	Cycle life test procedure of valve regulated lead-acid batteries for EVs		●	
D705:1999	JEVS	Capacity test procedure of sealed nickel-metal hydride batteries for EVs		●	
D706:1999	JEVS	Energy density test procedure of sealed nickel-metal hydride batteries for EVs		●	
D707:1999	JEVS	Specific power and peak power test procedure of sealed nickel-metal hydride batteries for EVs		●	
D708:1999	JEVS	Cycle life test procedure of sealed nickel-metal hydride batteries for EVs		●	
D709:1999	JEVS	Dynamic capacity test procedure of sealed nickel-metal hydride batteries for EVs		●	
E701-1994	JEVS	Combined power measurement of electric motors and controllers for EVs	●		
E702-1994	JEVS	Power measurement of electric motors equivalent to the on-board state for EVs	●		
E901-85	JEVS	Nameplates of electric motor and controller for EVs	●		
G101-1993	JEVS	Chargers applicable to quick charging system at Eco-Station			●
G102-1993	JEVS	Lead-acid batteries applicable to quick charging system at Eco-Station for EVs			

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
		Station for EVs			
G103-1993	JEVS	Charging stands applicable to quick charging system at Eco-Station for EVs			●
G104-1995	JEVS	Communications Protocol Applicable to Quick Charging System at Eco-Station			●
G105-1993	JEVS	Connectors applicable to quick charging system at Eco-Station for EVs			●
G106-2000	JEVS	EV inductive charging system: General requirements			●
G107-2000	JEVS	EV inductive charging system: Manual connection			●
G108-2001	JEVS	EV inductive charging system: Software interface			●
G109-2001	JEVS	EV inductive charging system: General requirements			●
G901-85	JEVS	Nameplates of battery charger for EVs			●
Z101-87	JEVS	General rules of running test method of EVs	●		
Z102-87	JEVS	Maximum speed test method of EVs	●		
Z103-87	JEVS	Range test method of EVs	●	●	
Z104-87	JEVS	Climbing hill test method of EVs	●		
Z105-88	JEVS	Energy economy test method of EVs	●	●	
Z106-88	JEVS	Energy consumption test method of EVs	●	●	
Z107-88	JEVS	Combined test method of electric motors and controllers for EVs	●		
Z108-1994	JEVS	Electric Vehicle - Measurement for driving range and energy consumption	●	●	
Z109-1995	JEVS	Electric Vehicle - Measurement for acceleration	●		
Z110-1995	JEVS	Electric Vehicle - Measurement for maximum cruising speed	●		
Z111-1995	JEVS	Electric Vehicle - Measurement for reference energy consumption	●	●	
Z112-1996	JEVS	Electric Vehicle - Measurement for climbing	●		
Z804:1998	JEVS	Symbols for controls, Indicators and telltales for EVs	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging infrastructure
		Station for EVs			
Z805:1998	JEVS	Glossary of terms relating to EVs (General of vehicles)	●		
Z806:1998	JEVS	Glossary of terms relating to EVs (Electric motors & controllers)	●		
Z807:1998	JEVS	Glossary of terms relating to EVs (Batteries)		●	
Z808:1998	JEVS	Glossary of terms relating to EVs (Chargers)			●
Z901-1995	JEVS	Electric Vehicle - Standard Form of Specification (Form of Main Specification)	●		

7.2.4. China

Table 79: Standards adopted in China

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging Infrastructure
GB/T18384.1-200	SAC	EV Safety Requirement Part1: Energy Storage		●	
GB/T18384.2-2001	SAC	EV Safety Requirement Part2: Function and protection	●		
GB/T18384.3-2001	SAC	EV Safety Requirement Part3: electric shock protection	●		
GB/T 4094.2-2005	SAC	Symbol of operator, indicator and signal of EV	●		
GB/T 19596-2004	SAC	Electric vehicle Terminology	●		
GB/T 18385-2005	SAC	Electric vehicle Power performance Test Procedure	●		
GB/T 18386-2005	SAC	Electric vehicle Energy consumption and Range Test procedure		●	
GB/T 18387-2008	SAC	30MHz EV EMC Limit and Test Procedure Broad band , 9kHz~30MHz	●		
GB/T 18388-2005	SAC	Electric vehicle Type Approval Test Procedure	●		
GB/T 24552-2009	SAC	EV Windshield defrost and defog requirement and Test procedure	●		
GB/T 19836-2005	SAC	Electric vehicle Instrument panel	●		
QC/T 838-2010	SAC	Electric Bus with Ultra-Capacitor	●	●	
GB/Z18333.1-2001	SAC	Li-ion Battery		●	
GB/Z18333.2-2001	SAC	Zinc-Air Battery		●	
QC/T 741-2006	SAC	Ultra- Capacitor		●	
QC/T 742-2006	SAC	Lead Acid Battery		●	
QC/T 743-2006	SAC	Li-ion Battery		●	
QC/T 744-2006	SAC	NiMH Battery		●	
QC/T 840-2010	SAC	Battery Structure and Size		●	
QC/T 897-2011	SAC	Technical specification of Battery Management System for Electric vehicles		●	
GB/T18488.1-2006	SAC	Motor and its Controller Part1: Specification	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging Infrastructure
GB/T18488.2-2006	SAC	Motor and its Controller Part2: Test Procedure	●		
GB/T 24347-2009	SAC	DC/DC convertor	●		
QC/T 896-2011	SAC	Interface of electrical machine system for electric vehicle	●		
QC/T 893-2011	SAC	Failure classification and assessment of electrical machine system for electric vehicle			
GB/T18487.1-200	SAC	Conduct Charging System General Requirement			●
GB/T18487.2-2001	SAC	Connect Requirement of EV and DC Charger			●
GB/T18487.3-2001	SAC	AC/DC Charger (and Charger station)			●
GB/T 20234.1-2011	SAC	Connection set for conductive charging of electric vehicles Part General requirements			●
GB/T 20234.2-2011	SAC	Connection set for conductive charging of electric vehicles Part 2:AC charging coupler			●
GB/T 20234.3-2011	SAC	Connection set for conductive charging of electric vehicles Part 3:DC charging coupler			●
QC/T 895-2011	SAC	On-board conductive charger for electric vehicles			●
QC/T 839-2010	SAC	Electric System of Ultra-Capacitor Bus	●	●	
QC/T 841-2010	SAC	Electric vehicle conductive charge coupler			●
QCT/842-2010	SAC	Communication Protocol between BMS and off board Charger			●
GB/T 24158-2009	SAC	Electric motorcycles and electric mopeds—General specifications	●		
GB/T 24157-2009	SAC	Electric motorcycles and electric mopeds - Energy consumption and range - Test procedure		●	
GB/T 24156-2009	SAC	Electric motorcycles and electric mopeds—Power performance—Test methods		●	
QC/T 791-2007	SAC	Electric motorcycles and electric mopeds—Type Approval Test Procedure	●		

Standard or specification	National Body	Title	Vehicle	Energy Storage	Charging Infrastructure
QC/T 792-200	SAC	Electric motorcycles and electric mopeds– Motor and its Controller Specification	●		
GB 24155-2009	SAC	Electric motorcycles and electric mopeds - Safety specifications	●		
GB/T 18384.1	SAC	Safety Requirements for Electric Vehicles – Part 1: rechargeable energy storage system		●	
GB/T 18384.2	SAC	Safety Requirements for Electric Vehicles– Part 2: Function Safety and Fault Defending	●		
GB/T 18384.3	SAC	Safety Requirements for Electric Vehicles– Part 3: Protection against Electrical Shock	●	●	

7.3

Business Model: Data Sheets

7.3.1. DC fast Charger

Charging requirement	
Battery capacity (kW. H)	17.6
Number of chargers at station	1

Taxes	w/o cess	eff.
Corporate tax	30%	35%
MAT	19%	21%
Surcharge	12%	
Education cess	3%	

Depreciation	
Book depreciation	6.67%
Tax depreciation	80.00%
WDV (no. of years)	15
SLM (no. of years)	15

Source of Funds	
Debt	70%
Equity	30%
Interest rate	5%
Repayment yrs.	10
Discount rate	13%

Useful conversions	
Minutes in an Hour	60
Hours in a day	24
Months in a year	12
Days in a year	365
Discount rate	13%

Type	Charger cost	Charging rate	Charging time	Installation cost	Maintenance cost %	Maintenance cost	Escalation in maintenance cost
Unit	(INR)	(kW)	(hrs)	(INR)	(% of installation cost)	(INR)	(%)
DC Fast charger	2,50,000	44	0.50	12500	1%	125	2%

Revenue assumptions	Commercial space
Cost of electricity (INR/kWh)	3.50
Escalation in cost of electricity	0%
Mark up on cost of electricity (%)	57%
Cost of electricity to consumer (INR/ kWh)	5.5
Duration of charge event (hrs per charge)	0.50
# of charge events per day	48
Charger utilization (hrs per day)	24.0
Per charge fixed fee	0
Escalation in per charge fixed fee	1%
Discount on charging fee (% per session)	0%
Monthly membership fee (INR/ month)	0
Number of charges	0
Lease expenses (INR/ month)	0
Escalation in lease rental	0%
Overheads (% of maint. Cost)	0%
Fixed revenue sharing with EVSP	0%
Var. revenue sharing with EVSP	0%
Total project cost	1,68,000
Debt	1,17,600
Equity	50,400

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Revenue											
Variable fee		70,664	70,664	70,664	70,664	70,664	70,664	70,664	70,664	70,664	70,664
Total revenue		70,664	70,664	70,664	70,664	70,664	70,664	70,664	70,664	70,664	70,664
Cost											
Electricity cost		44,968	44,968	44,968	44,968	44,968	44,968	44,968	44,968	44,968	44,968
Maintenance cost		125	125	125	125	125	125	125	125	125	125
Lease expenses		-	-	-	-	-	-	-	-	-	-
Total operating costs		45,093	45,093	45,093	45,093	45,093	45,093	45,093	45,093	45,093	45,093
EBITDA		25,571	25,571	25,571	25,571	25,571	25,571	25,571	25,571	25,571	25,571
Depreciation		17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Interest expenses		5,586	4,998	4,410	3,822	3,234	2,646	2,058	1,470	882	294
PBT		2,485	3,073	3,661	4,249	4,837	5,425	6,013	6,601	7,189	7,777
Tax		530	656	781	907	1,032	1,158	1,283	1,409	1,534	1,660
PAT		1,955	2,417	2,880	3,342	3,805	4,267	4,730	5,192	5,655	6,117
Cash flows											
Capex	(50,400)										
Subsidy	-										
Loan movement		(11,760)	(11,760)	(11,760)	(11,760)	(11,760)	(11,760)	(11,760)	(11,760)	(11,760)	(11,760)
Depreciation		17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
FCFE	(50,400)	7,695	8,157	8,620	9,082	9,545	10,007	10,470	10,932	11,395	11,857

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
NPV	155										
Eq. IRR	13.1%										
Book Depreciation schedule											
Opening block		2,62,500	2,45,000	2,27,500	2,10,000	1,92,500	1,75,000	1,57,500	1,40,000	1,22,500	1,05,000
Book Depreciation		17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Closing block for book dep.		2,45,000	2,27,500	2,10,000	1,92,500	1,75,000	1,57,500	1,40,000	1,22,500	1,05,000	87,500
Tax Depreciation Schedule											
Opening block		2,62,500	52,500	10,500	2,100	420	84	17	3	1	0
Tax Depreciation		2,10,000	42,000	8,400	1,680	336	67	13	3	1	0
Closing block for tax dep.		52,500	10,500	2,100	420	84	17	3	1	0	0
Interest schedule											
Opening debt		1,17,600	1,05,840	94,080	82,320	70,560	58,800	47,040	35,280	23,520	11,760
Interest expenses		5,586.00	4,998	4,410	3,822	3,234	2,646	2,058	1,470	882	294
Repayment		11,760	11,760	11,760	11,760	11,760	11,760	11,760	11,760	11,760	11,760
Closing debt		1,05,840	94,080	82,320	70,560	58,800	47,040	35,280	23,520	11,760	-
Tax schedule											
PBT		2,485	3,073	3,661	4,249	4,837	5,425	6,013	6,601	7,189	7,777
Add: Book Depreciation		17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Less: Tax Depreciation		(2,10,000)	(42,000)	(8,400)	(1,680)	(336)	(67)	(13)	(3)	(1)	(0)
Less: Tax Depreciation		(1,90,015)	(2,11,442)	(1,98,681)	(1,78,612)	(1,56,611)	(1,33,753)	(1,10,254)	(86,155)	(61,467)	(36,190)
MAT		530	656	781	907	1,032	1,158	1,283	1,409	1,534	1,660

Income Tax	-	-	-	-	-	-	-	-	-	-
Tax Payable Before Accounting for Mat Credit	530	656	781	907	1,032	1,158	1,283	1,409	1,534	1,660
Opening MAT	-	530	1,186	1,967	2,874	3,907	5,064	6,348	7,756	9,291
MAT Credit Earned	530	656	781	907	1,032	1,158	1,283	1,409	1,534	1,660
MAT Credit Setoff	-	-	-	-	-	-	-	-	-	-
Closing MAT	530	1,186	1,967	2,874	3,907	5,064	6,348	7,756	9,291	10,950
Tax to be paid	530	656	781	907	1,032	1,158	1,283	1,409	1,534	1,660
Effective tax rate of PBT (%)	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
NPV	155										
Eq. IRR	13.1%										
Book Depreciation schedule											
Opening block		2,62,500	2,45,000	2,27,500	2,10,000	1,92,500	1,75,000	1,57,500	1,40,000	1,22,500	1,05,000
Book Depreciation		17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Closing block for book dep.		2,45,000	2,27,500	2,10,000	1,92,500	1,75,000	1,57,500	1,40,000	1,22,500	1,05,000	87,500
Tax Depreciation Schedule											
Opening block		2,62,500	52,500	10,500	2,100	420	84	17	3	1	0
Tax Depreciation		2,10,000	42,000	8,400	1,680	336	67	13	3	1	0
Closing block for tax dep.		52,500	10,500	2,100	420	84	17	3	1	0	0
Interest schedule											
Opening debt		1,17,600	1,05,840	94,080	82,320	70,560	58,800	47,040	35,280	23,520	11,760
Interest expenses		5,586.00	4,998	4,410	3,822	3,234	2,646	2,058	1,470	882	294
Repayment		11,760	11,760	11,760	11,760	11,760	11,760	11,760	11,760	11,760	11,760
Closing debt		1,05,840	94,080	82,320	70,560	58,800	47,040	35,280	23,520	11,760	-
Tax schedule											
PBT		2,485	3,073	3,661	4,249	4,837	5,425	6,013	6,601	7,189	7,777
Add: Book Depreciation		17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500

Assessment of ownership structures for reducing risks

PPP: Private Investor and Municipal Corporation

Assumptions:

Charging requirement	
Battery capacity (kWh)	17.6
Number of chargers at station	1

EV specifications	
Range (km)	120
Battery capacity (kWh)	18

Source of Funds	
Debt	70%
Equity	30%
Interest rate	10%
Repayment yrs.	10
Discount rate	13%

Depreciation	
Book depreciation	6.67%
Tax depreciation	80.00%
WDV (no. of years)	15
SLM (no. of years)	15

Taxes	w/o cess	eff.
Corporate tax	**30%**	**35%**
MAT	19%	21%
Surcharge	12%	
Education cess	3%	

Useful conversions	
Minutes in an Hour	60
Hours in a day	12
Months in a year	12
Days in a year	365
Days in a month	30

Charger costs							
Type	Charger cost	Charger rating	Charging time	Installation cost	Maintenance cost %	Maintenance cost	Escalation in maintenance cost
Unit	(INR)	(kW)	(hrs)	(INR)	(% of installation cost)	(INR)	(%)
DC Fast charger	18,00,000	50	0.34	1,80,000.0	0%	-	2%

Revenue assumptions	Commercial space
Cost of electricity (INR/kWh)	7.50
Escalation in cost of electricity	5%
Mark up on cost of electricity (%)	13%
Cost of electricity to consumer (INR/ kWh)	8.5
Capital subsidy	0%
Duration of charge event (hrs per charge)	0.34
# of charge events per day	35.29
Charger utilization (hrs per day)	6.0
Per hour fixed fee (INR/hour)	20
Escalation in per charge fixed fee	5%
Discount on charging fee (% per session)	0%
Monthly membership fee (INR/ month)	0
Number of charges	0
Year on Year Improvement (%)	12%
Lease expenses (INR/ month)	0
Escalation in lease rental	10%
Overheads (% of maint. Cost)	2%
Mark up on lease (%)	30%
Private Investor revenue sharing	0%
MNC revenue sharing	10%
YOY improvement in rev sharing	0%
Total DC Charger Cost	19,80,000
Debt	13,86,000
Equity	5,94,000

Urban utility maintenance cost	2500
Urban utility maintenance escalation	5%

Escalation in opportunity cost for land	10%

Advertising	
Per month Cost (INR)	5000
Annual Escalation (%)	5%

Co-Branding	
Per month Cost (INR)	5000
Annual Escalation (%)	10%

Commercial Schedule:

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Revenue											
Charging revenue		9,27,517	10,90,760	12,82,734	15,08,495	17,73,991	2086,213	24,53,386	28,85,182	33,92,974	39,90,138
Advertising		60,000	63,000	66,150	69,458	72,930	76,577	80,406	84,426	88,647	93,080
Co-Branding		60,000	66,000	72,600	79,860	87,846	96,631	1,06,294	1,16,923	1,28,615	1,41,477
Total revenue from DCFC		10,47,517	12,19,760	14,21,484	16,57,813	19,34,767	22,59,420	26,40,086	30,86,531	36,10,237	42,24,695
Cost											
Electricity cost		8,21,250	9,65,790	11,35,769	13,35,664	15,70,741	18,47,192	21,72,298	25,54,622	30,04,235	35,32,981
Maintenance cost		-	-	-	-	-	-	-	-	-	-
Lease expenses		-	-	-	-	-	-	-	-	-	-
Total operating costs		8,21,250	9,65,790	11,35,769	13,5,664	15,70,741	18,47,192	21,72,298	25,54,622	30,04,235	35,32,981
EBITDA		2,26,267	2,53,970	2,85,715	3,22,148	3,64,026	4,12,229	4,67,788	5,31,910	6,06,002	6,91,714

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Depreciation		1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000
Interest expenses		1,31,670	1,17,810	1,03,950	90,090	76,230	62,370	48,510	34,650	20,790	6,930
PBT		(37,403)	4,160	49,765	1,00,058	1,55,796	2,17,859	2,87,278	3,65,260	4,53,212	5,52,784
Tax		-	888	10,621	21,354	33,249	46,495	61,310	77,952	96,723	1,66,642
PAT		(37,403)	3,272	39,144	78,704	1,22,546	1,71,364	2,25,968	2,87,307	3,56,489	3,86,142
Cash flows											
Capex	(5,94,000)										
Subsidy	-										
Loan movement		(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)	(1,38,600)
Depreciation		1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000
FCFE	(5,94,000)	(44,003)	(3,328)	32,544	72,104	1,15,946	1,64,764	2,19,368	2,80,707	3,49,889	3,79,542
NPV	(0)										
Eq. IRR	13.0%										
Land opportunity cost	20000	240000	264000	290400	319440	351384	386522	425175	467692	514461	565907
NPV of opportunity cost	Rs. 18,87,309.55										
Cash flow for PI		-33662	2945	35230	70834	110292	154228	203372	258577	320840	347527
Percentage revenue shared		10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Cash flow for MNC		-3740	327	3914	7870	12255	17136	22597	28731	35649	38614
NPV for MNC	63023										
Book Depreciation schedule											
Opening block		19,80,000	18,48,000	17,16,000	15,84,000	14,52,000	13,20,000	11,88,000	10,56,000	9,24,000	7,92,000
Book Depreciation		1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000
Closing block for book dep.		18,48,000	17,16,000	15,84,000	14,52,000	13,20,000	11,88,000	10,56,000	9,24,000	7,92,000	6,60,000
Tax Depreciation Schedule											
Opening block		19,80,000	3,96,000	79,200	15,840	3,168	634	127	25	5	1
Tax Depreciation		1584,000	3,16,800	63,360	12,672	2,534	507	101	20	4	1
Closing block for tax dep.		3,96,000	79,200	15,840	3,168	634	127	25	5	1	0
Interest schedule											
Opening debt		13,86,000	12,47,400	1108,800	9,70,200	8,31,600	6,93,000	5,54,400	4,15,800	2,77,200	1,38,600
Interest expenses		1,31, 670.00	1,17,810	1,03,950	90,090	76,230	62,370	48,510	34,650	20,790	6,930
Repayment		1,38,600	1,38,600	1,38,600	1,38,600	1,38,600	1,38,600	1,38,600	1,38,600	1,38,600	1,38,600
Closing debt		12,47,400	11,08,800	9,70,200	8,31,600	6,93,000	5,54,400	4,15,800	2,77,200	1,38,600	-
Tax schedule											
PBT		(37,403)	4,160	49,765	1,00,058	1,55,796	2,17,859	2,87,278	3,65,260	4,53,212	5,52,784
Add: Book Depreciation		1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000	1,32,000
Less: Tax Depreciation		(15,84, 000)	(3,16,800)	(63,360)	(12,672)	(2,534)	(507)	(101)	(20)	(4)	(1)

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Taxable Profit after Depreciation		(14,89 403)	(16,70, 042)	(15,51, 637)	(13,32, 251)	(10,46, 989)	(6,97,638)	(2,78,461)	2,18,778	5,85,208	6,84,783
MAT		-	888	10,621	21,354	33,249	46,495	61,310	77,952	96,723	1,17,973
Income Tax		-	-	-	-	-	-	-	75,715	2,02,529	2,36,990
Tax Payable Before Accounting for Mat Credit		-	888	10,621	21,354	33,249	46,495	61,310	77,952	2,02,529	2,36,990
Opening MAT		-	-	888	11,509	32,863	66,112	1,12,606	1,73,916	1,76,154	70,348
MAT Credit Earned		-	888	10,621	21,354	33,249	46,495	61,310	2,237	-	-
MAT Credit Setoff		-	-	-	-	-	-	-	-	1,05,806	70,348
Closing MAT		-	888	11,509	32,863	66,112	1,12,606	1,73,916	1,76,154	70,348	-
Tax to be paid		-	888	10,621	21,354	33,249	46,495	61,310	77,952	96,723	1,66,642
Effective tax rate of PBT (%)		0%	21%	21%	21%	21%	21%	21%	21%	21%	30%
Charger utilization											
Year on Year Improvement (%)		12%									
Charger Utilization (Hours per day)		6	7	8	8	9	11	12	13	15	17
		6.00	6.72	7.53	8.43	9.44	10.57	11.84	13.26	14.86	16.64
Electricity costs											
Year on Year Improvement (%)		5%									
Cost of electricity (INR/kWh)		7.50	7.88	8.27	8.68	9.12	9.57	10.05	10.55	11.08	11.63

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Cost of electricity to consumer (INR/ kWh)		8.47	8.89	9.34	9.81	10.30	10.81	11.35	11.92	12.51	13.14
Charging fee per minute											
Time to charge a car (min)		20.40									
Quantum of electricity to charge (kWh)		17									
Cost of electricity to charge a car (INR)		144.00	151.20	158.76	166.70	175.03	183.78	192.97	202.62	212.75	223.39
Cost of electricity to charge a car per min (INR/ min)		7.06	7.41	7.78	8.17	8.58	9.01	9.46	9.93	10.43	10.95
Fixed fee per hour (INR/ hour)											
Lease expenses (INR/ month)		0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Charges per hour (INR/ hour)											
Fixed fee per min (INR/ min)											
Total fee per minute (INR/ min)											
Total fee per minute (INR/ min)		7.06	7.41	7.78	8.17	8.58	9.01	9.46	9.93	10.43	10.95

	6-Jul-18	6-Jul-19	6-Jul-20	6-Jul-21	6-Jul-22	6-Jul-23	6-Jul-24	6-Jul-25	6-Jul-26	6-Jul-27	6-Jul-28
Rupees per km											
Range addition per minute of charge(km/min)		5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88
Charge per km (INR/km)		1.20	1.26	1.32	1.39	1.46	1.53	1.61	1.69	1.77	1.86

7.4

City model dashboard

7.4.1. Delhi

Table 80: Statistics dashboard for Delhi projections

	Units	2018	2020	2025	2030	CAGR
City population	no.	2,10,91,418	2,23,54,166	2,58,01,582	2,98,82,065	2.9%
Total Vehicle stock on road*	no.	1,08,94,161	1,23,81,046	1,69,85,525	2,34,28,142	6.6%
2W	%	65.4%	65.9%	66.7%	67.1%	
3W - PV	%	1.0%	0.9%	0.8%	0.8%	
3W - CV	%	0.6%	0.6%	0.5%	0.4%	
4W - PV	%	31.0%	30.8%	30.4%	30.3%	
4W - CV	%	1.7%	1.5%	1.3%	1.3%	
Bus	%	0.3%	0.3%	0.2%	0.1%	
Vehicle per unit 1000 Population	no.	517	554	658	784	3.5%
Total EVs stock on road	no.	8,602	1,14,488	20,43,091	86,28,783	54.1%
2W	no.	5,000	71,135	13,35,129	57,19,130	55.1%
3W - PV	no.	3,000	5,962	32,494	87,575	30.8%
3W - CV	no.	-	1,025	9,013	31,305	40.8%
4W - PV	no.	500	31,036	6,13,879	26,32,033	55.9%
4W - CV	no.	100	4,876	49,070	1,50,555	40.9%
Bus	no.	2	455	3,507	8,185	33.5%
EVs % mix of total vehicle stock on road in that year	%	0%	1%	12%	37%	
New EVs mix as % of total new vehicles added in that year	%	1%	5%	51%	100%	

	Units	2018	2020	2025	2030	CAGR
Total EVs stock on road	no.	8,602	1,14,488	20,43,091	86,28,783	54.1%
With Integrated LIBs	%	80%	83%	73%	60%	
With Swapping LIBs	%	14%	7%	8%	9%	
With Range Extension LIBs	%	7%	10%	19%	31%	
Cumulative LIBs in system	MWh	28	707	12,271	48,478	52.6%
Integrated LIBs	%	91%	95%	92%	88%	
Swapping + RE LIBs	%	9%	5%	8%	12%	
Total no. of LIB charges in a year	lakhs/ year	24	208	3,105	12,540	50.7%
Home charging	%	54%	66%	65%	61%	
Office/Private charging	%	6%	8%	8%	8%	
Public charging	%	10%	11%	10%	10%	
Swapping + RE	%	30%	15%	16%	21%	
Total Avg connected EV charging load to grid	MVA	16	346	4,321	15,901	47%

	Units	2018	2020	2025	2030	CAGR
Home charging (RESIDENTIAL)	%	17%	14%	15%	14%	
Office/Private charging (COMMERCIAL)	%	17%	34%	27%	23%	
Public charging (COMMERCIAL)	%	25%	22%	24%	23%	
Swapping + RE (COMMERCIAL)	%	32%	20%	24%	29%	
Peak EV Demand for charging (in TS2 6am to 12 noon slot)	MVA	3	72	878	3,024	45.2%
BAU Peak Demand of city (in TS4)	MVA	7,146	7,771	9,585	11,822	4.3%
Total Peak Demand of city including EVs (in TS4)	MVA	7,149	7,844	10,463	14,845	6.6%
% EV contribution to City Peak demand (in TS4)	%	0%	1%	8%	20%	
BAU Peak Demand CAGR	%	4.5%	4.3%	4.3%	4.3%	
EV Peak Demand CAGR	%		123%	46%	22%	
Combined total peak demand CAGR	%	4.6%	5.0%	7.8%	8.8%	
Electricity Consumption for EV charging (at network input incorporating Distribution losses)	MUs/ year	9	176	2,245	8,169	46.8%

	Units	2018	2020	2025	2030	CAGR
Home charging (RESIDENTIAL TARIFF)	%	54%	50%	51%	49%	
Office/Private charging (COMMERCIAL TARIFF)	%	9%	21%	16%	13%	
Public charging (COMMERCIAL TARIFF)	%	13%	13%	13%	13%	
Swapping + RE (COMMERCIAL TARIFF)	%	23%	17%	20%	25%	
BAU Total electricity consumption of the city w/o EV load (at network input incorporating Distribution losses)	%	29,820	32,626	40,853	51,155	4.6%
Total electricity consumption of the city including EV load (at network input incorporating Distribution losses)	MUs/ year	29,829	32,803	43,098	59,324	6.1%
% EV contribution in electricity consumption	%	0%	0%	5%	13%	
% Load factor of EV charging	%	6.3%	5.6%	5.9%	6.0%	
Total no. of EV chargers	no.	3,932	39,875	5,89,956	22,62,252	49.8%
Home Chargers	no.	3,529	37,627	5,54,624	20,95,473	49.5%
Fast Chargers (Office/ Private, Public Charging)	no.	81	835	12,015	48,328	50.1%

	Units	2018	2020	2025	2030	CAGR
Slow Chargers (Swapping, RE)	no.	322	1,413	23,317	1,18,451	55.7%
Home Chargers	%	90%	94%	94%	93%	
Fast Chargers (Office/ Private, Public Charging)	%	2%	2%	2%	2%	
Slow Chargers (Swapping, RE)	%	8%	4%	4%	5%	
EVs to Chargers ratio (including all EVs and all chargers including home chargers)	ratio	2.19	2.87	3.46	3.81	
EVs to Chargers ratio (including select EVs and other than home chargers)	ratio	8.68	22.15	22.67	17.15	
No. of Charging Locations	no.	3,544	37,763	5,56,624	21,03,772	49.5%
Home charging	no.	3,529	37,627	5,54,624	20,95,473	49.5%
Office/Private charging	no.	7	77	1,131	4,563	50.4%
Public charging	no.	4	45	636	2,552	49.7%
Swapping + RE	no.	3	14	233	1185	55.7%

7.4.2. Lucknow

Table 81: Statistics dashboard for Lucknow City projections

	Units	2018	2020	2025	2030	CAGR
City population	no.	55,58,170	57,82,720	63,84,590	70,49,103	2%
Total Vehicle stock on road*	no.	21,37,214	24,65,384	34,87,770	49,28,235	7%
2W	%	77.4%	76.0%	73.3%	71.1%	-1%
3W - PV	%	0.4%	0.4%	0.5%	0.5%	2%
3W - CV	%	1.3%	1.9%	2.7%	3.1%	5%
4W - PV	%	13.7%	15.2%	18.1%	20.2%	3%
4W - CV	%	7.0%	6.3%	5.3%	5.0%	-2%
Bus	%	0.2%	0.2%	0.1%	0.1%	-2%
Vehicle per unit 1000 Population	no.	385	426	546	699	5%
Total EVs stock on road	no.	30,145	64,022	4,98,783	19,55,749	41%
2W	no.	21,106	41,202	3,15,551	12,68,040	41%
3W - PV	no.	618	1,245	5,947	15,710	29%
3W - CV	no.	2,191	4,021	25,511	85,545	36%
4W - PV	no.	4,315	11,168	1,08,397	4,57,082	45%
4W - CV	no.	1,915	6,234	42,053	1,25,593	35%
Bus	no.	-	151	1,323	3,778	38%
EVs % mix of total vehicle stock on road in that year	%	1%	3%	14%	40%	31%
New EVs mix as % of total new vehicles added in that year	%	6%	9%	53%	100%	27%
Total EVs stock on road	no.	30,145	64,022	4,98,783	19,55,749	41%

	Units	2018	2020	2025	2030	CAGR
With Integrated LIBs	%	85%	85%	75%	63%	-3%
With Swapping LIBs	%	6%	6%	8%	10%	4%
With Range Extension LIBs	%	9%	9%	17%	28%	12%
Cumulative LIBs in system	MWh	150	387	3,305	13,669	43%
Integrated LIBs	%	87%	87%	80%	70%	-2%
Swapping + RE LIBs	%	13%	13%	20%	30%	9%
Total no. of LIB charges in a year	lakhs/ year	58	139	1,025	3,703	39%
Home charging	%	69%	67%	62%	56%	-2%
Office/Private charging	%	8%	9%	8%	10%	1%
Public charging	%	11%	12%	12%	11%	-1%
Swapping + RE	%	11%	12%	18%	23%	7%
Total Avg connected EV charging load to grid	MVA	65	224	1,707	6,000	39%
Home charging (RESIDENTIAL)	%	24%	19%	17%	14%	-3%
Office/Private charging (COMMERCIAL)	%	23%	30%	25%	27%	-1%
Public charging (COMMERCIAL)	%	31%	25%	23%	19%	-2%
Swapping + RE (COMMERCIAL)	%	12%	16%	25%	30%	7%

	Units	2018	2020	2025	2030	CAGR
Total electricity consumption of the city including EV load (at network input incorporating Distribution losses)	MUs/ year	17,417	24,316	56,221	1,29,500	18%
% EV contribution in electricity consumption	%	0%	0%	1%	2%	17%
% Load factor of EV charging	%	7%	6%	6%	6%	-1%
Total no. of EV chargers	no.	11,664	26,818	1,87,704	6,27,201	37%
Home Chargers	no.	11,125	25,437	1,75,134	5,71,949	37%
Fast Chargers (Office/ Private, Public Charging)	no.	233	617	4,237	15,923	38%
Slow Chargers (Swapping, RE)	no.	306	764	8,332	39,329	48%
Home Chargers	%	95%	95%	93%	91%	0%
Fast Chargers (Office/ Private, Public Charging)	%	2%	2%	2%	3%	1%
Slow Chargers (Swapping, RE)	%	3%	3%	4%	6%	8%
EVs to Chargers ratio (including all EVs and all chargers including home chargers)	ratio	2.58	2.39	2.66	3.12	3%

	Units	2018	2020	2025	2030	CAGR
EVs to Chargers ratio (including select EVs and other than home chargers)	ratio	27.42	20.88	15.06	11.48	-6%
No. of Charging Locations	no.	11,161	25,535	1,75,828	5,74,752	37%
Home charging	no.	11,125	25,437	1,75,134	5,71,949	37%
Office/Private charging	no.	20	58	373	1,634	40%
Public charging	no.	4	33	237	775	37%
Swapping + RE	no.	3	8	83	393	48%

	Units	2018	2020	2025	2030	CAGR
Total electricity consumption of the city including EV load (at network input incorporating Distribution losses)	MUs/ year	17,417	24,316	56,221	1,29,500	18%
% EV contribution in electricity consumption	%	0%	0%	1%	2%	17%
% Load factor of EV charging	%	7%	6%	6%	6%	-1%
Total no. of EV chargers	no.	11,664	26,818	1,87,704	6,27,201	37%
Home Chargers	no.	11,125	25,437	1,75,134	5,71,949	37%
Fast Chargers (Office/ Private, Public Charging)	no.	233	617	4,237	15,923	38%
Slow Chargers (Swapping, RE)	no.	306	764	8,332	39,329	48%
Home Chargers	%	95%	95%	93%	91%	0%
Fast Chargers (Office/ Private, Public Charging)	%	2%	2%	2%	3%	1%
Slow Chargers (Swapping, RE)	%	3%	3%	4%	6%	8%
EVs to Chargers ratio (including all EVs and all chargers including home chargers)	ratio	2.58	2.39	2.66	3.12	3%

7.4.3. Nagpur

Table 82: Statistics dashboard for Nagpur projections

	Units	2018	2020	2025	2030	CAGR
City population	no.	27,50,000	29,45,869	34,98,768	41,55,439	3%
City population	no.	27,50,000	29,45,869	34,98,768	41,55,439	3%
Total Vehicle stock on road*	no.	15,77,721	17,17,519	21,66,936	28,19,481	5%
2W	%	88.0%	88.1%	88.0%	87.7%	0%
3W - PV	%	1.4%	1.4%	1.4%	1.5%	0%
3W - CV	%	0.6%	0.6%	0.6%	0.5%	-1%
4W - PV	%	8.3%	8.3%	8.3%	8.4%	0%
4W - CV	%	1.5%	1.5%	1.6%	1.8%	2%
Bus	%	0.1%	0.1%	0.1%	0.1%	1%
Vehicle per unit 1000 Population	no.	574	583	619	679	2%
Total EVs stock on road	no.	650	12,395	2,19,345	9,18,575	54%
2W	no.	500	9,537	1,82,225	7,81,163	55%
3W - PV	no.	50	788	7,342	20,929	39%
3W - CV	no.	-	171	1,501	5,205	41%
4W - PV	no.	-	873	18,226	80,390	57%
4W - CV	no.	100	945	9,238	28,542	41%
Bus	no.	-	81	813	2,346	40%
EVs % mix of total vehicle stock on road in that year	%	0%	1%	10%	33%	46%
New EVs mix as % of total new vehicles added in that year	%	1%	6%	52%	100%	33%

	Units	2018	2020	2025	2030	CAGR
Total EVs stock on road	no.	650	12,395	2,19,345	9,18,575	54%
With Integrated LIBs	%	85%	84%	74%	64%	-3%
With Swapping LIBs	%	8%	7%	7%	8%	1%
With Range Extension LIBs	%	8%	9%	18%	29%	13%
Cumulative LIBs in system	MWh	2	55	875	3,729	52%
Integrated LIBs	%	89%	85%	78%	70%	-2%
Swapping + RE LIBs	%	11%	15%	22%	30%	7%
Total no. of LIB charges in a year	lakhs/ year	2	26	370	1,434	49%
Home charging	%	65%	65%	65%	61%	-1%
Office/Private charging	%	9%	9%	7%	8%	-1%
Public charging	%	11%	10%	9%	9%	-1%
Swapping + RE	%	15%	16%	19%	22%	3%
Total Avg connected EV charging load to grid	MVA	2	44	467	1,600	43%
Home charging (RESIDENTIAL)	%	24%	14%	15%	13%	-1%
Office/Private charging (COMMERCIAL)	%	28%	43%	34%	35%	-2%
Public charging (COMMERCIAL)	%	28%	17%	18%	16%	-1%

	Units	2018	2020	2025	2030	CAGR
Swapping + RE (COMMERCIAL)	%	11%	16%	23%	26%	5%
Peak EV Demand for charging (TS2)	MVA	1	13	134	468	43%
Peak EV Demand for charging (TS4)	MVA	1	11	104	335	41%
BAU Peak Demand of city (without EVs, in TS4)	MVA	496	526	608	703	2.9%
Total Peak Demand of city including EVs (TS4)	MVA	497	536	712	1,038	6.8%
% EV contribution to Peak demand (TS4)	%	0%	2%	15%	32%	32%
BAU Peak Demand CAGR	%	13%	3%	3%	3%	0%
EV Peak Demand yearly CAGR	%		137%	47%	20%	-18%
Combined total peak demand CAGR	%	13%	4%	8%	8%	7%
Electricity Consumption for EV charging (at network input incorporating Distribution losses)	MUs/ year	1	22	240	798	43%
Home charging (RESIDENTIAL TARIFF)	%	60%	43%	43%	39%	-1%

	Units	2018	2020	2025	2030	CAGR
EVs to Chargers ratio (including all EVs and all chargers including home chargers)	ratio	2.08	2.52	3.10	3.53	3%
EVs to Chargers ratio (including select EVs and other than home chargers)	ratio	19.16	23.15	24.86	20.20	-1%
No. of Charging Locations	no.	296	4,637	66,585	2,41,980	49%
Home charging	no.	295	4,621	66,387	2,41,120	49%
Office/Private charging	no.	1	11	117	545	48%
Public charging	no.	4	5	65	243	48%
Swapping + RE	no.	0	1	16	71	54%

7.5

Discussion points from stakeholder interactions

1. SNDL, Nagpur	
Date	02 April 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	Great Nag Rd, Near Baidhyanath Chowk, Rambagh, Nagpur, Maharashtra 440003
Agenda	Stakeholder consultation with SNDL, Nagpur to gain insights on the charger's impact on Grid for Nagpur case study
Participants	SNDL : ▸ Ms. Sonal Khurana ▸ Mr. Rajesh Turkar P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. Nagpur EV adoption model and its impact on grid -- all Discom nos. collected and model vetted with SNDL team (3 meetings)	

2. Department of Science and Technology (DST)	
Date	04 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	Technology Bhavan, New Mehrauli Road, Block C, Adchini, New Delhi, Delhi, 110016
Agenda	Stakeholder consultation with DST to gain insights on standards for EV Charging Infrastructure
Participants	SDST : ▸ Dr. Sajid Mubashir P-Manifold- ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani

The following points were highlights of the discussion:

1. The mandate of framing new standards has been given to Secretary, DST who will through support of BIS will frame IS standards.
2. As discussed the IEC standards needs to be tweaked for Indian conditions such as ambient temperature range of 0 to 50 deg. Cel.
3. The directive to frame new standards similar to GB/T, CHAdeMO, CCS has come from NITI Aayog with rationale of having Indian specific standards to meet domestic market and planning to have everything "Make in India"
4. For public heavy vehicles such as intra-city electric buses, India is looking to "Opportunity Charging" as well as swapping
5. Committees are being formed to take global perspectives so that the standards developed will form a level playing field for all the OEMs
6. It was also discussed that DHI specifications for Bharat Chargers as well as AIS standards developed by ARAI are not traceable and hence will be eventually dropped.
7. Ather, an electric 2 wheeler manufacturing start-up has developed an AC & DC combo connector for 2 wheelers which they can open for adoption by India

3. CharIn: CCS association	
Date	04 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	NA
Agenda	Stakeholder consultation with CharIn to gain insights on standards for Charging Infrastructure
Participants	CharIn : ▸ Mr. Sivam Sabesan P-Manifold ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani

The following points were highlights of the discussion:

1. Government is planning to prepare new IS standards
2. Though govt. was interested in CCS but still is not ready to adopt it
3. Most of the OEMs comply with CCS while a few such as Honda, Mitsubishi, Peugeot support both CCS and CHAdeMO standards
4. GB/T is followed by Chinese manufacturers
5. Bharat Charger Standards are not for 2 wheeler & 3 wheelers though being a standard below 100VDC
6. A slow charger for car could be a fast charger for 2 & 3 wheelers is a misnomer as a 2 & 3 wheeler will not have circuitry capable to handle the rated power of a charger. It will only absorb as per the load connected to charger i.e. the vehicle itself with its own circuit characteristics.
7. There is no global standards for chargers below 120 VDC
8. Currently most 2 Wheeler and 3 Wheeler manufacturers use lead acid batteries which cannot be fast charged due to constraints in chemistry
9. Even in conditions of high ambient temperature BMS will not allow the charger to charger EV at faster rate which was also the case with OLA's Nagpur pilot. So, how fast an EV will charger shall also depend on thermal management of battery
10. In India CharIn is looking for CCS standards below 100VDC for 2 Wheelers and 3 Wheelers

4. Exicom Tele-Systems Limited	
Date	05 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	Plot No-77A, Sector-18, Sector 18, Gurugram, Haryana 122015
Agenda	Stakeholder consultation with CEA to gain insights on Standards for Charging Infrastructure & Supply Chain"
Participants	Exicom : ▸ Mr. Priyank Agarwal ▸ Mr. Akshay Ahuja P-Manifold- ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani

The following points were highlights of the discussion:

1. Li-ion batteries are the only alternative for use in commercial scale as of now due to lower costs, wide range of applications such as electric vehicles and storage solutions.
2. Exicom has supplied over 600MWh of Li-ion batteries mostly for telecom infrastructure
3. Exicom intends to establish 1GWh of Li-ion battery assembly unit
4. As per recent meetings, it has been confirmed that India is looking forward to bring in a 4th Standard for EVSE. Other three being CCS, CHAdeMO and GB/T
5. It has been mentioned that the instruction has come from NITI Aayog for developing a new IS standard for EVSE.
6. Exicom is ready to adapt to any standard and currently is complying to Bharat Charger Specs and in process of development of CCS chargers
7. It was also informed that Exicom is a member of standardization committee for EVSEs
8. The EESL tender has witnessed 14 participants and Exicom was allotted to supply 125 chargers to be installed at govt. buildings in Delhi-NCR
9. Other manufacturers don't have products ready as most of them being MNC's don't have chargers of ratings below 100 VDC.
10. Delta, RRT, BHEL Mastech were a few competitors in the tender
11. Due to discussions of a new standard for EVSE, industry has lost clarity of which way to move forward and align their supply chains
12. Most of the components used in EVSEs of Exicom are domestically manufactured and use advanced circuit components such as IGBTs while its competitors are still relying on MOSFET
13. Certain components such as connectors needs to be imported as they comply to certain standards such as GB/T for DC-001 which is a Chinese standard and not manufactured in India

5. BSES Rajdhani	
Date	05 April 2018
Time of Meeting	13:30 – 18:00 hours
Place of Meeting	BSES Bhawan, Nehru place, Delhi
Agenda	Stakeholder consultation with BSES to validate study done for BEE on "Techno-commercial assessment for charging infrastructure"
Participants	BSES: ▸ Mr. Abhishek Ranjan ▸ Mr. Chetan Pathak ▸ Mr. Naveen EY: ▸ Mr. Kaustuv Mohapatra ▸ Mr. Tanmay Nag ▸ Mr. Raghav Bhasin P-Manifold: ▸ Mr. Rahul Bagdia
The following points were highlights of the discussion:	
Points from BSES's meeting with Ministry of Power -	
1. Upon the role of discom in charging infrastructure, BSES suggested to MoP that prior permission to establish charging station involving technical feasibility should be taken from discoms. 2. MoP is considering an initial one year charging infrastructure deployment through PSUs - a. 10 cities (population > 4 Million) – 1200 charging stations b. 1 charging station at every 3-4 km c. INR 240 Cr investment 3. MoP is considering to put an upper cap on the price which discom will levy from the charging station.	
Points from EY's discussion with BSES -	

1. DERC has extended ToD for all consumers except single phase domestic consumers -
2. ToD slabs are applicable in the following slots-

   a. Peak time :13:00 to 17:00 & 22:00 to 1:00 – 20% surcharge
   b. Off Peak : 3:00 to 9:00 – 20% rebate

- V2G without ancillary services has no benefit to the consumer

3. Because of solar uptake, smart bidirectional meters have been installed even though they are in miniscule percentage
4. BSES has requested CEA to include the parameters of communication link in their report, this will help BSES to identify the increasing load.
5. Earlier BSES used to depreciate a capex over 12 years, and it used to take close to 12 years for asset recovery. But now, assets are getting redundant in 4 years and BSES/DISCOMs don't have a long time frame. Network needs to be upgraded regularly.
6. Following questions were posed -

   a. EV usage is random and dynamic, so will early network recovery be possible?

   b. Regulator should permit to socialize the cost if DISCOMs have to recover sooner. Due to this non-EV users will see impact in their tariffs

c. The load will be at 6% load factor in terms of energy demand but to cater to that there'll be an addition of 26-27% to network upgrade. Now, how the differential will be recovered?

7. There can be no fixed charges for EVs and single point delivery system.
8. Losses in residential are observed to be higher compared to industries because of distribution and localization.
9. DERC Public charging tariff for EV is incentivized at INR 5.5/KWh. Personal home charging is as per the home tariff.
10. BSES has recommended to update supply codes as per EVs

Q&A-
1. What significant patterns in load growth have been observed in the past few years? 1.1. AC has significant impact but it is covered below 4% 1.2. Solar penetration is reducing load. BSES has done 600 installations, 21 MW and another 20 MW is in pipeline. 2. Any benchmarks on power infrastructure investments in NEP or other govt. documents to act as guideline to plan EV related grid expansion? 2.1. Not aware of such guidelines on BSES, but Govt. is quantifying in Uday scheme certain specific investments to be made. Input distribution franchise will need to invest based on CAPEX. 3. What changes envisaged in providing new connections for charging to following types of customers – meter, tariff, connected load, supply point, DT limits etc. 3.1. Smart Meter and V2G: 3.1.1. Development of ancillary services is crucial and will provide advantage to the consumer. 3.1.2. Because of solar uptake, smart bidirectional meters have been installed even though they are in miniscule percentage. 3.2. Compatibility of currently procured smart meters with EVs? 3.2.1. EESL's initial tender was for 2G meters which they revised to 3G with dual (2G & 3G) compatibility. Success of the meters is yet to be determined 3.2.2. Problems are arising with the integration to the cloud platform 3.2.3. Smart Meters have two ledgers export and import which need to be enabled for V2G. 3.3.Charging network companies are pricing their analytical platforms exorbitantly equal to the electricity rate which should be capped. DISCOMs need real time Overloading/under loading data which network providers cannot provide, they are more customer centric. 3.4. If charging mandate is declared as service then BSES is ready to tie up in long term contract with land owner and will provide operation and technical support. Chargers will be procured from empaneled vendors. 3.4.1. Revenue sharing will depend on the footfall 3.4.2. Income from this source will be considered as Non-tariff income. 3.4.3. Priority 1: Charging station assets to be capitalized. Comments by stakeholders is that it is not a level playing field. 3.4.4. Priority 2: If it is owing to the conventional business then 60 % profit will be passed on ARR and 40 % can be retained. 3.4.5. Priority 3: Land owner takes connection from DISCOMs and DISCOMs performs O&M. 40 % profit will be passed on ARR and 60 % can be retained. 3.4.6. If charging station is not considered as services then BSES will be interested in 100% capitalization. 4. Whether need felt for separate feeders for EV charging – what different characteristics and SLAs? 4.1. No need is felt. Will be managed on a case to case basis 5. What POV on tariff structure for HHs for self-charging at homes – ToD (kVAh vs. kWh), smart meter, etc. 5.1. There should be a shift from ToD to ToU. This will enable decision making with respect to local grid. ToU enablers are CMS (central monitoring system) and Smart meters.

6. Central Electricity Authority of India (CEA)	
Date	18 April 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	Sector B 1, RK Puram, New Delhi, Delhi 110066
Agenda	Stakeholder consultation with CEA to gain insights on standards for interconnection of EV Charging Infrastructure.
Participants	CEA : ▸ Ms. Seema Saxena, P-Manifold- ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani

The following points were highlights of the discussion:

1. Technical Standards for flicker, Harmonic Injection, etc. has been incorporated in Distributed Energy Regulations.
2. Dr. Sajid Mubashir from DST is drafting technical standards for EVSE.
3. Change in operational temperature from 0 to 55 Degree Celsius for global standards that are being adopted for EVSE .
4. Standards for charging of fleets and heavy vehicles is yet to be determined.
5. Permission to set up of charging infrastructure needs to be taken from DISCOM.
6. Testing centers to be located across India and not limited to ARAI & IIT Madras.
7. CCS standard will be adopted as minimum for public charging standards. Market is open to adopt any other standards as well.

7. NTPC	
Date	18 April 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	Plot No. A-8A, Block A, Sector 24, Noida, Uttar Pradesh 201301
Agenda	Stakeholder consultation with NTPC to gain insights on PSUs POV around investing in EV Charging Business
Participants	NTPC: ▸ Mr. Anil Kaushik ▸ Mr. Anurag Singh P-Manifold- ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. NTPC has signed MOU with Jabalpur STU for setting up EV charging station. Inclined to do more POCs. 2. NTPC is interested in Energy Operator opportunity	

8. RTO, Nagpur	
Date	19 April 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	Dipti Signal Road, Near Water Tank, Nagpur, Maharashtra 440035
Agenda	Stakeholder consultation with RTO, Nagpur to gain insights on the Nagpur case study for study done for BEE on "Techno-commercial assessment for charging infrastructure"
Participants	RTO : ▸ Mr. Shivaji Jagtap P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. Nagpur EV adoption model and its impact on grid -- model inputs and outputs vetted for overall transportation data of Nagpur 2. Nagpur has taken out tender for small e-Buses	

9. Nagpur Metro Rail Project	
Date	19 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	Metro House, Bunglow No: 28/2,, Anand Nagar,C K Naidu Road, Civil Lines, Nagpur, Maharashtra 440001
Agenda	Stakeholder consultation with Nagpur Metro to gain insights on the Nagpur case study for study done for BEE on "Techno-commercial assessment for charging infrastructure"
Participants	Nagpur metro : ▸ Mr. Mahesh Gupta P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. Nagpur Metro keen to have e-Buses and e-3Ws for last mile connectivity to and from its metro stations	

10. ACME	
Date	19 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	152, Sector 44 Rd, Kanhai Colony, Kanahi, Gurugram, Haryana 122003
Agenda	Stakeholder consultation with ACME to gain insights on EVSE and broader Charging Eco-system and Supply Chain Readiness
Participants	ACME : ▸ Mr. Anil Chutani P-Manifold- ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani

The following points were highlights of the discussion:

1. Bharat Charger Standards are not mature considering non-standard connector such as IEC 60309 which has not been used anywhere in the world and is not designed for the intended purpose
2. Standards of Bharat Charger prescribe a locking mechanism that is not provided by IEC 60309 connector
3. No. of output charging point should not be fixed such as has been fixed to be three in case of AC001
4. Connector for 3.3 KW output of DC001 is yet not defined
5. DHI notification of 13 March 2018 suggests multiple standards
6. Either India should follow one global standard or derive from one from them
7. If the Indian market continues with the multiple standards, in next 10 years there will be inter-operability issues. This situation will be similar to what cellphone users faced for incompatible chargers during late 90s. The automobile OEMs would have to play important role in setting up charging stations to facilitate the sale of their EVs.
8. IEC 62196 Type 2 is a better solution as connector for 3 wheelers and 4 wheelers
9. CCS Combo Type 2 should be adopted for fast charging of 4 wheelers and CHAdeMO for heavy vehicles
10. ACME is looking to manufacture both AC&DC chargers
11. 50% domestic content requirement should be adequate
12. ISO 15118 is an international standard defining a vehicle to grid (V2G) communication interface for bi-directional charging/discharging of electric vehicles which should be adopted by India.

11. Kinetic Green	
Date	27 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	Innovation Park, D-1 Block Plot No.18/2, 411019., MIDC, Bhosari, Pimpri-Chinchwad, Maharashtra
Agenda	Stakeholder consultation with Kinetic Greens to gain insights on the e-3W Supply Chain Readiness and Learning from Nagpur pilot"
Participants	Kinetic Greens : ▸ Ms. Sulajja Firodia P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	

1. E-Rickshaw with battery swapping ready and under testing at IITM. Also e-Auto battery swapping prototype ready and to go for testing.
2. All components but motor and motor controller are currently getting imported
3. Financing of e-3W is missing link to enable big adoption

12. ARAI	
Date	27 April 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	Survey No.102, Paud Road, Kothrud, Rambaug Colony, Vetal Hill, Pune, Maharashtra 411038
Agenda	Stakeholder consultation with ARAI to gain insights on Testing Standards for EV Charging
Participants	KARAI : ▸ Dr. Anand Deshpande P-Manifold- ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani

The following points were highlights of the discussion:

1. GOI is aligning with European Regulations (UNEC).
2. AIS 138 (Part-1 and Part-2) prepared by ARAI led Committee has been passed on to DST/ BIS for incorporating it into IS standards (ETD-51).
3. A custom Charging standard (communication protocol + Connector) for Medium and High voltage is a possible direction that India can take and under high level discussion.
4. Car OEMs may consider to adopt higher than 100V architecture.
5. ARAI has a simulator that can simulate a Charger for EV testing and can an EV for Charger testing
6. Indian testing standards for EVs are aligned with global standards and India has all testing infra and skills
7. Nail penetration test is important and is already included and happening
8. UNEC has a mechanism called GTP (Global Technical Regulation) through which it can harmonize the standards globally. It has been done for Motors.
9. Life cycle test and temperature performance test for LIBs are being performed as asked by OEMs, but are not mandatory.
10. Group/ bulk chargers will need separate standards.

13. CHAdeMO	
Date	17 May 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	Conference call
Agenda	Stakeholder consultation with CHAdeMO association to validate Japan's electric mobility landscape study done for BEE on "Techno-commercial assessment for charging infrastructure"
Participants	CHAdeMO : ▸ Mr. Yoshida San, Secretary General EY: ▸ Mr. Kaustuv Mohapatra ▸ Mr. Tanmay Tyagi ▸ Mr. Tanmay Nag P-Manifold- ▸ Mr. Rahul Bagdia
The following points were highlights of the discussion:	

1. Buses will adopt DC charging (Pantograph) without connectors because of safety concerns over human operation.
2. AC standards charging standards in Japan are based on IEC standards
3. Japan has an unbundled electricity market and pricing is based on market forces.
4. There are three types of charging station business models prevalent in Japan-
   a. Gas station model: a particular fee is charged by the operator similar to gasoline station model
   b. Monthly subscription: An EV user can take a subscription and use charging facilities for a month etc. similar to telecom model
   c. Free at commodity locations like malls, stores but user has to shop.
5. CHAdeMO supports V2X functionality
6. Parking areas at companies will most likely have slow charging facility.
7. Communication protocol is different in CCS's AC and DC

14. DERC	
Date	18 May 2018
Time of Meeting	11:30 - 14:00 hours
Place of Meeting	DERC Office, Viniyamak Bhawan, Basant Kaur Marg, Block C, Shivalik Colony, Malviya Nagar, New Delhi, Delhi 110016
Agenda	Stakeholder consultation with DERC to validate study done for BEE on "Techno-commercial assessment for charging infrastructure"
Participants	DERC: ▸ Sh. B.P. Singh (Member) ▸ Sh. Surendra Edupghanti, Secretary ▸ Sh. R.K. Mehta Executive Director (law) ▸ Sh. Mahender Singh, Executive Director (Tariff) ▸ Sh. U.K. Tyagi Executive Director (Engg.) EY: ▸ Mr. Ashish Kulkarni ▸ Mr. Kanv Garg ▸ Mr. Kaustuv Mohapatra ▸ Mr. Sushovan Bej ▸ Mr. Tanmay Tyagi ▸ Mr. Tanmay Nag
The following points were highlights of the discussion:	

1. 1. EY presented to DERC-
   a. Global review of the electric mobility study
   b. Key initiatives by Govt. of India to develop the sector
   c. mpact assessment of electric mobility
   d. Business models developed by the EY team
2. DERC has mandate to decide the tariff for EV charging.
3. Points on Standards:
   a. Developing new standards for EV charging is not necessary
   b. The decision to choose a standard should be with the installer of the charger.
   c. Govt. should take a neutral stand on the standards and let market forces decide.
4. Main issue with charging infrastructure is the availability of the land
5. Initial deployment of charging infrastructure should not be considered as a profit motive but rather to build market and get customers used to the e-mobility.
6. DERC initially focused on E-rickshaws as they were presently operating in Delhi in around 1-1.5 Lakhs in number. DERC suggested that initially chargers should be placed in locations where currently E-rickshaws are available. DERC gave the following statistics -
   a. Each e-rickshaw uses 7 units/day
   b. For 1.5 Lakh rickshaws it is ~ 1 million units
   c. This load is present and is not straining the system
   d. Total loss estimated to discoms through e-rickshaw's electricity theft is around 200 cr.

7. DERC has observed that public sector authorities are reluctant to give land for chargers without financial motives.
8. E-mobility can learn from telecom, dish TV or cab aggregator models as they initially offered heavy discounts and low tariffs to create a market demand.
9. Member planning DERC stated that he would prefer to have a portable charger in the car than to go a few Kms for charging. At the end of day people will shift to EVs if they'll get easy access mobility and better accessibility.
10. Traffic conditions should be taken into the performance and range of a battery as EVs will operate in urban areas.
11. Discoms will gain by reducing commercial losses.
12. Separate charger for separate vehicle category should be defined
13. There should a uniform tariff structure across the country
14. In Delhi all meters are ToD enabled just needs to be programmed
15. Blended tariff is at 5-5.5INR
16. Taxes should be put on petrol/diesel vehicles rather than imposing heavy taxes on HEV

15. TATA Motors	
Date	30 May 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	NA
Agenda	Stakeholder consultation with TATA motors to gain insights on the Electrical vehicle OEM on charging infrastructure
Participants	CTata Motors : ▸ Mr. Ajit Kumar Jindal P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	

1. The key trends which will have a significant effect on the Charging Infrastructure
   a. Higher range of the vehicle
   b. Bigger Battery Size triggered by reduction in the battery prices
   c. Reduced Charging Time
2. OEMs have a 500km range benchmark to match the ICE
3. Success Factors for the Charging Infrastructure for CVs and PVs
4. Suggested that we should have a common standard for fast charging across various categories of vehicles

16. E Connectivity India Pvt. Ltd	
Date	30 May 2018
Time of Meeting	10:30 – 12:00 hours
Place of Meeting	NA
Agenda	Stakeholder consultation with TE Connectivity India Pvt. Ltd. to gain insights on the charging connectors and standards for India
Participants	CTE Connectivity India Pvt. Ltd.: ▸ Mr.Vinod Viswanath P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. Charging inlets performance, customization and flexibility 2. Charging cable safety and reliability	

17. PGCIL	
Date	14 June 2018
Time of Meeting	11:00 – 13:00 hours
Place of Meeting	Power grid's corporate office, Gurugram
Agenda	Stakeholder consultation with PGCIL to validate study done for BEE on "Techno-commercial assessment for charging infrastructure"
Participants	PGCIL: ▸ Sh. S. Victor P. Selvakumar ▸ Dr. Rajesh Kumar Panda EY: ▸ Mr. Kaustuv Mohapatra ▸ Mr. Sushovan Bej ▸ Mr. Tanmay Tyagi ▸ Mr. Tanmay Nag
The following points were highlights of the discussion:	

1. Power grid is currently working in the following locations on charging infrastructure projects:

   a. Hyderabad – Deploying chargers on the metro corridor with L&T and Hyderabad metro rail corporation (HMRC)

   - PGXCIL will own and operate the stations
   - PGCIL has adopted a lease model and HMRC may give land free for 2 years

   b. Chennai

   c. Delhi

   d. Kochi

   e. Gurgaon – Project is in collaboration with IOCL and DMRC following a revenue sharing model

   f. Mumbai-Pune corridor

   g. Bhubaneshwar-Puri corridor

2. PGCIL has categorized real estate for charging infrastructure projects as per the following three categories:

   a. Barren Land – type of land without basic construction and amenities. The lease expense for such a land shall be: 30 /sq. feet

   b. Built up land – areas such as parking with basic construction but little or no basic amenities like electricity, water etc. The lease expense for such a land shall be: 70-80 /sq. feet

   c. Super built-up land – Area like metro parking where there is easy access to electricity and other amenities. The lease expense for such a land shall be:100-130 /sq. feet

   d. Basements - As per the CEA safety regulations, basements are not preferred to install EV chargers. This is primarily due to the water clogging conditions.

3. It is necessary to implement differential tariff for following reasons-

   a. Personal EV owners are expected to most likely charge their vehicles at night.

   b. 'Time of use' regime for EV charging can help balancing the load curve during peak and off peak hours.

   c. A low differential pricing in low footfall areas will enable the traffic density to shift from high pricing in high footfall areas.

4. EV charging is ideally suited for maximizing capacity utilization from renewable (solar) energy plants. Peak load from such plants can be utilized effectively through EV charging.
5. BOOT model is not expected to be viable due to high electric infrastructure costs.
6. Vehicle to Grid:

   a. V2G implementation without government incentives will be difficult. This is primarily because EV users will need to install a separate 30,000-40,000/- costing meter to enable V2G.

   b. One thought is to sell V2G enabling devices along with the vehicle itself.
7. Standards:

   a. It is better to adopt international standards as it promotes interoperability.

   b. Moreover, most of our car makers in India are international players supporting international standards.

   c. CEA has almost mandated CCS standards.
8. Collaboration:

   a. PGCIL is actively exploring collaboration opportunities. They are in discussions with various STUs, Oil & Gas players, Discoms, Railways, Airport authorities, Municipalities etc. to build charging infrastructure.

   b. PGCIL is only working with public sector entities and has not been approached for any public private partnership.

   c. With Smart E, PGCIL has suggested to buy batteries with almost 50: 50 cost split.
9. Public EV charging stations should be adopted to deal with real world parking issues, like that observed in CNG stations.
10. Revenue sharing between various business entities will depend upon the locations of deployment. Factors like land will be a major determinant.
11. The current EV charging market is observed to be about interest rather than business value.
12. Tariff charged to user should be a factor of parking, service, lease and electricity costs.
13. Electrical infrastructure is a major cost component of the charging infrastructure, with component such as –

    a. 11 kV or 33 kV line

    b. Transformer

    c. Small substation etc.
14. Metro authorities use two kinds of electrical connections –

    a. Primary line (25kV) – Used for train operation

    b. Auxiliary line – This will be used for EV charging
15. MoP should consider amendment in the Electricity act regarding EV operations. Act should specify EV charging is not trading and should allow EV charging without a license.
16. Points on Model:

    a. It will be difficult to differentiate between an EV load and other loads, unless to install a separate meter for EV.

    b. PGCIL was skeptical on the validity of preferential tariff and its implementation.

    c. Government should consider tax free lease for EV charging. When no subsidy is considered for electric mobility then tax should be waived off to reduce costs.

    d. Consider at-least 300 sq. feet for land and 50 KW charger (18 Lakhs).

    e. Losses should consider transformer losses as well.

    f. Rename mark-up as service cost.

    g. Model should include shared manpower costs.

    h. Since model's accounted capex is low we should take into account other additional costs such as fire extinguisher costs, lights, water supply etc.
17. i. Site construction costs should be accounted into the model like shed, tiles, roof etc.

18. Sun Mobility	
Date	20 June 2018
Time of Meeting	10:30 - 12:00 hours
Place of Meeting	Epsilon Office, A1 First floor, 1, Kariyammana Agrahara, Yemalur, Bengaluru, Karnataka 560037
Agenda	Stakeholder consultation with Sun Mobility to gain insights on e-3W and charging perspective
Participants	Sun Mobility.: ▸ Mr. Yuvraj Sarda P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. 3W market landscape and challenges were discussed 2. OEM Majors are required to invest INR 50,000 for Bharat VI standard conversion, they shall resist adoption of EV. 3. A typical OEM shall require 7 years to recover increased capital investment in Bharat VI standards 4. Battery swapping has the lowest upfront cost and lowest refueling time	

19. GrinnTech	
Date	Multiple meetings held
Time of Meeting	NA
Place of Meeting	NA
Agenda	Stakeholder consultation with GrinnTech to gain insights on Battery OEM Supply Chain Readiness
Participants	Sun Mobility.: ▸ Mr. Yuvraj Sarda P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. Frequent share of info and knowledge on Batteries and EV ecosystem	

20. IIT-Madras	
Date	Multiple meetings held
Time of Meeting	NA
Place of Meeting	NA
Agenda	Stakeholder consultation with IIT-Madras to gain insights on Battery OEM Supply Chain Readiness
Participants	SIIT-M : ▸ Dr. Prabhjot Kaur P-Manifold: ▸ Mr. Rahul Bagdia ▸ Mr. Kunjan Bagdia ▸ Mr. Rishabh Badlani
The following points were highlights of the discussion:	
1. Frequent share of info and knowledge on Batteries and EV ecosystem	

21. Madhyanchal Vidyut Vitran Nigam limited (MVVNL)	
Date	24 October 2018
Time of Meeting	12:00 – 14:00 hours
Place of Meeting	Madhyanchal Vidyut Vitran Nigam limited head office, 4-a, gokhale marg, Lucknow :- 226001
Agenda	Stakeholder consultation with MVVNL for BEE study on "Techno-commercial assessment for Electric vehicle and charging infrastructure"
Participants	MVVNL: ▸ Sh. S.K. Singh (Director, Technical) ▸ Sh. B.P. Saini (Director, Commercial) EY: ▸ Mr. Tanmay Nag ▸ Ms. Jagrati Yadav

The following points were highlights of the discussion:

1. EY team presented the following to MVVNL -
   a. Overview of the scope of the study being conducted with BEE
   b. Parameters being assessed in the Lucknow city level assessment
   c. Overview of electric mobility landscape in India
2. Discussion was based on the adoption and feasibility of charging infrastructure in Lucknow
3. It was deliberated that different charging solutions needs to be developed for different kinds of vehicles
4. MVVNL recommended that charging infrastructure needs to be established around the city to cater to the issue of range anxiety
5. It was deliberated that private vehicle will mostly charge at home, hence such a pattern needs to be studied and will be important for the discom
6. Land was identified as a challenge for the uptake of charging infrastructure and it was recommended that new ecosystems needs to be developed for electric mobility. MVVNL recommended that substation land is an ideal location to install chargers.
7. It was further deliberated that swapping as a solution would emerge soon and is ideal for light vehicles such as e-rickshaws and 2-wheelers

22. Uttar Pradesh New & Renewable Energy Development Agency (UPNEDA)	
Date	26 October 2018
Time of Meeting	16:00 - 18:00 hours
Place of Meeting	Bapu Bhawan, Secretariat, Lucknow
Agenda	Stakeholder consultation with UPNEDA for BEE study on "Techno-commercial assessment for Electric vehicle and charging infrastructure"
Participants	UPNEDA: ▸ Smt. Amrita Soni (Director) ▸ Sh. Alok Kumar (Secretary/CPO) ▸ Sh. Ashok Srivastava (Project officer) ▸ Smt. Namrata Kalra (Project officer) EY: ▸ Mr. Tanmay Nag ▸ Ms. Jagrati Yadav
The following points were highlights of the discussion:	

1. EY team presented the following to UPNEDA -
   a. Overview of the scope of the study being conducted with BEE
   b. Parameters being assessed in Lucknow city level assessment
   c. Overview of electric mobility landscape in India
2. It was deliberated that to solve the chicken and egg issue of chargers and vehicles, available and accessible charging stations shall be adopted before electric vehicles.
3. Alliances on the supply side to ensure supply of appropriate EVs and charging infrastructure facilities, a city level collaborative effort on the facilitation side and awareness creation about electric mobility on the demand side are the three necessary factors to enable the ecosystem.
4. To set up charging stations, availability of accessible land is a major hurdle, which can only be solved by a collaborative approach of the city level stakeholders such as the urban, transport and power utilities.
5. Further, city level administrations should facilitate by conducting assessments such as location, feasibility and technology assessments to address needs, gaps and develop a structured roadmap to deploy electric mobility. Please find attached a presentation on city level perspective highlighting the assessments.
6. It was deliberated that every Indian state will have different mobility and infrastructure requirements and hence considering no size fits all approach, customised policies at a state level is more appropriate than at a national level.
7. Authorities should look beyond the present higher upfront costs of an EV and should focus on entire life cycle/operational feasibility of an EV compared to an ICE vehicle.
8. The total cost of ownership of an EV is very low by the virtue of its lower maintenance and cheap electricity for charging. Hence, with a lifecycle approach, an EV is feasible, sustainable and efficient compared to an ICE vehicle. This can be proven with an observation of rapid uptake of EVs in fleet businesses.

Notes

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