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Florence School of Regulation

CHARGING UP INDIA'S ELECTRIC VEHICLES

INFRASTRUCTURE DEPLOYMENT & POWER SYSTEM INTEGRATION

RESEARCH REPORT

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About this report

The Florence School of Regulation, as part of its FSR Global initiative, has prepared this report with the aim to consolidate and frame the debate on electric vehicles in India from two key perspectives of infrastructure deployment and power system integration. The report is a consolidation of dialogues and research undertaken by the team over the last few months in consultation with multiple and multinational stakeholders from the power sector. The report will enable the development of state specific electric vehicles reports in collaboration with key partners working on this topic in the future.

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FOREWORD

"Life is divided into three terms - that which was, which is, and which will be. Let us learn from the past to profit by the present, and from the present, to live better in the future." - William Wordsworth

The era of electric vehicles is rapidly approaching. What was a futuristic dream just a few years ago is now a reality. India would have to play a pivotal role in this transition to succeed globally. The Government of India has already taken several steps for enabling the transition to electric mobility; nevertheless, there is always a scope to do more. A vital aspect of facilitating electric mobility is to ensure the preparedness of our EV charging infrastructure and the power sector. Herein lies the crucial question: How can we achieve this? And what lessons can we learn from more mature EV markets?

This report by the Florence School of Regulation addresses these questions by presenting a toolbox of solution choices and recommendations for addressing the issue of EV charging infrastructure deployment and integration of EV into the power system. A comprehensive discussion is presented on policy enablers and business model innovation for charging infrastructure deployment as well as insights on managing additional EV load in the power system and future vehicle0-to-X applications. The study is founded on existing literature and international practices to draw recommendations to support the development of the EV market in India.

I found the report to be very timely and relevant to steer the discussions amongst all stakeholders who wish to contribute to India's shared, connected and electric mobility transition.

(Amitabh Kant)

Dated: 04-10-2019
Place: New Delhi

केन्द्रीय विद्युत विनियामक आयोग
CENTRAL ELECTRICITY REGULATORY COMMISSION

सत्यमेव जयते

P. K. Pujari
Chairperson

के वि वि आयोग
CERC

11th October 2019

Foreword

Deployment of electric vehicles have evoked significant interest in India in the past few years. It is being seen not only from the point of view of environment but also energy security.

Some of the challenges facing the deployment of electric vehicles are availability of innovative business models for adoption for electric vehicle and charging business as well as its impact on the power demand and grid security. It is important that academic and research institutions pitch in with their academic and research capabilities to address these challenges and provide viable solutions.

I am pleased to note that Florence School of Regulation (FSR) is publishing this report on "Charging up India's Electric Vehicles: Infrastructure Deployment & Power System Integration" with the objective of providing valuable insights for quickening the pace of electric vehicle adoption in the country. I am sure this will serve as a useful reference document for the key stakeholders in the industry for developing innovative business model and practices for ensuring its seamless integration with the power system.

I congratulate the team FSR for this effort.

(P. K. Pujari)

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Abbreviations

AMI	Advanced Metering Infrastructure
ANM	Active Network Management
AP	Andhra Pradesh
APERC	Andhra Pradesh Electricity Regulatory Commission
B2B	Business to Business
B2C	Business to Consumer
BCS	Battery Charging Station
BESCOM	Bangalore Electricity Supply Company
BEV	Battery Electric Vehicles
BM	Business Model
BSO	Battery Swapping Operator
CBA	Cost-Benefit Analysis
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CPP	Critical peak pricing
DG	Distributed Generation
DISCOM	Distribution company
DL	Delhi
DT	Dynamic Transformer
EESL	Energy Efficiency Services Limited
EO	Energy Operator
EV	Electric Vehicles
FAME	Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles
FOR	Forum of Regulators
GOI	Government of India
GST	Goods& Services Tax
ICE	Internal combustion vehicle
IEA	International Energy Agency
IEX	Indian Energy Exchange
KA	Karnataka
KL	Kerala
kW	Kilowatt
kWh	Kilowatt Hour
MH	Maharashtra
MNRE	Ministry of New and Renewable Energy
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MSPI	Ministry of Statistics and Program Implementation
MWh	Megawatt Hour
NEMMP	National Electric Mobility Mission Plan
NITI Aayog	National Institute of Transforming India
NPC DC	Non-Peak Coincident Demand Charges
NTPC	National Thermal Power Corporation
PC DC	Peak Coincident Demand Charges
PCS	Public Charging Station
PG&E	Pacific Gas and Electric
PHEV	Plug-in Hybrid Electric Vehicles
PSU	Public Sector Undertaking
PTR	Peak Time Rebate
PV	Photovoltaic

RMI	Rocky Mountain Institute
RTP	Real-Time Pricing
SCE	Southern California Edison
SGST	State Goods & Services Tax
TCO	Total Cost of Ownership
TOU	Time of use tariff
TOD	Time of day tariff
TRAI	Telecom Regulatory Authority of India
TS	Telangana
UDAY	Ujwal DISCOM Assurance Yojana
UK	United Kingdom
UP	Uttar Pradesh
USA	United States of America
USD	United States Dollar
V2B	Vehicle to Building
V2C	Vehicle to Community
V2G	Vehicle to Grid
V2H	Vehicle to House
V2L	Vehicle to Load
V2X	Vehicle to X
VCC	Variable Capacity Contract
VPP	Variable Peak Pricing

Executive Summary

India has embarked on an ambitious path towards more sustainable mobility by promoting the electrification of its transport sector. The push for electric vehicles is driven by the global agenda established under the Paris Climate Agreement to reduce carbon emissions, and by the national agenda, which includes improvement of air quality in its urban areas, reduction of dependence on oil imports, and encouragement of the local EV manufacturing sector.

The country has set a target of 30% electric vehicle sales across all vehicle types by 2030. To achieve this, NITI Aayog, with the support of select central ministries, has been serving as the nodal agency to develop the electric mobility plan for India. Although the e-mobility plan is established at central level, the onus is on the state governments, which have to develop policies and regulatory frameworks to enable the adoption of EVs and the deployment of charging infrastructure in their respective states.

India has over 250 million vehicles, and this fleet is dominated by 2-wheelers, accounting for 78% of the total vehicles. Currently, EVs represent a minimal share with approximately 750,000 vehicles. Amongst the different vehicle characteristics, public buses, taxi fleets, 2-wheelers and three-wheelers are expected to be the first adopters of EVs. As the country is at an early stage of EV deployment, public charging infrastructure is still limited. In this regard, the Ministry of Power has already identified 9 major cities and 11 intercity routes as pilots to enable EV charging infrastructure. Similarly, a number of states have also started introducing policies to promote EV adoption and charging infrastructure deployment.

The rapid growth in EV uptake required to reach India's policy targets will have to address two major challenges. **The first challenge** is ensuring the deployment of the ***charging infrastructure*** required to serve the needs of the ever-growing number of EVs. This raises two questions**:**

- What policies and regulatory frameworks are required to enable the efficient deployment of charging infrastructure?
- What business models can reach the sufficient coverage of charging infrastructure that meets the needs of the EV user?

The second challenge is the integration of the EVs into the power system securely and efficiently. This raises two questions:

- How can the potential impacts of the additional EV load in the power system be managed?
- How can the flexibility potential of Vehicle-to-X (V2X) be unlocked?

This study aims to provide a vision for the future of EV charging infrastructure deployment and power system integration via a ***toolbox*** consisting of solution choices and recommendations for addressing each of the questions mentioned, by:

- assessing the current state and national policies for EV charging infrastructure deployment;
- identifying business models being implemented in India and key business innovation trends from practices in countries at the growth stage of EV adoption;
- assessing current practices for managing the impacts of the additional EV load in the power system and identifying insights from international practices; and
- providing insights on unlocking the flexibility potential of EVs with V2X capability.

1. *What policies and regulatory frameworks are required to enable the efficient deployment of charging infrastructure?*

EV policies in India are proactively pursuing the development of EV charging infrastructure. Under India's constitutional structure, the responsibility of policymaking for EV charging infrastructure deployment is shared between the central government and the state governments. Consequently, several Indian states have developed EV policies. Furthermore, the central government's Ministry of Power has also introduced guidelines for the deployment of public charging infrastructure. These policies cater to the charging infrastructure used for both fleets (B2B) and individual consumers (B2C). The recommendations can be categorised as those for enabling the supply-side (the EV charging service provider) and the demand-side (user of the EV charging infrastructure).

<u>*The recommendations on the supply-side*</u> can be further categorised based on whether these are applied at the introductory, growth or a mature stage of market development.

During the introductory and the growth stage, 1) it is recommended to mandate a time-bound, single-window clearance for permissions required to develop charging stations; 2) policymakers should clarify within the EV policy the long-term role of state-owned utilities that are at the forefront of EV charging station deployment. Furthermore, as the EV charging market takes off and starts to follow demand, 3) it can be recommended to reassess the approach to EV charging tariff structure periodically; 4) Incentives for installing EV chargers should be recalibrated to ensure that coverage in remote or low demand areas is not forgotten; 5) the EV policy must include some provisions for the development of frameworks to ensure ethical handling and use of user data and privacy.

As the market nears the high level of maturity, 6) policymakers must consider developing a regulatory framework for the utilisation of V2X capabilities, which can be a valuable resource. A cost-benefit analysis can become the basis for deciding the extent to which V2X should be enabled and incentivised.

__The demand-side__ can be enabled by improving the customer experience in terms of ease of use.

From this perspective, 1) EV policy should specify a comprehensive set of minimum payment methods to be made available to the consumer at the charging station. 2) Provisions should be developed for minimum facilities required at the public charging station based on the Government of India guidelines. 3) A harmonised intra/inter-state registration process for using charging infrastructure should be developed, thus allowing the use of the wider network. 4) Finally, it can also be recommended that policymakers proactively take a step within the EV policy by mandating minimum standards for a mechanism to address consumer complaints.

Table 1 provides summary of the assessment results.

Table 1: Summary of assessment results

Dimensions	Elements	KA	MH	AP	TS	KL	DL	UP	UK	GoI
Enabling EV charging on supply-side	Definition of fundamental market design framework to limit distortions and entry barriers	Treated	Treated	Treated	Treated	Treated	Treated	Treated	Treated	Treated
	The incentive for launching the EV charging market	Treated	Treated	Treated	Treated	Treated	Treated	Treated	Treated	Treated
	Prioritisation in terms of EV characteristics and social geography	Treated	Not treated	Treated	Treated	Treated	Treated	Treated	Treated	Treated
	Elimination of administrative barriers for establishing charging stations	Not treated	Treated	Treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated
	Mandate on user data sharing and privacy	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Treated
	Mandate on the utilisation of V2X capabilities	Not treated	Not treated	Treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated
Enabling EV charging on demand-side	Technical standardisation of chargers for interoperability	Treated	Not treated	Treated	Treated	Treated	Treated	Not treated	Not treated	Treated
	The mandate for the development of digital platforms and database management systems	Not treated	Treated	Treated	Not treated	Treated	Treated	Not treated	Not treated	Treated
	Specification of the use of a wide range of payment methods	Not treated	Not treated	Not treated	Not treated	Not treated	Treated	Not treated	Not treated	Not treated
	Specification of minimum facilities required at the charging stations	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Treated
	Harmonisation of Intra/interstate registration for using charging infrastructure	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated
	Establishment of a mechanism to address consumer complaints	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated	Not treated

Treated in the policy | Not treated in the policy

2. ***What business models can reach the sufficient coverage of charging infrastructure that meets the needs of the EV user?***

The business model of EV charging in India is *<u>at the introductory stage</u>*, with the focus being on kick-starting the market. *The dominant business model* is the provision of charging solutions to business (B2B) such as bus and taxi fleets with some B2C service providers. The current charging station roll-out is led by Utilities and Public sector undertakings (PSUs) with limited but growing private sector involvement. Hence, there is a large scope for business innovation in India's EV charging space.

This study looked at case studies of EV charging business models from the market that are currently *<u>in the "growth" stage of development</u>*. This is intended to provide some indication of possible pathways for innovation and evolution of the EV charging business models in India in the near future. Case studies of growth stage markets indicate that as the market develops, there is *greater competition in the market* arising from higher private sector participation. The focus shifts from providing basic vehicle charging to innovation in incorporating *more <u>value-added services</u>* in their offerings and how these services are offered.

<u>Innovation in business models</u> is evident in three key areas, namely; services, partnerships, and pricing (See Table 2). Within service innovation, businesses are promoting retailing of green power, providing a choice between multiple speeds, multiple sockets, multiple power retailers, and developing software applications for users. Partnership innovation is focused on ensuring increased access to the wider charging network and partnering with actors that specialise in a particular service; pricing innovation is occurring in the offering of subscription. In varying combinations, charging subscriptions provide users preferential rates, while access subscriptions provide priority access to the wider network.

As India increases its EV penetration, business models will evolve as the sector transitions from introductory stage to the growth stage, where the focus could be on incorporating one or more of the innovation attributes as presented in Table 2.

Table 2: Innovation trends in EV charging businesses

	Service innovation		**Partnership innovation**		**Pricing innovation**	
EV charging businesses	**Green retailing**	**Additional services**	**Access to a wider network**	**Service Specialisation**	**Charging Subscription**	**E-roaming Subscription**
Ubitricity	✓	✓	✓	✓	✓	✓
Plug N Go	✓	✓		✓		
IZIVIA	✓	✓	✓	✓	✓	✓
Nuvve		✓		✓	✓	
Fastned	✓	✓	✓	✓	✓	✓
Share&Go		✓	✓	✓		
Allego		✓	✓	✓		✓
EnelX		✓		✓	✓	✓

3. *How can the potential impacts of the additional EV load in the power system be managed?*

EV as a load represents a unique additional electrical load that is mobile, power-dense, variable and mostly connected to the distribution grid. Therefore, starting from the introductory stage of EV market development, the long-term power system planning should anticipate the growth of EV adoption and deployment of charging infrastructure while considering the unique characteristics of the load.

Forecasts for 2030 indicate that the total energy consumption of EVs in India will be approximately 3% of total demand, and it can be accommodated without a significant impact on the power system. However, as the EV market enters the growth stage, if the charging of EV is not well distributed in terms of time and location, it may lead to: a) high cost of electricity supply due to the increase in peak demand, and b) grid ageing and service interruption due to congestion in the distribution grid.

Conventionally, utilities would invest in additional new generation and distribution capacity (wire or storage) to ensure adequacy at any time and location of consumption. This way peaks are accommodated, and the possibility of congestion is significantly reduced. However, *various solutions are emerging* as alternatives to help defer these investments (see figure 1).

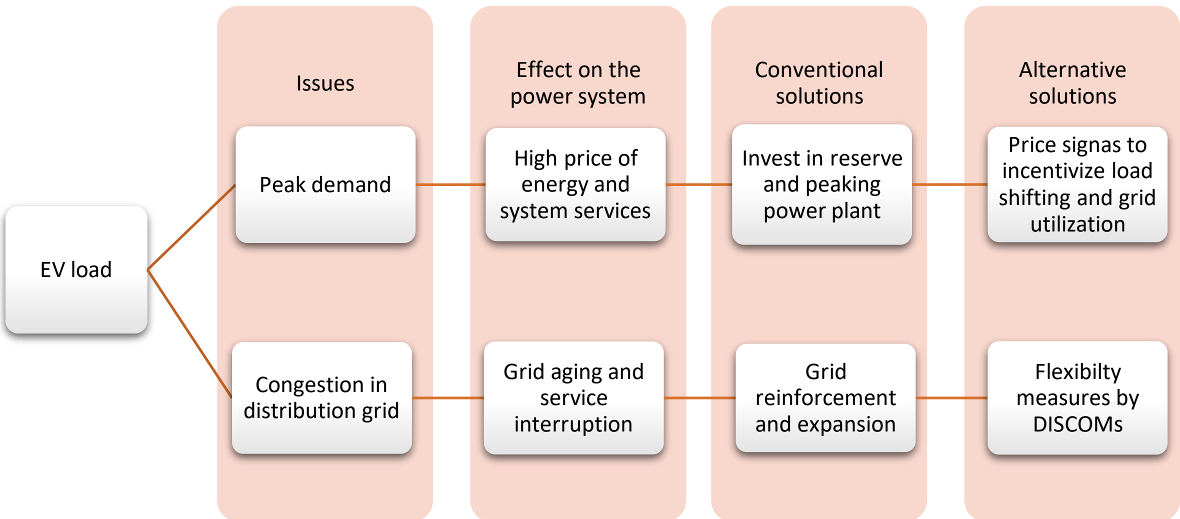


Figure 1: Potential issues caused by additional EV load, and their effects and solutions

First, the peak demand contribution of EVs can be reduced by sending price signals to EVs, both for B2B and B2C charging, to shift charging to off-peak hours through time-varying energy tariffs (e.g., time of day and real-time pricing) and demand tariffs. However, the application of such tariff designs in India is challenged by the low penetration of enabling technologies such as smart meters, even though the solutions are compatible with the current regulatory framework. This can be addressed by introducing mandatory standards for charging stations to be equipped with the required technologies and encouraging business model innovation to reduce the upfront cost of enabling technologies.

Moreover, the effectiveness and acceptance of these price signals depend on the flexibility and price sensitivity of the EV user. This can be improved by encouraging innovative business models where intermediaries (e.g., aggregators) play a role of optimizing and directly controlling EV charging by considering price signals and the mobility needs of the EV user.

Second, to deal with distribution grid congestions, proactive measures should be prioritised. These include, regularly publishing state of the grid information to encourage optimal siting of charging infrastructure and integrating the anticipated EV adoption and infrastructure into the grid planning process. With the increase in penetration of enabling technologies and EV adoption, more sophisticated solutions such as variable capacity contracts and flexibility markets for congestion management services can be considered.

The choice of appropriate solutions will depend on the development of the EV and power sector. This includes the growth in EV adoption, penetration of enabling technologies, the maturity of the wholesale and retail market, and the severity of congestion in the distribution grid. Consequently, the influx of EV in the system needs to be considered in the long-term power system planning process, leading to an efficient mix of conventional and alternative solutions to deal with the peak demand and congestion issues.

4. How can the flexibility potential of Vehicle-to-X (V2X) be unlocked?

EVs as flexibility source with V2X capability can offer *various V2X services in the future*. Currently, the concept of V2X is still in an early stage of development globally. In the context of India, where the EV sector itself is in a nascent stage, V2X services would become relevant in the future when the market is at a mature stage of development. Nevertheless, proactive policymaking will aid in ensuring that the full potential of the V2X services can be utilised.

In this context, *four recommendations on the V2X regulatory aspects* are provided, keeping in mind the perspective of individual EVs with varying characteristics, thus relevant for both fleets (B2B) and individual consumers (B2C). The accuracy in predicting the availability of V2X resource at a given time and location by the provider can be improved and the market entry barriers for EVs to provide V2X be minimized by 1) enabling aggregation of EVs to provide V2X resources. 2) Allowing smaller minimum volume and minimum contract period for trade. 3) allowing trade of asymmetric products (for instance upward and downward balancing products). 4) Having a lead time that is as short as possible, from the time of commitment to the time of provision of the service, will allow better forecasting and reduce risk of unavailability. Table 3 provides summary of the assessment.

Table 3: Summary of the assessment

Service Attributes →		Volume	Contract Period	Product Symmetry	Location	Lead time	Reservation Period
Constraints	Range	✓		✓	✓		
	Time		✓			✓	✓
Solutions	Smaller min volume	✓					
	Smaller min contract period		✓				
	Shorter lead time			✓	✓	✓	✓
	Asymmetric products			✓			
	Aggregation	✓	✓	✓	✓	✓	✓

In short, ***the challenge of charging infrastructure deployment and the planning and management of the power system to accommodate the EV influx go hand in hand***. While some measures are focused on enabling solutions to address these two challenges, some others are focused on issues and tools that need to be factored in the future while the EV market in India moves from introductory to growth to mature stages. Figure 2 summarizes the relevance of the various elements within the toolbox in the context of the EV market development stages.

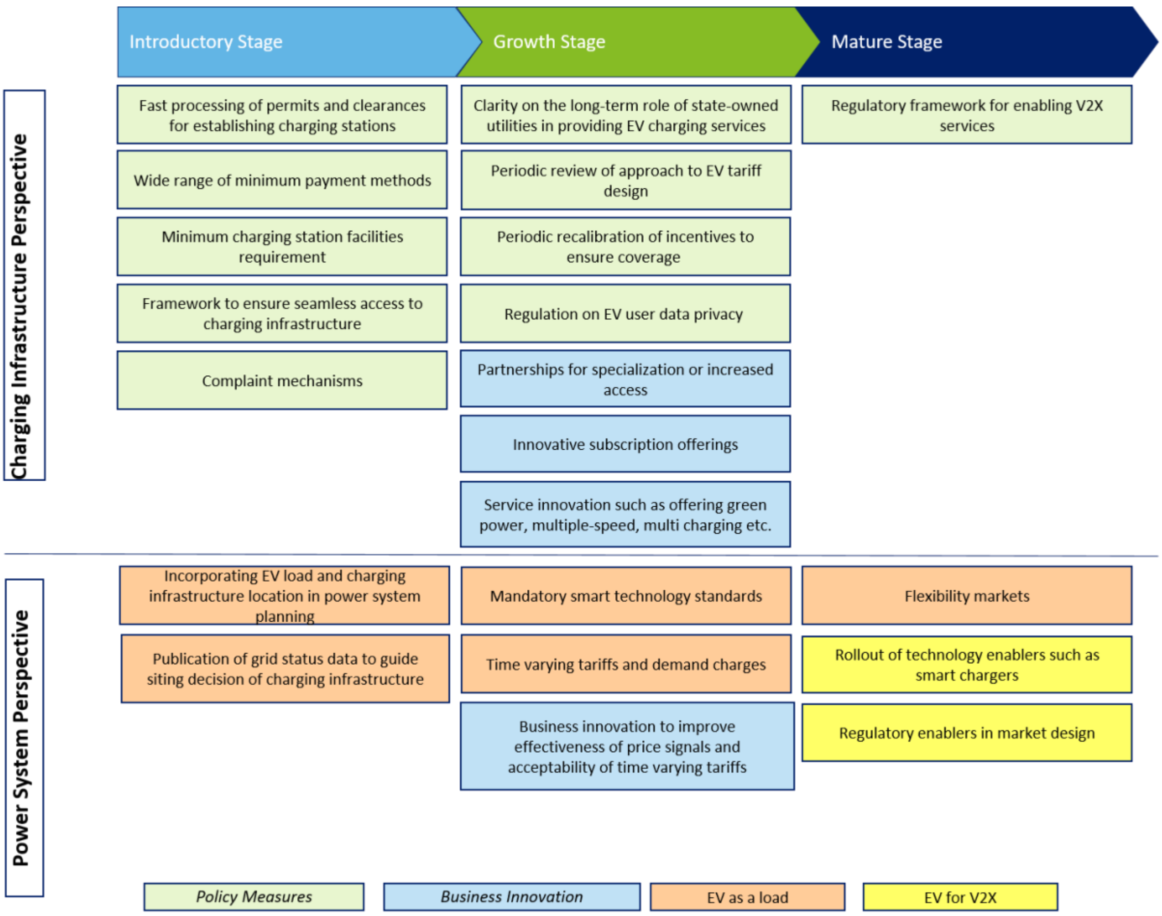


Figure 2: Relevance of the various elements within the toolbox in the context of EV market development stages

Importantly, the EV challenges discussed in this study should be viewed in the context of *the overall energy transition and disruptive innovations* that are shaping the power sector of the 21st century. This calls for the development of *smart infrastructure* alongside smart users and smart use of data to capture values through *innovative business models*. Thus, the search for the most appropriate solutions in this time of change should be supported by regulatory sandboxes both at the national and state level that help test different solutions to gain better insights.

Introduction

The global electric mobility landscape is developing at a rapid pace. In 2018, the world global electric vehicle fleet exceeded 5.1 million, which is an increase of 2 million on the previous year, almost doubling the number of new electric vehicle sales (IEA, 2019). Considering the automotive industry at large, the numbers may seem insignificant, but the trend indicates that the penetration of electric vehicles will increase rapidly in the coming years. According to IEA, (2019), by 2030, the share of EV will be 37% in Japan, over 30% in Canada and the United States, 29% in India, and 22% in aggregate of all other countries. The uptake is driven by enabling policies and the decline in battery price. Price parity between EVs and internal combustion vehicles (ICE) is expected to be achieved by mid-2020 (BloombergNEF, 2019).

The development of the EV market varies between various regions depending on national policies and priorities (IEA, 2019). In general, the development of a market can be broadly categorized into three stages: the introductory stage when a new product enters the market; then a growth stage as the product gets new users and more competition enters the market; finally, the maturity stage when the product has been in the market for some time already with many competitors and the demand growth begins to plateau (Anderson and Zeithaml, 1984).

India has over 250 million vehicles, whose composition is dominated by 2-wheelers accounting for 78% of the vehicles. Currently, EVs represent a tiny share with approximately 750,000 vehicles. However, the country has set a target of 30% EV sales across all types of EV by 2030. Amongst the different vehicle characteristics, public buses, taxi fleets, 2-wheelers and three-wheelers are expected to be the first adopters of EV in India. According to NITI Aayog and RMI, (2019), it is possible to realize an EV sales penetration of 30% of private cars, 70% of commercial cars, 40% buses and 80% of two and three-wheelers by 2030 if the second phase of the Faster Adoption and Manufacturing of Electric Vehicles (FAME II) [1] and other measures are successfully executed.

Four key policy drivers can be observed for the shift to electric mobility in India. First, the Indian government sees an opportunity to reduce the heavy dependence of the country on imported crude oil, which is mainly used to fuel its mobility needs. As of 2017/18, India's imported crude oil accounted for 18% of India's total commodity imports (Ministry of Commerce and Industry, 2018). It is estimated that the vehicles eligible under the FAME II scheme can cumulatively save oil imports worth ₹173 billion[2] over their lifetime (NITI Aayog and RMI, 2019). Therefore, the transition to EV can help the

[1] FAME II aims to reduce "*the purchase price of hybrid and electric vehicles, with a focus on vehicles used for public or shared transportation (buses, rickshaws and taxis) and private two-wheelers*" (IEA, 2019).
[2] 1 € = 77 ₹ (Approximate – July 2019)

country to gain significant monetary savings and reduce the country's geopolitical risk that comes with heavy dependence on imported fuel. Second, 12 out of the 15 top polluted cities in the world are located in India (IQAir, 2018). According to the Health Effects Institute, (2019), deaths attributed to ambient air pollution were estimated to be 1.2 million in India in 2017. The adoption of electric mobility is considered to be an important measure to reduce the pollution in Indian cities and consequently improve public health. Third, if EVs are powered by carbon-neutral electricity, it can significantly reduce the country's net carbon emissions. India's nationally determined targets (NDC) include a reduction in *"emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level"*(UNFCCC, 2015). Electric vehicles eligible under FAME II will lead to a reduction of 7.4 million tons of CO2 emissions over their lifetime (NITI Aayog and RMI, 2019). Fourth, the transition is part of the industrial strategy of the country to promote the development of the EV manufacturing sector. The Indian automobile industry accounts for more than 7% of India's GDP (SESEI, 2018), and the Indian Government is providing an impetus for developing EV manufacturing in the country, most recently with the FAME II policy.

Institutionally, NITI Aayog with the support of select central ministries has been serving as the nodal agency to develop the electric mobility plan for India. Although the e-mobility plan is developed at the central level, the onus is on the state governments to adopt and enable EVs at the state level. As shown in Figure 3, the EV policies for India have developed overtime. Historically, the Ministry of New and Renewable Energy (MNRE) began providing subsidies for electric vehicles in 2010 (Chaudhary, 2014). In 2012, the National Electric Mobility Mission Plan (NEMMP) for 2020 was introduced to boost the EV industry in India (Government of India, 2012). In April 2015, Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME-India) was introduced to provide several incentives (Government of India, 2015). In May 2017, NITI Aayog published a roadmap for EV (NITI Aayog and Rocky Mountain Institute, 2017). In 2018, a national E-Mobility program was launched by the Ministry of Power and to be implemented by Energy Efficiency Services Limited (EESL). In 2019, NITI Aayog and the RMI published a report on current progress and future opportunities of electric mobility in India (FAME II), and the government approved it in February 2019 (Government of India, 2019a; NITI Aayog and Rocky Mountain Institute, 2019). Recently, the central electricity regulatory commission (CERC) has published guidelines on charging infrastructure, identifying nine major cities and 11 intercity routes as starting points to enable EV charging rollout. Furthermore, several states have developed their EV policies. As of August 1st, 2019, the central goods and services Tax (GST) is reduced from 18% to 5%. On October 4th 2019, the Power Minister approved amendments to the EV charging guidelines (Ministry of Power, 2019).

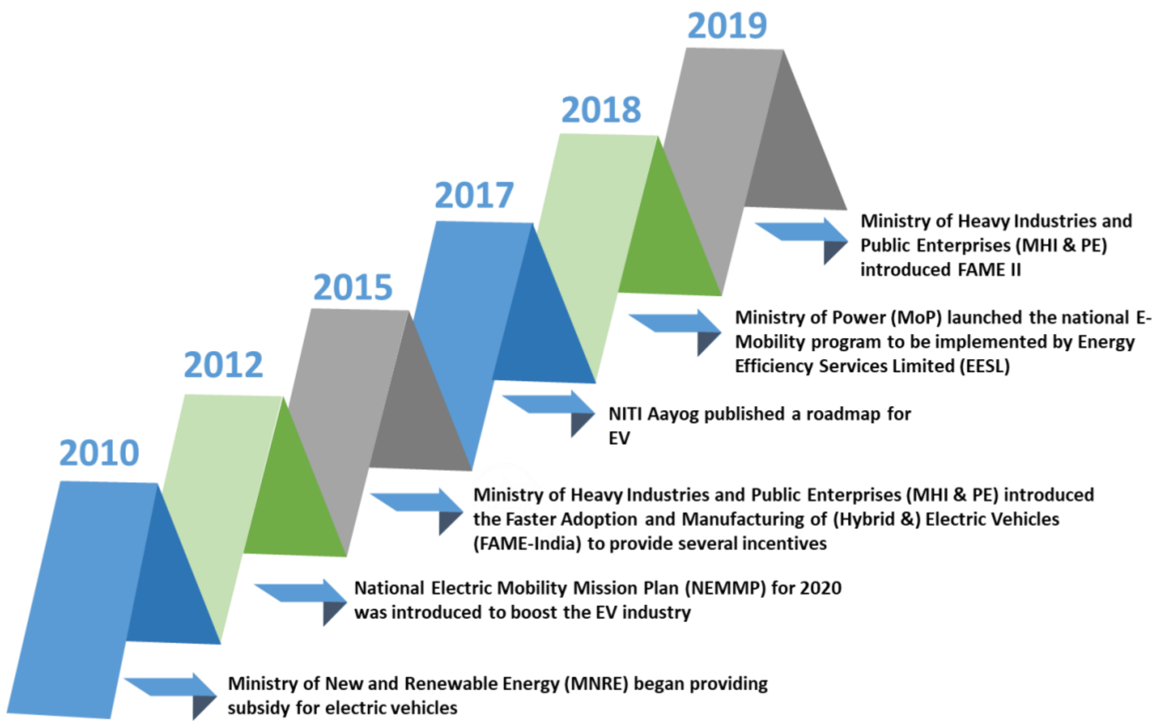


Figure 3: EV policy timeline of India

The rapid growth in EV uptake required to reach India's policy targets would lead to challenges on two fronts – development of charging infrastructure and adaptation of the power system. First, the current public charging infrastructure in India is underdeveloped but with ambitious targets for the coming years. For EV adoption, there exists a chicken or egg problem of which comes first: the vehicle or the charging station? The development of charging infrastructure would be dependent upon the policy and regulatory environment, which in turn would impact the business models that evolve for enabling the provision of EV charging services.

Second, as the EV adoption grows, the integration of EVs into the power system can raise additional challenges and opportunities. That is, the additional EV load which has unique characteristics of being mobile, power-dense and less predictable can have a significant impact on the power system, leading to higher cost of electricity supply and grid cost due to the capacity required to accommodate the new load. In contrast, the controllable and flexible characteristics of the additional load present an opportunity to efficiently integrate not only EVs but also intermittent renewables into the system by providing ancillary services. Apart from the system-level benefits, permitting EVs to participate in the electricity markets would present new revenue generation opportunities for vehicle owners. This, in turn, would further improve the business case for EVs by reducing its total cost of ownership (TCO).

The objective of this study is to provide a vision for the future of EV charging infrastructure deployment and power system integration via a ***toolbox*** consisting of solution choices and recommendations for addressing these challenges. To this end, the report is structured into two parts and four chapters, as illustrated in Figure 4.

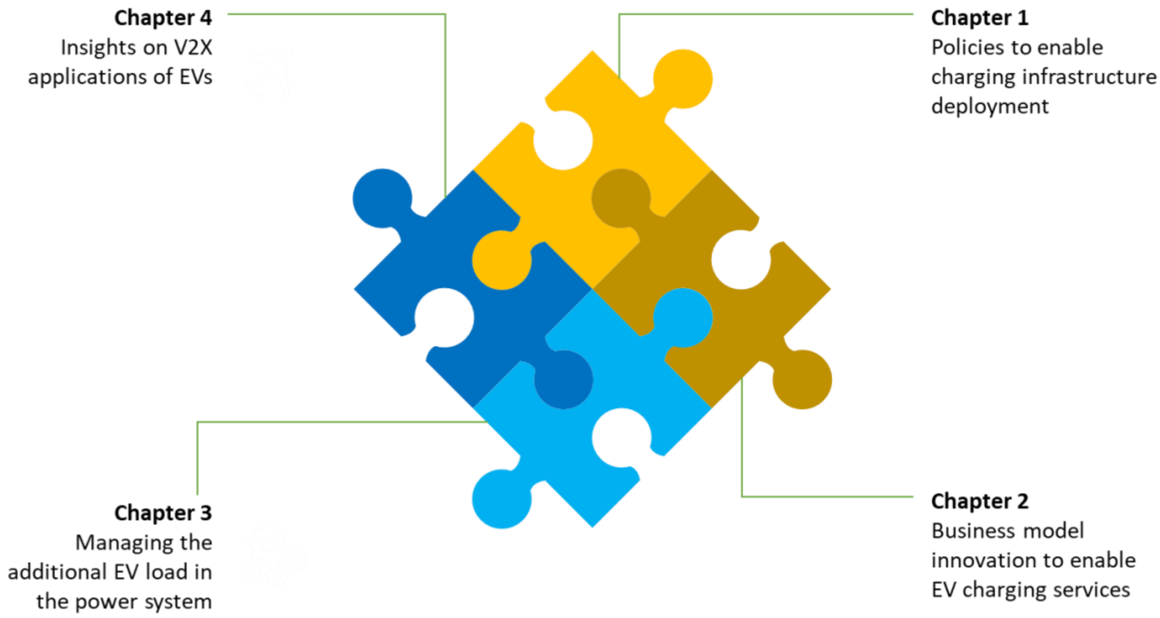
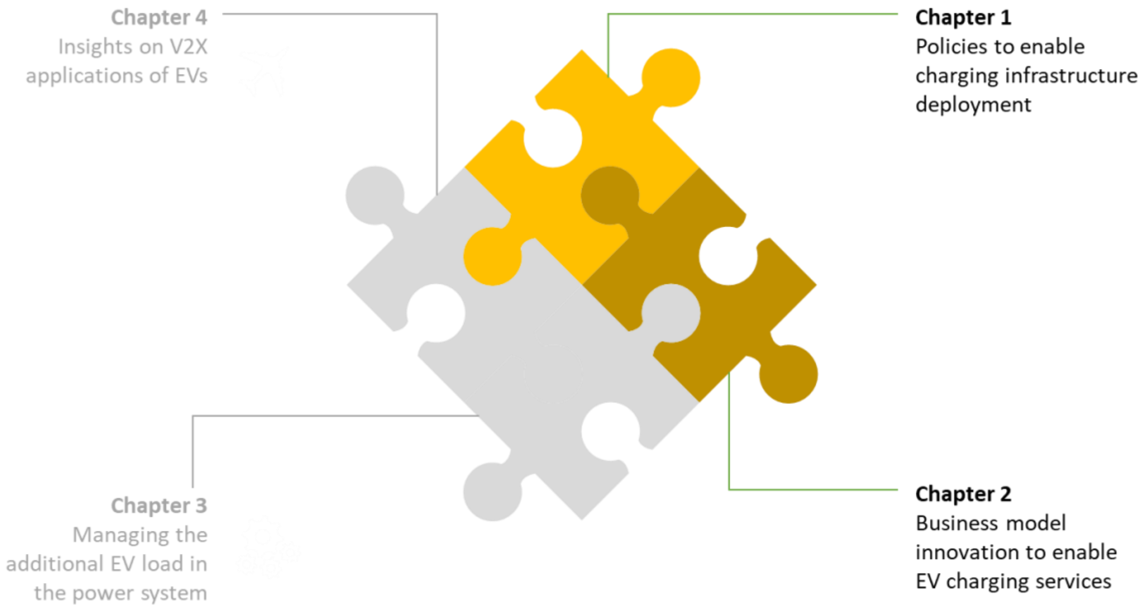


Figure 4: Structure of the report

The first part takes the perspective of the charging infrastructure deployment in which enabling policies at the central and state level are assessed in chapter 1, and various workable business models are identified based on international experiences in chapter 2. The second part covers the perspective of the integration of EVs into the power system. This is studied in terms of managing the additional load that arises with the increasing penetration of EVs in chapter 3 and unlocking the potential of EV as a flexibility resource with V2X capability in chapter 4. Finally, conclusions and recommendations are presented in chapter 5.

PART I: EV Charging Infrastructure Deployment Perspective



1 Policies to enable charging infrastructure deployment

The development of EV charging infrastructure depends on the policy and regulatory environment, which in turn influences the emergence of viable business models. This chapter first defines the EV charging infrastructure ecosystem. This is followed by an assessment of national and state-level EV policies and guidelines developed to enable charging infrastructure deployment in India. The business models for charging infrastructure business are addressed in Chapter 2.

1.1 Defining the EV charging infrastructure ecosystem

The policies for enabling EV charging infrastructure should make a distinction between various elements of a) charging infrastructure, b) stakeholders involved, c) EV users and d) EV types. This is illustrated in Figure 5. The constraints and priorities of these four dimensions would together govern the policy and regulatory choices that would be made.

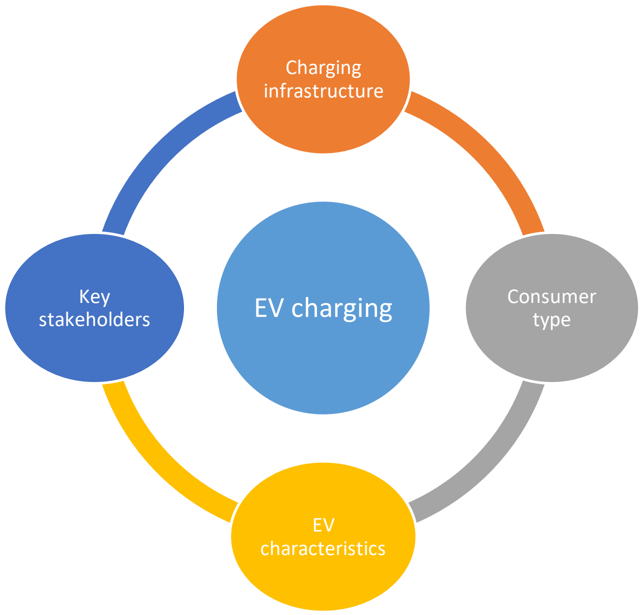


Figure 5: EV charging infrastructure ecosystem [Source: Own representation]

In what follows each of these dimensions are defined and discussed.

1.1.1 Charging Infrastructure

The charging infrastructure can be distinguished in terms of the speed of charging, standardisation of chargers, ownership, process of charging and power flow directionality (See: Figure 6). First, according to Falvo et al., (2014), the charging speed can be slow (less than 3.7kW), medium (3.7kW – 22kW), or fast (greater than 22kW). In terms of the order of magnitude in time, slow charging would correspond to a full charge in a few hours, medium charging in less than an hour and fast charging in minutes. The second element is the technical standardisation of the chargers. Policymakers can choose a country specific charging point standard or allow the use of existing international standards. From a policy direction perspective, policymakers can either apply a top-down approach of specifying charging standards or allow a market leader to emerge using a bottom-up approach where manufacturers are allowed to utilise their own charger standards[3]. Third, the charger can either be for private use by an individual or a company, or public use by any vehicle owner. Fourth, in the process of charging an EV, two alternatives can be differentiated: plug-in charger and battery swapping[4]. The fifth element is whether the charger is unidirectional allowing the EV to only charge the EV or if it allows bidirectional power flow that enables vehicle-to-grid (V2G) applications. Note that the function that the charger would be able to provide will also rely on its level of 'smartness'. It is evident that several permutations of these five elements are possible (for instance: supercharge-national-public-plugin or slow-international-private-plugin) and the policy and regulatory choices would have an impact on what model would succeed or fail.

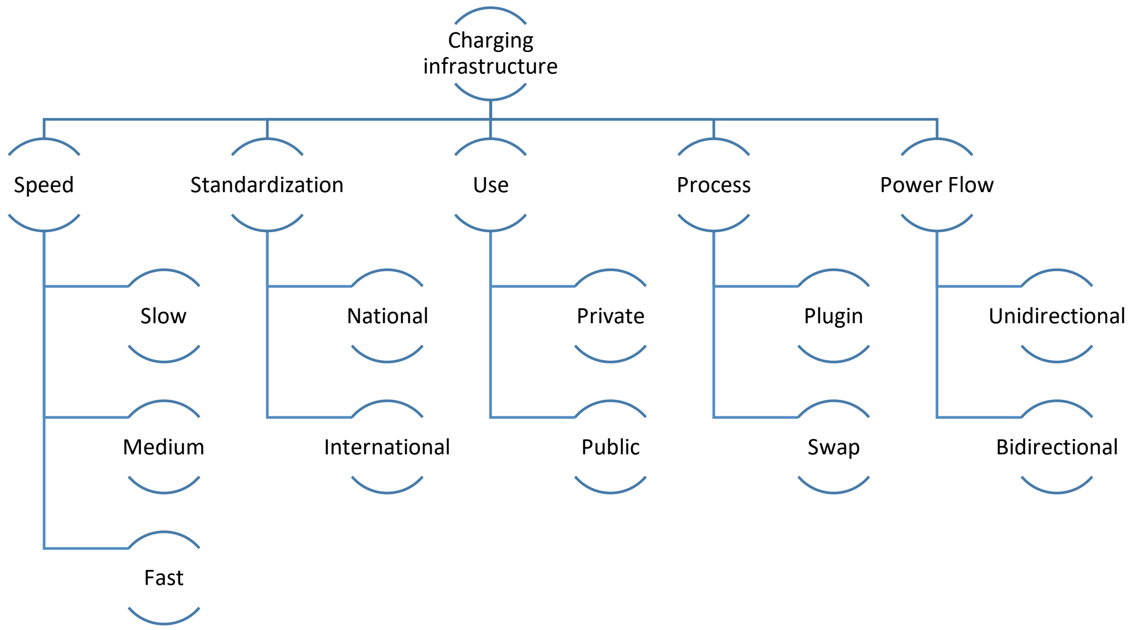


Figure 6: Illustration of various elements of charging infrastructure

1.1.2 Consumer type

The types of consumers can be classified into three based on social geography, income and purpose of the vehicle. First, based on social geography, the charging infrastructure can be used for intra-regional application (i.e., urban or rural) or inter-regional application (i.e., urban-urban, rural-rural, urban-rural interconnecting roads)[5]. Second, the consumer can also be from the high, medium or low-income category[6]. Third, the type of vehicle can be used for commercial or private mobility purposes.

[3] See Sabatier, (1986) for more details on top-down versus bottom-up approaches
[4] For more information on plug-in and swapping see: Mak et al., (2013); Yilmaz and Krein, (2013)
[5] See Bhagat, (2005) for more information on criteria for rural-urban classification.
[6] See Desai et al., (2010) for more information on income categories.

Depending on the combination, each consumer type will have different preferences, including choice of EV type and sensitivity to prices.

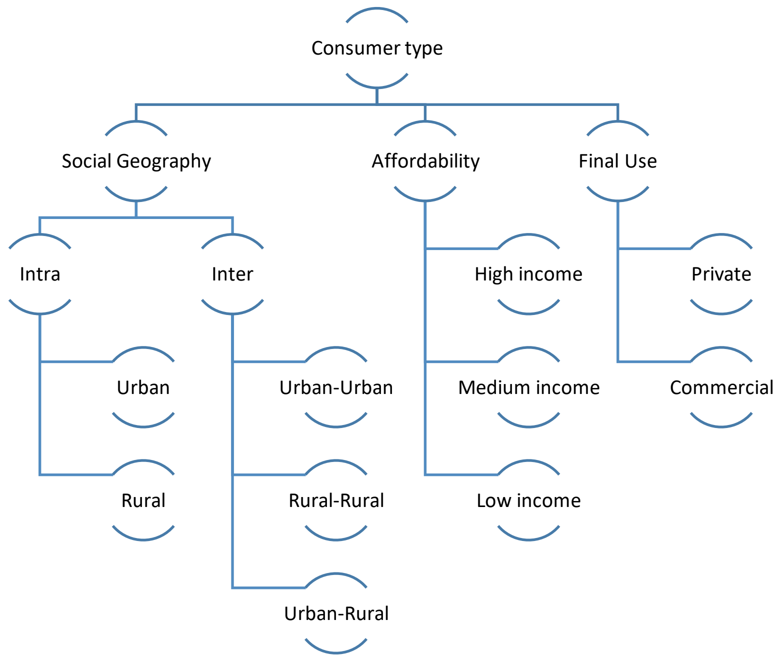


Figure 7: Illustration of various elements of consumer types

1.1.3 EV characteristics

EVs can be classified according to their chassis and type of engine. The chassis includes 2 Wheelers, 3 Wheelers, 4 Wheelers, Trucks, Buses and Mobile Machinery[7,8]. Furthermore, UNECE, (2017), classify vehicles in the following categories

- Category 1: "a power-driven vehicle with four or more wheels designed and constructed primarily for the carriage of (a) person(s)." With two sub-categories (1-1: less than eight seats and 1-2: More than eight seats).
- Category 2: "a power-driven vehicle with four or more wheels designed and constructed primarily for the carriage of goods." This includes mobile machinery.
- Category 3: "a power-driven vehicle with 2 or 3 wheels designed and constructed for the carriage of persons and/or goods." (3-1: 2W Moped, 3-2: 3W Moped, 3-3: 2W Motorcycle, 3-4: tricycle, 3-5: Motorcycle with sidecar).

[7] According to Council of the European Union and European Parliament, (2007) Mobile Machinery means *"any self-propelled vehicle which is designed and constructed specifically to perform work which, because of its construction characteristics, is not suitable for carrying passengers or for transporting goods. Machinery mounted on a motor vehicle chassis shall not be considered as mobile machinery;"*

[8] For more details of automotive vehicle type terminology in India see ARAI, (2016)

The type of engine can be either a hybrid EV (HEV), battery electric vehicle (BEV) or fuel cell electric vehicle (FCEV) (Orecchini and Santiangeli, 2010). The charging needs can be different for each of these vehicle types.

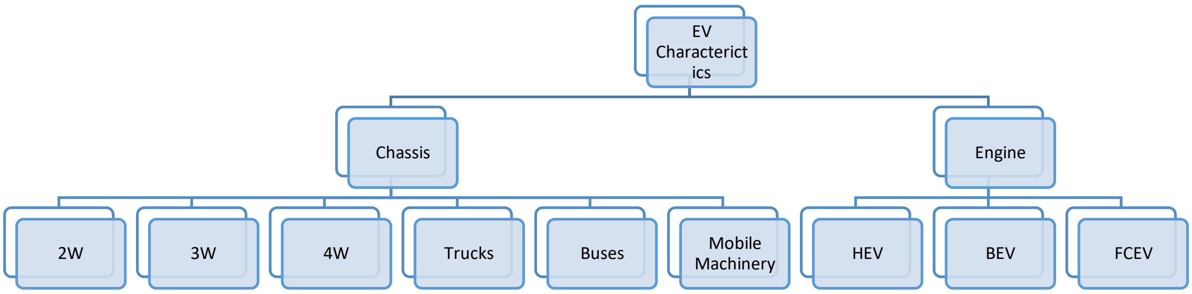


Figure 8: Illustration of various elements of EV characteristics

1.1.4 Key stakeholders

Considering the coupling of the transport and power sector through EV charging, two key stakeholders would be most impacted by the regulatory and policy choice with regards to EV charging. The automotive sector would be impacted by the regulation on charger standardisation strategy and the uptake of chassis characteristics. The power sector could be impacted by the speed of charging infrastructure deployment and the charging speed (slow, medium, fast) provided to the EV user at this charging infrastructure.

Beyond these two sectors, the third key stakeholder would be the public authorities, which have the responsibility to ensure fair distribution of costs and benefits arising from the growth of electric mobility while ensuring the achievement of their policy goals. Other stakeholders that could be impacted by the policy and regulatory choices regarding EV charging infrastructure also include companies developing the software and providing ICT services required to run the EV chargers and individual business that wish to enter into the charging infrastructure business would be impacted by the policy and regulatory choices (See: Figure 9).

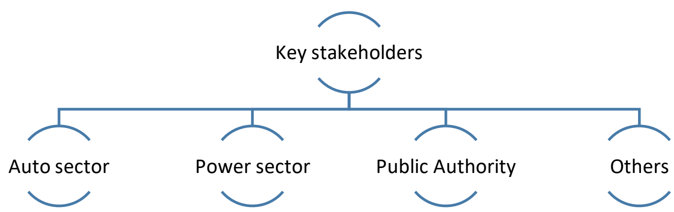


Figure 9: Illustration of various elements of key stakeholders

1.2 Assessment of state EV charging policies and central guidelines

Under the central structure and constitutional provisions in India, the Ministry of Power has introduced guidelines for the deployment of public charging infrastructure. Accordingly, various State

Governments have also developed their own EV policies that vary depending upon their socio-economic and political priorities. These policies cater to the charging infrastructure used for both fleets (B2B) and individual consumers (B2C).

In this section, the EV policy of eight Indian states which have so far introduced dedicated EV policy as well as the guidelines established by the Ministry of Power from the perspective of enabling charging infrastructure deployment is assessed. An analytical framework that captures the supply (EV charging infrastructure developers and charging service providers) and the demand side (EV users) of charging infrastructure policy is used for the assessment. Subsequently, the recommendations for possible future extension to the state policies are provided. Note that the analysis does not make a judgement on the choice made by states but instead looks at whether key elements were considered or not.

1.2.1 Analytical Framework

To assess EV charging infrastructure policies in India, an analytical framework that comprises twelve elements is developed based on a literature review[9] of current international EV policy trends. As presented in Table 4, some of these elements cover the supply side of EV charging while others are related to the demand side.

Table 4: Analytical framework: Two dimensions, each having six elements

Dimensions	Elements
Enabling EV charging on supply-side	Definition of a fundamental market design framework to limit distortions and entry barriers
	The incentive for launching the EV charging market
	Prioritisation in terms of EV characteristics and social geography
	Elimination of administrative barriers for establishing charging stations
	Mandate on user data sharing and privacy
	Mandate on the utilisation of V2X capabilities
Enabling EV charging on demand-side	Technical standardisation of chargers for interoperability
	The mandate for the development of digital platforms and database management systems
	Specification of the use of a wide range of payment methods

[9] See (BMVI and BMU, 2015; Cansino et al., 2018; DG-IPOL, 2018; European Alternative Fuels Observatory, 2019; European Parliament and Council of the European Union, 2014; Forum of Regulators, 2017; Global Green Growth Institute and Center for Study of Science Technology and Policy, 2016; Hamelink, 2017; House of Commons - Business Energy and Industrial Strategy committee, 2018; ICCT, 2016, 2018; IEA, 2016; Liebes et al., n.d.; Lutsey and Sperling, 2012; Pu et al., n.d.; RVO, 2017; San Román et al., 2011; Shen et al., 2016; Sierzchula et al., 2014; Soltani-Sobh et al., 2017; Steinbacher et al., 2018; Transport and Environment, 2018, 2016; UK Parliament, 2018; Van der Wees, 2014)

	Specification of minimum facilities to be provided at the charging stations
	Harmonisation of Intra/interstate user registration for accessing charging infrastructure
	Establishment of a mechanism to address consumer complaints

1.2.1.1 *Enabling EV charging on supply-side*

The supply side refers to the entities that would eventually set up the charging infrastructure and provide the charging services. The first six elements are therefore aimed at qualitatively assessing whether and to what extent a particular EV policy includes these elements that enable the supply side in the deployment of public charging infrastructure.

A. Definition of a fundamental market design framework to limit distortions and entry barriers

For any market to function efficiently, it is crucial to develop clear and precise policy choices and market design frameworks right from the beginning. This would ensure that any possibility of market distortion and barrier to entry are minimised. In the context of EV charging, this could include 1) the level of competition allowed and 2) the price-setting approach.

A fundamental choice is whether to introduce competition or not. Competition can be broadly introduced using two approaches. The first approach is in-market competition, in which any entity is allowed to establish the infrastructure and provide the service commercially. The second approach is competition for the market, where a competitive bidding process is used for awarding the winner a time-limited concession to set up charging infrastructure and providing services within a particular area. Alternately, the policymakers may also choose to mandate the state-owned utility to set up and operate charging stations. The use of a combination of different approaches can also be considered.

Another crucial element is the principle for EV charging price setting. A choice needs to be made by policymakers between a fully regulated price, a fully market-based price-setting or a price cap. Finally, once the fundamental design choices are made, the policy also needs to mandate changes to existing regulation (such as open access, deregulation of electricity retail, etc.) to minimise entry barriers.

B. The incentive for launching the EV charging market

The 'chicken or egg' problem of whether the EV will come first or the charging infrastructure has been debated for a long time (For example see: Gnann et al., 2018, 2015; Meeus, 2017; Perkowski, 2016; Transport and Environment, 2018b). It is clear from international experiences that the push has to come from both ends. Thus, initially, incentives for both setting up charging stations and for innovation that may be required to launch the market.

The level and type of incentive would depend upon the social, economic and political priorities of a given state or country. However, it is essential that to enable the rollout of charging infrastructure, EV policy provides clarity on whether or not an incentive for launching the EV charging market is to be provided and if it is provided then at least its boundary conditions (limits) must be specified.

C. Prioritisation in terms of EV characteristics and social geography

The deployment of charging infrastructure can follow two approaches. On the one hand, there is a coverage-based approach where the goal is to have to charge infrastructure covering an entire region. On the other hand, there is the demand-based approach, where the charging infrastructure deployment follows demand. Thus, a choice needs to be made concerning the social geography (see Section 1.1).

Another element that would influence EV charging is the EV attribute (chassis and engine). For instance, the charging needs of an electric bus fleet would be different from that of electric scooters in terms of speed, location, process and ownership. Similarly, *ceteris paribus*, the frequency of charging required for an EV would differ depending on battery capacity. These nuances need to be taken into account during policy development.

Thus, a forward-looking EV charging policy must provide a road map in the short, medium and long term of the priority with regards to the EV characteristics (which will become electric first?) and what social geography is targeted (which will impact the choice between coverage, demand or mixed approach?).

D. Elimination of administrative barriers for establishing charging stations

As is the case for setting up any new business, any entity to set up a public EV charging infrastructure, would have to acquire several clearances and permissions (For example permission for the use of land). In most cases, these permissions are handled by several different agencies, which may or may not function in coordination. As a result, there is a risk of unnecessary delays and inefficiencies in setting up of the charging infrastructure and creating a barrier to market entry. Therefore, the EV policy should include provisions that identify and eliminate administrative barriers to the establishment of charging stations.

E. Mandate on user data sharing and privacy

Disruptive and rapid innovation in the field of information and communication technologies has brought new opportunities and challenges to all sectors, including power. One of the key discussions on this topic has been concerning the use and protection of consumer data, and data privacy. In the European Union, the right to protection of personal data is fundamental (European Union, 2016).

The EV charging industry would grapple with the same issues in the coming years. Smart chargers and smart grids would enable service providers to gather large quantities of data on consumer choices and behaviour. This data can be a valuable resource for the charging service provider to optimise its operations, and its value could be monetised. However, there is also a significant risk of unethical mishandling of this personal data of the consumer. The privacy concerns arising from ‘ big-data’ are discussed in detail by Tene and Polenetsky, (2013). In the context of concerns regarding predictive analysis, the authors state *“Predictive analysis is particularly problematic when based on sensitive categories of data, such as health, race, or sexuality. It is one thing to recommend for a customer books, music or movies she might be interested in based on her previous purchases; it is quite another thing to identify when she is pregnant before her closest family knows.”* Thus, it is crucial that the EV policy acknowledges and mandates the development of a regulatory framework to govern the use of consumer data and protect the consumers’ privacy.

F. Mandate on the utilisation of V2X capabilities

As widely discussed in the literature, EVs can become a valuable resource for providing V2X services. The different aspects of V2X services that can be provided by EVs are discussed in detail in chapter 4 of this report.

However, to unlock the full potential of the V2X services that the EVs can provide, EV charging policy must provide clear direction on the development of regulations and guidelines on various aspects of the V2X services. This would provide clarity to not just the possible service providers but also network operators and other consumers of these services. Note that V2X is still in the early stage of development and would gain greater relevance in the future.

1.2.1.2 *Enabling EV charging on demand-side*

The demand side refers to the EV user that would eventually make use of the charging infrastructure and the services that it provides. The remaining six elements are therefore applied to qualitatively assess whether and to what extent does a particular EV policy enable the “demand-side” in terms of ease of use.

A. Technical standardisation of chargers for interoperability

Interoperability of charging infrastructure is a crucial component in enabling the demand-side (DG-IPOL, 2018; Hall and Lutsey, 2017). The key element of interoperability is the technical standard used for the charger. In general, charger standardisation can either occur top-down or bottom-up.

In a top-down approach, the concerned authority specifies standards, and charging service providers have to provide at least the standard chargers, thus ensuring interoperability. The bottom-up approach is more evolutionary where no standards are specified, and eventually, a dominant or consensus design emerges, which becomes the standard over time. In either situation, it is essential for the EV policy to specify the approach that is to be followed.

B. The mandate for the development of digital platforms and database management systems

The rapid innovation in the field of information and communication technologies is providing users with fast access to information as never before. Everything from banking to shopping needs tends to use digital platforms such as websites and mobile applications.

In the context of EV charging, these systems can be used to provide the EV user with detailed information on the EV charging network. This information could range from identifying the nearest charging point to reserving it and beyond. Thus, digitalisation has a positive impact on enabling the demand-side. The EV policy can, therefore, mandate the development of these digital platforms and can define their basic functionality. See (Glachant and Rossetto, 2018) for discussion on how digitalization plays out in the electricity sector.

C. Specification of the use of a wide range of payment methods

Today consumers have access to wide-ranging payment methods that go beyond coins and notes. These vary from digital wallets to cryptocurrencies. The consumer preference of the payment method may differ depending upon individual constraints. Having a wide range of payment options available at the charging station would have a positive impact on enabling the demand-side and could be promoted through the EV policy.

D. Specification of minimum facilities to be provided at charging stations

As it is the case with most services, there must be a minimum standard and quality of facilities that must be provided to consumers. Having minimum requirements would have a positive impact on enabling demand-side, as the consumer would know what to expect when arriving at the charging station. For example, specifying the minimum vehicle parking space requirement within the EV charging policy will ensure that the owner of a large SUV is sure of having enough space to park the vehicle while charging. Therefore, this element will play a key role in enabling the demand-side. Thus, the EV policy must consider the inclusion of minimum standard facilities and their quality at a charging station.

E. Harmonisation of Intra/interstate user registration for accessing charging infrastructure

The use of EVs over long distances and across borders would require more than the existence of compatible physical infrastructure. Different countries and states may have different market designs and charging service providers. Thus, depending upon the regulation, the use of these charging stations may require EV users to register with each of these service providers separately following varying processes and requirements. Furthermore, this issue may also crop up in an intra-state context with an in-market competition where different suppliers may require independent registration.

An unharmonized registration system can create a barrier on the demand-side and hinder EV adoption. In an inter-state context, there will be uncertainty for EV-users on their ability to charge the vehicle when crossing states and driving over long distances. EV owners may or may not be able to comply with the varying registration requirements in different states or suppliers. In an intra-region context, an unharmonised registration system can limit the access of EV users to charging station provided only by companies with which the users are registered.

F. Establishment of a mechanism to address consumer complaints

Attending to the concerns of consumers rapidly and efficiently would lead to greater trust in the functioning of the public charging services. In today's competitive environment with widespread access to social media, most commercial establishments have mechanisms for addressing complaints. However, mandating the establishment of a robust mechanism to address consumer complaints (in a time-bound fashion) within the EV policy would add certainty to the existence and quality of such mechanism rather than leaving it to the discretion of the service provider, thereby enabling the demand-side further.

1.2.2 Comparative analysis of eight Indian states and central government guidelines

In this section, we apply the analytical framework described in the earlier section to eight Indian states (See Figure 10) which have so far developed policies on EV charging infrastructure (It is expected that other states will develop policies in the future). The main aim is to conduct a comparative analysis by mapping the current trends for public EV charging infrastructure in these states. Furthermore, the contents of the Government of India (GoI) guidelines on charging infrastructure are mapped. The implementation approach varies from state to state depending upon their socio-economic and political priorities. Therefore, this research does not make a judgment on the choice made by states but instead looks at whether key elements were considered or not.

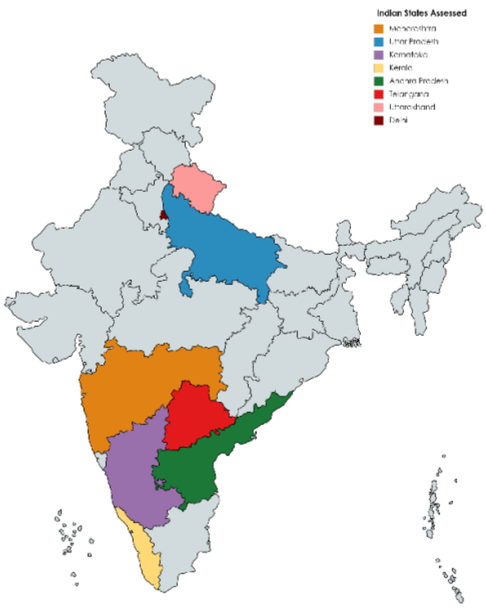


Figure 10: States assessed in this research

The eight states selected are Maharashtra (MH), Delhi (DL), Karnataka (KA), Andhra Pradesh (AP), Telangana (TS), Uttar Pradesh (UP), Uttarakhand (UK) and Kerala (KL). Relevant data has been collected from the following policy documents: GNCTD, (2018); Government of Andhra Pradesh, (2018); Government of Karnataka, (2017); Government of Kerala, (2017); Government of Maharashtra, (2018); Government of Telangana, (2017); Government of Uttar Pradesh, (2018); Government of India, (2019b, 2018)[10]; and Government of Uttarakhand, (2018). The assessment results are presented in Table 5.

Table 5: Summary of assessment results

Dimensions	Elements	KA	MH	AP	TS	KL	DL	UP	UK	GoI
Enabling EV charging on supply-side	Definition of fundamental market design framework to limit distortions and entry barriers									
	The incentive for launching the EV charging market									
	Prioritisation in terms of EV characteristics and social geography									
	Elimination of administrative barriers for establishing charging stations									
	Mandate on user data sharing and privacy									
	Mandate on the utilisation of V2X capabilities									
Enabling EV charging on	Technical standardisation of chargers for interoperability									

[10] Note: On October 4th 2019, the Power Minister approved amendments to the EV charging guidelines (Ministry of Power, 2019).

demand-side	The mandate for the development of digital platforms and database management systems									
	Specification of the use of a wide range of payment methods									
	Specification of minimum facilities required at the charging stations									
	Harmonisation of Intra/interstate registration for using charging infrastructure									
	Establishment of a mechanism to address consumer complaints									

	Treated in the policy		Not treated in the policy

1.2.2.1 *Enabling EV charging on supply-side*

In this section, the EV policies in the eight Indian states are qualitatively assessed based on the six identified elements to ascertain whether and the extent to which these policies enable the supply side in the deployment of public charging infrastructure. In this context, the supply side refers to the entities that would eventually set up the charging infrastructure and provide the charging services.

A. Definition of fundamental market design framework to limit distortions and entry barriers[11]

All assessed states have defined the fundamental elements to limit distortions and entry barriers. States apply differing market design frameworks. A trend observed is that state-owned utility leads the rollout followed by in-market competition.

It should be noted that Delhi chose a concession approach for charging infrastructure deployment while the Kerala policy states that *"These stations could be set-up by DISCOMs or companies in partnership with DISCOMs"* (Government of Kerala, 2017).

In the context of the states with a state-owned utility led deployment followed by in-market competition approach, it is crucial that the long-term mandate of these state-owned utilities is clarified within the EV policy. For example, if the vision is only to use the state-owned utilities to break the chicken or egg problem in the initial phase, then sunset clauses for ownership can be considered. This holds further importance given the current discussion on the introduction of retail competition for electricity (splitting of content and carriage).

[11] The choice between the use of plug-in or battery swapping approaches is outside the scope of this study. However, the general trend in the EV policies of the states assessed appears to be to remain neutral towards the two approaches.

The trend also indicates the use of a special EV charging tariff. The GoI, (2018) guideline specifies that the *"tariff shall not be more than the average cost of supply plus 15 (fifteen) per cent"*. The 2019 revised guidelines have revised this to: *"in accordance with the Tariff Policy issued under section 3 of the Electricity Act 2003 as amended from time to time"* It also provides guidelines on the implementation mechanism and selection of implementation agency for the deployment.

As the EV market matures, it can be good practice to reassess the approach to EV charging tariff design periodically. An example of this evolution comes from the Netherlands. In the initial phase, the charging of EV was free for all users, and a regulated tariff was introduced as the market matured (Wolbertus, 2016). Currently, the pricing for EV charging is fully deregulated, thus allowing the market to set the price. Furthermore, in the times of rapid disruptive innovation, such a review would also allow the regulators to re-evaluate and provide clarity on the pricing of value-added services.

Box I: Greening of the value-chain

As discussed in the introduction, the shift to electric vehicles provides several benefits, such as reducing pollution and direct use of fossil fuels for mobility. However, from a sustainability and climate change perspective, it is important that the electricity used for powering the EV fleet comes from carbon-neutral technologies (Jochem et al., 2018, 2015; Sioshansi and Denholm, 2009). The trend from the state policies indicates that there is support for the use of renewable energy sources for charging EVs. For example, the Andhra Pradesh policy states *"(v) Third party EV charging service providers will be allowed to procure power through open access route from renewable energy sources irrespective of the size of the demand. (vi) Third party EV charging service providers can also setup their own renewable energy generating stations at their premises for charging Electric Vehicles only."* This can be considered as a welcome step in the greening of the value chain. However, remaining questions about the availability of sufficient renewable energy - either generated at the charging station itself or through the main grid - need further discussion that is outside the scope of this research.

B. The incentive for launching the EV charging market

The states have considered providing incentives to charging infrastructure for launching the market in their EV policy. A trend towards providing capital subsidy for setting charging stations is observed. Furthermore, the policies provide a varying degree of exemption on taxes (State Goods and Services Tax (SGST)) and levies. For example, in Andhra Pradesh there is a 100% SGST reimbursement on purchase of fast chargers and advanced batteries for battery swapping stations. Telangana provides a 75% reimbursement on procurement of fast charging equipment to set up charging stations. As of

August 1st, 2019, the central goods and services Tax (GST) is reduced from 18% to 5%. The Government of India has also included setting up of charging stations as part of the FAME-II policy initiative.

As the charging market takes off and starts to follow demand (new chargers installed where there is demand), the incentives can be made more targeted to ensure that coverage in remote or low demand areas is not forgotten. In the international context, the need for targeted incentives has also been highlighted in DG-IPOL, (2018).

C. Prioritisation in terms of EV characteristics and social geography

State policies have generally identified priorities in terms of EV characteristics and social geography. The general trend appears to be of initially using a coverage-based approach, especially for highways connecting urban areas and also for urban regions. The initial priority in terms of EV characteristics appears to be for buses, 3W and 4W shared fleets and intra-city goods carriers. Note that in Delhi, 2W are the initial targets. The GoI guidelines identify priorities over different time horizons.

D. Elimination of administrative barriers for establishing charging stations

Only two states (Maharashtra and Andhra Pradesh) provide a direction on the elimination of administrative barriers. The Maharashtra policy states, *"After the receipt of application for setting up a charging point is received, the concerned planning authority & electricity supplying agency shall grant permission within 15 days. If permission is not received within 15 days, it will be deemed to be permitted."* The Andhra Pradesh policy states *"(v) DISCOM shall release supply to charging/battery swapping stations within 48 hours of application. (vi) Municipalities shall issue provisional permissions online immediately to setup charging/battery swapping stations. Any verification shall only be post sanction of provisional permission."*

It is important that in the future the states will consider specific provisions within the EV policy for eliminating barriers to the establishment of charging stations. The one key dimension that would form part of these provisions, namely (reasonable) time frames is already identified by Maharashtra and Andhra Pradesh. Another dimension is single-window clearance at the state level. Such a process is common practice for improving the ease of doing business. In the context of the state EV policies, it is observed that such a provision exists for the manufacturing sector in several states. Extending this policy to EV charging services business would aid in enabling supply-side of EV charging.

E. Mandate on user data sharing and privacy

The trend in the assessed states indicates that the current EV regulation does not identify or consider the issue of user data sharing and privacy. The GoI provides guidelines only on a database of public EV charging stations. The GoI, (2018) states that *"Share charging station data with appropriate DISCOM* *and to maintain appropriate protocols as prescribed by such DISCOM for this purpose. CEA shall have access to this database." The 2019 update modifies this as: "CEA, Central Nodal Agency (CNA), and State nodal agency (SNA) shall have access to this database."*

In today's world of digitalisation, it is essential that consumers be protected from the misuse of their data. This is no different from data on the charging behaviour and preferences of EV users. At the same time, ethical valorisation of this data by service providers for profit can have a positive impact on enabling charging infrastructure from the supply-side. Thus, the EV policy must include some provisions that mandate the development of frameworks on the handling and use of user data and privacy. The development of such a framework would entail coordination with the Telecom Regulatory Authority of India (TRAI) and other stakeholders from the ICT sector.

F. Mandate on the utilisation of V2X capabilities

The trend in the assessed states indicates that V2X aspects have not been identified or considered in the current regulation except in Andhra Pradesh. The Andhra Pradesh policy states that *"Andhra Pradesh Electricity Regulatory Commission (APERC) will issue regulations, defining tariff and related terms & conditions, for vehicle to grid (V2G) sale of power to meet the requirements of real time and ancillary services for DISCOM. Sale of power from battery swapping stations to the grid will also be considered as V2G sale of power."*

V2X resources are a valuable resource in the power sector (See section 3.2 for details). Policymakers must proactively consider the possibility of unlocking the full value of the services that this resource can provide. To do so, state policymakers can include provisions that mandate the development of a framework for the utilisation of V2X capabilities. Another possible early step is to mandate a cost-benefit analysis at the state level to assess the need and extent to which V2X should be enabled and incentivised.

1.2.2.2 *Enabling EV charging on demand-side*

In this section, the EV policies in the eight Indian states are qualitatively assessed based on the eight identified elements to ascertain whether and to what extent these policies enable the demand side in the deployment of public charging infrastructure. In this context, the demand side refers to the EV user that would eventually make use of the charging infrastructure and the services that it provides.

A. Technical standardisation of chargers for interoperability

A trend towards adopting a top-down approach that specifies technical standards to ensure interoperability is observed, except in the states of Maharashtra and Uttar Pradesh. The GoI guidelines also provide a list of minimum requirements for type and number of chargers of each type.

B. The mandate for the development of digital platforms and database management systems

The trend indicates that most states have considered the development of digital platforms in their EV policy. In this context, the GoI guidelines (2019b, 2018) state that *"Central Electricity Authority (CEA) shall create and maintain a national online database of all the Public Charging Stations through DISCOMs. Appropriate protocols shall be notified by DISCOMs for this purpose which shall be mandatorily complied by the PCS/BCS. This database shall have restricted access as finalised between CEA and Ministry of Power."*

C. Specification of the use of a wide range of payment methods

The trend in the assessed states indicates that only the policy in Delhi identifies the issue of intra/interstate user registration for enabling seamless access to charging stations. The Delhi EV policy states *"EOs, BSOs and mini swapping station operators will be expected to accept payments by multiple modes (e.g., cash, cards, mobile wallets, UPI); payments through the common mobility card payment system will also need to be offered as an option for payments."*

Having a wide range of payment methods would provide greater flexibility to EV users. State policymakers can enable this element by mandating or specifying the availability of a wide range of payment methods at the charging stations. There is a possibility of even going further by specifying minimum standards.

D. Specification of minimum facilities to be provided at charging stations

Minimum infrastructure requirements for the public charging station is only specified in the GoI guidelines. The states can use this as a basis for developing provisions in the state regulation on this aspect. This would ensure consistent quality of facilities at all public charging stations in the states. In turn, this would lead to an improvement in the user experience, thus enabling the demand-side.

E. Harmonisation of Intra/interstate user registration for accessing charging infrastructure

The trend in the assessed states indicates that the current EV policies do not identify or consider the issue of intra/interstate user registration for enabling seamless access to charging stations.

An unharmonized user registration system for access to charging infrastructure of different service providers can create a barrier for the demand-side. These issues can be mitigated in the EV policy by including provisions that mandate the development of regulation that ensures seamless access. This would mean a harmonised user registration process for accessing charging stations of different providers, which can be done either by the central regulator at a national level or through bilateral coordination and agreement between to states.

F. Establishment of a mechanism to address consumer complaints

The establishment of a mechanism to address consumer complaints is not considered in any of the assessed state policies nor in the GoI guidelines. Attending to the concerns of consumers rapidly and efficiently would lead to greater trust in the functioning of these services, thereby enabling the demand-side. Policymakers proactively take a step within the EV policy by mandating minimum standards for a mechanism to address consumer complaints. However, in this context, care must be taken that such a standard does not create a market entry barrier as setting up of such a complaints mechanism may be significantly easier and viable for a large company as compared to small businesses (for instance a shop that provides one commercial charging point).

1.3 Chapter conclusions and recommendations

Indian policymakers at a state and national level are proactively pursuing actions for developing a robust EV charging infrastructure in India. These policies cater to the charging infrastructure used for both fleets (B2B) and individual consumers (B2C). In this chapter, we assessed eight state policies from the perspective of enabling charging infrastructure from the supply-side and the demand side. Based on our assessment, it follows our recommendations on a future enhancement that the policymakers may consider for inclusion in their EV policies.

From the supply-side perspective, six recommendations are made:

- To reduce entry barriers, it is recommended for the states to mandate a process for time-bound, single-window clearance for permission required to develop charging stations. Such a process is common practice for improving the ease of doing business. In the context of the state EV policies, such a provision exists for the manufacturing sector in several states. Extending this policy to EV charging services business would aid in enabling supply-side of EV charging.
- To foster competition and eliminate any market power concerns in the future as the market enters the growth stage, it is crucial that policymakers clarify within the EV policy the long-term role of state-owned utilities, which appear to lead the initial deployment of charging infrastructure currently, in providing EV charging services.
- As the EV market enters the growth stage, it can be a good practice to reassess the approach to designing the EV charging tariff structure periodically. In these times of rapid disruptive innovation, such a review would also allow the regulators to re-evaluate and provide clarity on the pricing of value-added services.
- In general, a coverage-based approach is already observed in state policies. However, as the EV charging market takes off and starts to follow demand (new chargers installed where there is

demand), the incentives should be recalibrated to ensure that coverage in remote or low demand areas is not forgotten.

- Furthermore, it is essential that EV users be protected from the misuse of their data. At the same time, this data can be a valuable resource for the charging service provider to optimise its operations, and its value could be monetised for additional revenue. Thus, the EV policy must include some provisions that mandate the development of frameworks on the ethical handling and utilisation of user data and privacy.
- In the future, when the EV market matures V2X service has the potential to become a valuable resource. Policymakers must consider developing a regulatory framework for the utilisation of V2X capabilities. A cost-benefit analysis can become the basis for deciding the extent to which V2X should be enabled and incentivised.

From the demand-side perspective, four recommendations are made:

- It is crucial that the EV policy specifies a wide set of minimum payment methods that should be made available to the consumer at a charging station. This would lead to improved consumer convenience by increasing their payment flexibility, thus enabling the demand-side.
- Minimum facilities required at the public charging station (such as the size of parking space, number and types of chargers etc.) are specified in the GoI guidelines. States can use this as a basis for developing provisions in the state regulation on this aspect. This would consequently lead to an improvement in the consumer experience.
- An unharmonized registration system for EV users with different charging service providers can create a barrier for the demand-side by limiting access for consumers to the full EV charging network. These issues can be mitigated in the EV policy by including provisions for the development of regulation that ensures seamless access. This would mean a harmonised registration process, which can be done either by the central regulator at a national level or through bilateral coordination and agreement between two states. This harmonisation would improve access to a wider charging network for EV users after a single registration process for using EV charging infrastructure.
- Finally, attending to the concerns of consumers rapidly and efficiently would lead to greater trust in the functioning of these services, thereby enabling the demand-side. Policymakers proactively take a step within the EV policy by mandating minimum standards for a mechanism to address consumer complaints.

Figure 11 illustrates the relevance of the chapter recommendations and conclusions in the context of the market development phases.

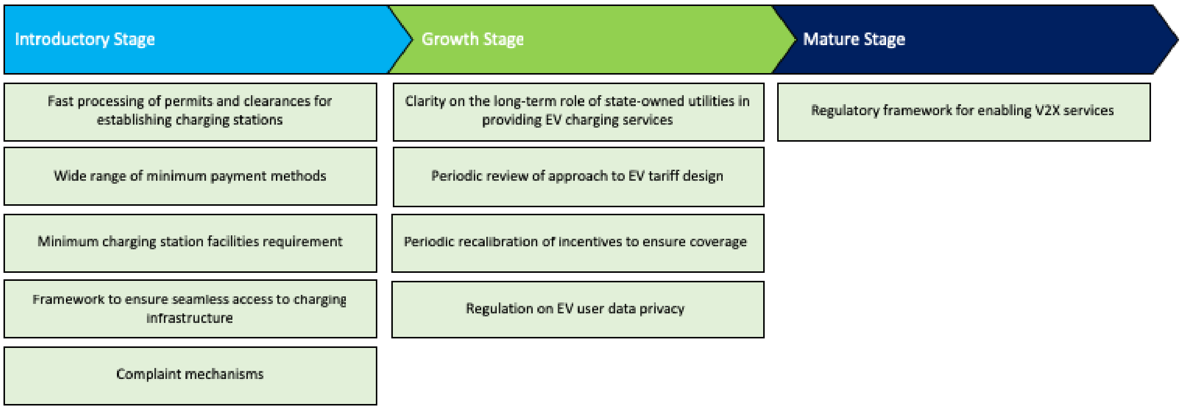


Figure 11: Relevance of chapter recommendation and conclusions in the context of market development stages

2 Business model innovation to enable EV charging services

A robust EV charging infrastructure is needed for India to reach its ambitious electric mobility targets. Apart from the policy and regulatory push, a key driver for the development of this infrastructure would require the existence of viable business models for the provision of charging services. Furthermore, these business models may have to evolve as the market matures.

India today has limited players in the sector who compete to offer essential EV charging services; therefore, the market is at the introductory stage of development. Other markets (e.g. Norway, Italy, USA, France) are in a growth stage of market development with an increasing number of players offering varied EV charging services with ever-evolving business models.

In this chapter, we structure the debate on business models for the provision of EV charging services. In this research, business models of companies who are actively engaged in providing EV charging services in India and in countries that are in the growth stage of market evolution are assessed using a case-study approach.

2.1 Conceptual business model frameworks and their application for EV charging

Demil and Lecocq, (2010) define a business model (BM) as *"the concept refers to the description of the articulation between different BM components or 'building blocks' to produce a proposition that can generate value for consumers and thus for the organization".* The definition is not limited to just what companies do as a business, but also includes what value it has to offer to the consumer.

Several business model frameworks have been discussed in the literature. However, there is no consensus on the components that make up a business model framework. For this study, we apply the framework proposed by Gassmann et al. (2014). Similar framework has been applied to discuss new business models in the electricity sector, see (Glachant, 2019).

2.1.1 The conceptual business model framework

Gassmann et al., (2014) identify four central dimensions that form part of a business model framework, namely, the Who, the What, the How and the Value. The Who refers to 'who is the consumer' (See Figure 12). The 'What' refers to 'what is offered to the consumer' in terms of a bundle of products and services' or in other words, what the customer values, i.e. value proposition. The How refers to 'how to build and distribute the value proposition', and the Value refers to 'revenue and pricing model' or in other words, how to make money in the business.

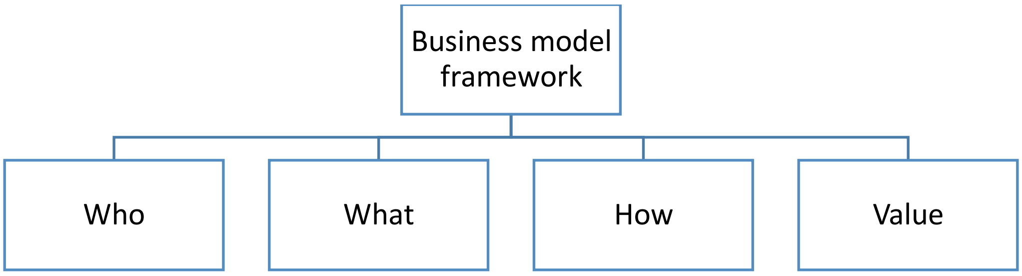


Figure 12: Gassmann's business model framework

2.1.2 The business model framework applied to EV charging infrastructure

The business model framework proposed by Gassmann et al. (2014) is applied to the EV charging businesses by identifying relevant attributes under each dimension to understand their interlinkages in the EV charging ecosystem.

Dimension one (Who) can be further categorised as either public or private consumer. The consumer segmentation is done based on how the charging infrastructure is used and is, therefore, vehicle type agnostic. Consumer segment ***'Public'*** refers to EV infrastructure that can be used by multiple users. Thus, the EV charging infrastructure is not limited to an exclusive set of users. Consumer segment ***'Private'*** refers to EV infrastructure, which is set up for the exclusive use by either a single user or a set of users (e.g. fleets, gated communities, workplace, etc.). In both private and public categories, the EV charging business can offer both businesses to business (B2B) or business to customer (B2C) services.

Dimension two (What) consists of the bundle of services that can be offered via the EV charging infrastructure. Three service attributes are identified under this dimension[12] — the first being ***'Charger'*** itself, which is the hardware component. The charger could include the physical pole and the socket to plug-in for charging. The second attribute is ***'Retail'***, which refers to the supply of electricity to the EV user via the charger. The third attribute is the ***'Additional Services'*** offered that go beyond the basic charger plus electricity retail model. Additional services could include multi-speed, multi-socket, multi-retail or software applications for aspects such as location, payments, billing, grid services, and data analytics.

Dimension three (How), consists of the partnerships that can be formed between the key actors in the EV charging ecosystem to provide the bundle of services that can be offered. Three key sets of actors are identified. First is the '***Public Authority'***, which include ministries, local municipal bodies, transport authorities and public sector undertakings, who are tasked with the EV rollout. Second is

[12] While referring to service attributes charger and retail, it is technology agnostic, therefore in business cases where battery swapping is used instead of pole (or equivalent) based charging, it could be considered as a type of service within either of these attributes.

the ***'Power Utilities'*** which include distribution and retail companies that supply the electricity needed to charge EVs. The third is the ***'Enterprise'*** which could include, automobile manufacturers, charging hardware manufacturers, software application companies, fleet operators, parking facilities, oil marketing companies and other public sector undertakings, who will participate in enabling EV charging infrastructure.

Dimension four (the Value) refers to the pricing strategy, which will determine the revenues flow for the business entity. There are two key attributes to this dimension. One being the ***'Pay-as-you-go' (PAYG)***, in other words, pay per use. The other is ***'Subscriptions'***, which could be for billing or access arrangements which are time frame bound.

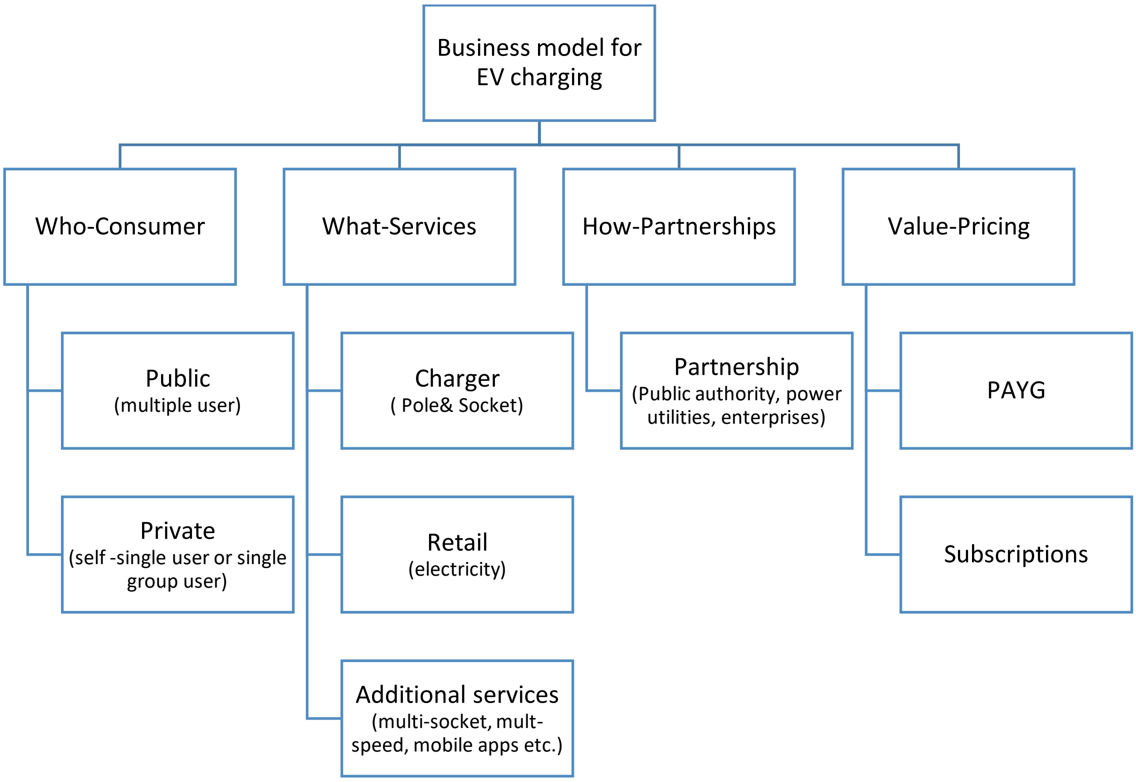


Figure 13: Gassmann's business model framework adapted for EV charging business.

2.2 EV charging business model trends in India

Current EV charging business initiatives in India could be classified into two broad categories. The first category groups the initiatives undertaken by public sector undertakings (PSUs) and energy utilities, which are diversifying their business portfolio. The second category covers the initiatives undertaken by fleet operators (mostly public state transport authorities) who are the first adopters of EVs.

Several initiatives that fall under the first category exist across various cities in India. According to media reports, there are several announcements about investment in charging infrastructure in different parts of the country. Tata Power intends to install up to 1000 EV charging stations in Delhi

(Narasimhan, 2018) and 100 in Maharashtra (going beyond the 21 already existing in Mumbai, Delhi, and Hyderabad) (Raj, 2018). Bangalore Electricity Supply Company (BESCOM) intends to set up to 650 EV charging stations in Karnataka (going beyond the 100 expected to be operational in 2019) (Iyer, 2019) and Maharashtra Electricity Distribution Company (MSEDCL) intending to set up to 500 EV charging stations in Mumbai, Thane, Pune, and Nagpur (PTI, 2018a). Other companies such as National Thermal Power Corporation (NTPC), GAIL, Powergrid, and India Oil are also gearing up for entry into the EV charging business shortly (Kumar, 2018; PTI, 2018b, 2018c, 2018d).

Under the second category, many state-owned and private city transport fleet operators are taking the lead in procuring EV fleets. Consequently, setting up charging infrastructure to service these vehicles. Example cities include Nagpur, Lucknow, Kolkata, Jammu, Guwahati, Bangalore, Ahmedabad, Mumbai, Hyderabad, and Jaipur (News18, 2019).

2.2.1 Case studies of EV charging business models in India

In what follows, we present three representative cases of business models for EV charging that are currently active in India. These include the utility model by BESCOM, the fleet model by Ola, and a private company setting up charging infrastructure by Fortum India. Each of the cases is described in terms of the states they are operating, the consumers they are targeting, the services they are offering, the partnership they are in and their pricing models.

2.2.1.1 *BESCOM – a utility*

BESCOM, the state-owned utility plans to set up 650 public EV charging points across its jurisdiction in partnership with local authorities. The charging stations may offer two speeds of charging at the regulated price set by the Karnataka electricity regulator. The utility also intends to launch an application to enable consumers to plan and access the charging points easily. The key features of this business model are presented in Table 6.

Table 6: Key features of the BESCOM business models

<table>
<tr><td colspan="2">City of Operation</td><td>Bangalore</td></tr>
<tr><td rowspan="4">Business model</td><td>Consumer</td><td>- The company provides public B2C charging</td></tr>
<tr><td>Services</td><td>- The utility is setting up charging stations to provide two speeds of charging. It is also in the process of developing a dedicated mobile application for consumer convenience.</td></tr>
<tr><td>Partnership</td><td>- The local authority sets up charging stations in strategic locations.</td></tr>
<tr><td>Pricing</td><td>- The pricing is Pay-As-You-Go (PAYG) pricing in ₹/kWh based on the tariff set by state regulators.</td></tr>
<tr><td colspan="2">Key Highlights</td><td>- Portfolio expansion
- Utility-driven</td></tr>
</table>

2.2.1.2 *Ola –fleet operator*

Ola is a transport network company that has procured 200 multi-vehicle EV fleet (e-rickshaws and e-cabs) to operate in the city of Nagpur. In partnership with the municipality of Nagpur and public sector undertakings such as Indian Oil, the company has set up its own private charging stations to service their EV fleet. The fleet drivers access the charging station data via the in-house Ola app. Some of the charging stations also have solar panels for self-generation. The key features of this business model are presented in Table 7.

Table 7: Key features of the Ola business model

City of Operation		Nagpur
Business model	Consumer	- The company provides private charging services to fleets (B2B).
	Services	- The company provides multi-speed and multi-socket charging solutions for its own fleets using its own charging infrastructure. The company has a mobile application for customer convenience. At select stations, self-generation with Solar PV is utilised.
	Partnership	- Local authorities and PSUs for provision of land - Power utilities for electricity
	Pricing	The pricing is PAYG pricing in ₹/kWh based on the tariff set by state regulators.
Key Highlights		- Multi-chassis (3W and 4W) charging solutions for its fleet operations - Self-Generation

Source: (Arora and Raman, 2019)

2.2.1.3 *Fortum India – a company*

Fortum offers turnkey solutions for setting up EV charging stations. After a successful venture in Europe, the company has set foot into the Indian market. The company offers services in setting up both plug-in charging station or swapping stations. It also has its own novel in house application called 'Charge & Drive', which offers consumers with location, time, and pricing details of the charging stations, and offers multiple payments methods for consumer convenience. One of the recent projects undertaken by the company is to set up 200 charging stations in the city of Hyderabad, under a build-own-operate-transfer model in partnership with Indian Oil. The key features of this model are presented in Table 8.

Table 8: Key features of Fortum India business model

City of Operation		Hyderabad, Delhi
Business model	Consumer	- The company provides public B2C charging and private B2B solutions.
	Services	- Fortum India provides turnkey solutions for setting up EV charging infrastructure. Fortum also offers its own in-house software 'Charge & Drive' EV charging platform which offers flexible payments options besides providing location, time and price details to the consumer. The charging stations offer two-speed and multi-socket charging.
	Partnership	- Power utilities for providing electricity - The local authority sets up charging stations in strategic locations - In Hyderabad, under the Build-Own-Operate the company is setting up to 150 to 200 EV charging stations, which will later be transferred to Indian Oil after 7 years.

		- In Delhi, it is partnering with an e-rickshaws fleet operator to service their charging needs by setting up battery swapping stations.
	Pricing	- The pricing is PAYG pricing in ₹/kWh based on the tariff set by state regulators.
Key Highlights		- Turn-key charging solution provider - Provide swapping and plug-in solutions. - Versatile mobile application

Source: (Fortum, 2019)

2.2.2 Observed business model trends in India

From the Indian case studies, the Indian EV charging market is at an introductory stage. The current focus is clearly on kick-starting the market and providing basic minimum charging services to EV users. The geographical attention is primarily on urban clusters and consequently on short to medium range mobility. Utilities and public sector undertakings are taking the lead in kick-starting and setting up public EV charging infrastructure with limited (but growing) private sector involvement. However, the current dominant actor in India is private B2B consumers; basically, the fleet operators.

Thus, in the context of the Gassmann's business model framework, as shown in Figure 14, in the Indian market, the demand is led by private B2B consumers. At this stage, innovation is occurring in how companies are partnering with each other to roll out charging stations. However, it should be noted that public B2C charging providers are emerging and they are offering multiple sockets and multiple speed options.

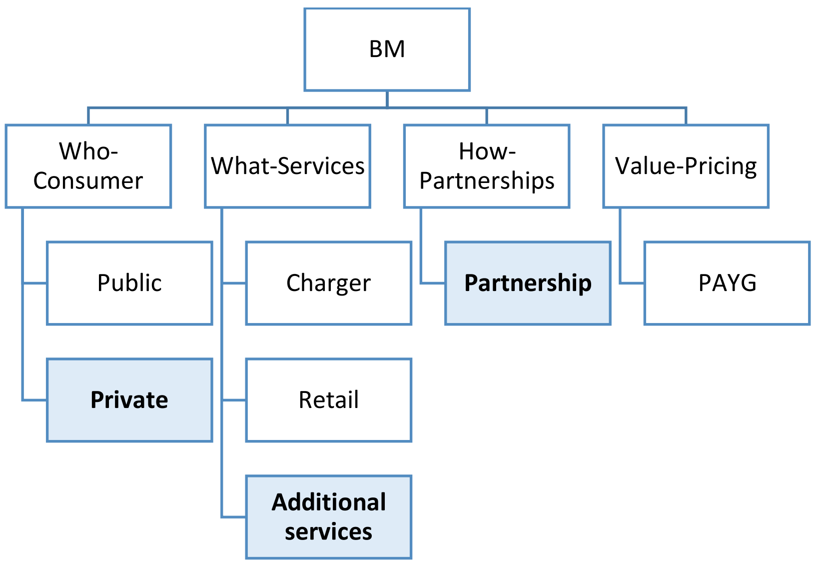


Figure 14: Indian charging business model focus areas within the Gassmann framework

2.3 EV charging business model trends for EV markets in the growth stage

Countries such as Norway, United States of America (USA), United Kingdom (UK), Germany, France, Italy and others with higher penetration of EVs when compared to India, are at the growth stage of their EV market. That is, many companies are competing in the business of setting up EV charging infrastructure and have diverse offerings. Amongst the many companies that currently exist, a selection of eight representative cases of EV charging infrastructure business - in markets that have seen significant growth in EV adoption over the past few years - is presented.

2.3.1 Case studies of EV charging business models in growing markets

In what follows, we present EV charging business model case studies from growing EV markets in Europe and the USA. These include Ubitricity, PlugNgo, Nuvve, Allego, Izivia, Fastned, Share&charge and EnelX. Each of the cases is described in terms of the states they are operating, the consumers they are targeting, the services they are offering, the partnership they are in and their pricing models.

2.3.1.1 *Ubitricity*

Ubitricity primarily specialises in offering lean charging points, which occupy less space and can easily integrate into public or private spaces. Their novelty is the smart cable along with a smart meter that enables a consumer to link their EV with any of their charging points with ease. Besides offering various pricing subscriptions options, the company also offers access to a wider network of charging stations via e-roaming 'PlugSurfing' network. The key features of this business model are presented in Table 9.

Table 9: Key features of the Ubitricity business model.

Country of Operation		Germany, UK
Business model	Consumer	- The company provides both private B2B and B2C as well as public B2B and B2C charging solutions.
	Services	- The customer is provided with a smart cable which consists of a meter for measuring usage and the two ends to connect to the EV and a charging point. The company aims at providing hardware that is lean and space-saving. There are two charging speeds offered. The company also provides its own user mobile app.
	Partnership	- Power retailers for providing electricity - Other EV Charging providers for E-roaming via PlugSurfing - The local authority sets up charging sockets
	Pricing	- Subscription: The price depends upon the contract of the users with their energy provider. The smart cable combined with the simple sockets offers three variations (SimpleSocket-start, SimpleSocket, SimpleSocket-Plus) for metering and billing requirements of the consumer
Key Highlights		- The user chooses its energy provider - Smart billing - Access to a wider network - Specialised lean hardware

Source: (Ubitricity, 2019)

2.3.1.2 *PlugNgo*

PlugNgo offers turnkey solutions for setting up a charging station. It offers both slow and fast charging options and caters to all consumer segments. The company strategically partners with locational charging such as parking lots, fleet owners and EV charger manufacturers for procurement of hardware to set up the charging stations. The key features of this model are presented in Table 10.

Table 10: Key features of the PlugNGo business model.

Country of Operation		UK
Business model	Consumer	- The company provides both private B2B and B2C as well as public B2B and B2C charging solutions.
	Services	- PlugNgo provides turnkey solutions for setting up slow and fast charging infrastructure right from demand surveys to installation to usage monitoring.
	Partnership	- Location owners (such as parking lots) for setting up charging points - EV fleets - Charging hardware manufacturers
	Pricing	- The standard rate for charge points in UK and Gibraltar is £0.36/kWh, plus a connection fee of £1.00.
Key Highlights		- Turn-key charging solution provider - Provides Multi-speed and multiple chargers

Source: (PlugNgo, 2019)

2.3.1.3 *Nuvve*

Nuvve primarily caters to private fleets and offers bi-directional charging solutions to its consumers. Their own EV management software NERA helps in aggregating the EVs and aims at reducing the consumer bills via V2G services. The key features of this business model are presented in Table 11.

Table 11: Key features of the Nuvve business model.

Country of Operation		Denmark, France, UK, USA, Belgium, Italy
Business model	Consumer	- The company focuses on the private B2B market.
	Services	- Nuvve provides grid-integrated vehicle platform for V2G (V2G-Give). It consists of a smart bi-directional charger and EV management software for V2G (NERA-Nuvve energy regulation aggregator). The company focuses on reducing charging costs for fleets with aggregated V2G service provision.
	Partnership	- Fleet operators - Network companies for providing V2X (Dreev – a joint venture between EDF and Nuvve for Belgium, France, Italy, and the UK)
	Pricing	- Subscription: Monthly invoice in €/kWh
Key Highlights		- Bi-directional chargers - V2G services aggregation and provision

Source: (Nuvve, 2019)

2.3.1.4 *Allego*

Allego offers charging station solutions using its own charging hardware. It caters to all consumer segments and offers multi-speed and multi-socket solutions. As the company operates close to 10,000 charging stations, it offers different pricing and access benefits to its consumer via a charge card. Also, the consumers can access data on the charging stations via their application called SMOOV. The key features of this business model are presented in Table 12.

Table 12: Key features of the Allego business model.

Country of Operation		Netherlands, Germany
Business model	Consumer	- The company provides both private B2B and B2C as well as public B2B and B2C charging solutions.
	Services	- Allego provides multi-speed and multi-socket charging options through its own charging hardware. It also provides a mobile app for its customers called SMOOV. Ecotap and Allego have the concession to install and operate around 4500 public charging sockets in 43 cities in the Netherlands.
	Partnership	- Charge card providers for subscription billing and registration. - Other EV Charging providers for E-roaming (e.g., E-Flux)
	Pricing	- Standard tariffs with E-Flux card (Transaction cost 0.15€ or 2.95 €/month): - Fast charging: 0.69 €/kWh - Public locations: 0,34 €/kWh Note prices may vary for different countries and some specific locations.
Key Highlights		- Access to a wider network - Pricing may differ with location

Source: (Allego, 2019)

2.3.1.5 *Izivia*

IZIVIA focuses solely on providing fast charging to public consumers across intercity routes under its 'Corri-door' project, using its own hardware. A novelty of this company is in the use of green power and in some cases, the use of solar panels for self-generation at the charging station. The company offers both monthly and pay-as-you-go payments options, and unlike many other companies, it bills customers based on the time taken to charge the vehicle. In addition, the company, in partnership with other companies, offers access to a wider network of charging points for its consumers. The key features of this business model are presented in Table 13.

Table 13: Key features of the Izivia business model.

Country of Operation		France
Business model	Consumer	- The company provides public fast-charging services to individual customers (B2C) along motorways.
	Services	- The company focuses on the provision of fast charging using their own hardware. The company currently has a network of 200 rapid charging points distributed every 80km along motorways in France called 'Corri-door'. At some locations, the company provides an EV charging infrastructure that is powered by Solar PV (Ombriwatt).
	Partnership	- Power utilities to procure green power - Other EV Charging providers for E-roaming - Parking providers for price bundling

	Pricing	- Subscription: Monthly Invoice in €/Min
		  o ZEN: 3€/Month + 0.7 €/5min
		  o Premium 30€/Month + 0.5 €/5min
		- Pay as you go 1€/5min

Key Highlights		- Green Power - Self-generation - Time-based pricing - Access to a wider network

Source: (Izivia, 2019)

2.3.1.6 *Fastned*

Fastned, focuses on providing a network of rapid charging points across motorways using its own hardware. The company, via its own software application, offers consumers route planning, reservation and different payment methods as services. The chargers use green power, which is either procured or self-generated using solar panels. The company offers a wide range of subscription plans from monthly billing to pay-as-you-go, along with access to a wider network via the 'E-Flux' network. The key features of this business model are presented in Table 14.

Table 14: Key features of the Fastned business model.

Country of Operation		Belgium, Germany, UK
Business model	Consumer	- The company provides fast charging solutions for both public B2C and private B2B consumers. Therefore, it is open for fleets and individual EV owners.
	Services	- The company focuses the provision of fast charging using their own hardware as well as have their own mobile app for payments, route planning, and reservation. The company currently has a network of rapid charging points along motorways.
	Partnership	- Power utilities to procure green power - Other EV Charging providers for E-roaming - Various payment solution providers - Joint partnerships with ABB
	Pricing	- Subscription: o Member: 0€/Month + 0.59 €/kWh o Gold Member: 11.99€/Month + 0.35 €/kWh - Pay as you go 0.59 €/kWh
Key Highlights		- Green power - Self-generation - Access to a wider network (E-flux card) - Versatile mobile app

Source: (Fastned, 2019)

2.3.1.7 *Share&Charge*

Share&Charge offers a peer-to-peer marketplace platform to connect the various EV users with the various EV charging service providers, using technology such as blockchain. The key features of this business model are presented in Table 15.

Table 15: Key features of the Share&Charge business model.

Country of Operation		Germany, USA, UK, Norway
Business model	Consumer	- The company provides public B2B and B2C charging solutions.
	Services	- Share&Charge acts as an intermediary to provide peer to peer matchmaking between charging service provider and consumers (using blockchain technology).
	Partnership	- Charging service providers (CSP) - Mobility service providers (MSP)
	Pricing	- Set by the charging service provider selected by the user.
Key Highlights		- Peer to the peer marketplace platform - It connects consumers, CSPs, and MSPs.

Source:(Share&Charge, 2019)

2.3.1.8 *EnelX*

EnelX offers multiple charging solutions to all consumer segments across multiple countries. The company offers dedicated charging stations that offer both uni-directional charging and bi-directional charging solutions. With the aim to offer flexibility, it uses specialised hardware 'JuicyBox' and software 'JuicyNet" to offer grid services. In addition, the company also offers various pricing subscriptions. The key features of this business model are presented in Table 16.

Table 16: Key features of the EnelX business model.

Country of Operation		Italy, France, Denmark, Germany, Austria, Switzerland, Netherlands, UK, Belgium, Sweden, Norway
Business model	Consumer	- The company provides both private B2B and B2C as well as public B2B and B2C charging solutions.
	Services	- The company offers charging solution of multiple speeds and multiple socket types. The company also provides bidirectional chargers for V2G service provision (JuicyBox). Enel X currently has 3363 charging stations across Europe with the largest concentration in Italy, and via its own JuiceNet software platform it offers grid services.
	Partnership	- EV Fleets - Public administration for setting up EV stations. - Recharge partners such as commercial establishment with parking space to install chargers.
	Pricing	Multiple pricing options are provided - Basic: 0.45€/kWh for Quick sockets and 0.50€/kWh for Fast sockets - Premium: 25€/Month will give Basic plus the possibility for booking service for one year - Flat Plan - Small: 25 €/month for monthly 60 kWh - Flat Plan - Large: 45 €/month for monthly 120 kWh.
Key Highlights		- Wide dedicated coverage - V2G services aggregation and provision for grid services

Source: (EnelX, 2019)

2.3.2 Observed business model innovation trends in growth stage markets

From the case studies, it is evident that private sector participation in the EV charging business is growing. It can also be seen that the focus of businesses has evolved from purely providing access for charging to more on how the service is being offered in order to increase market share by improving consumer convenience and differentiating their product offer. Enterprises are innovating to improve the value of the services they provide the EV user. The Geographical context has expanded to incorporate long-range mobility, i.e., intercity with several businesses providing fast charging along highways.

Consequently, innovation trends in business models are evident in three key attributes, namely, services, partnerships, and pricing. As shown in Figure 15, is occurring is in 'what' services are being provided in terms of the charger, retail, additional services; the types of partnerships being developed; and pricing in which subscriptions are offered to the customer.

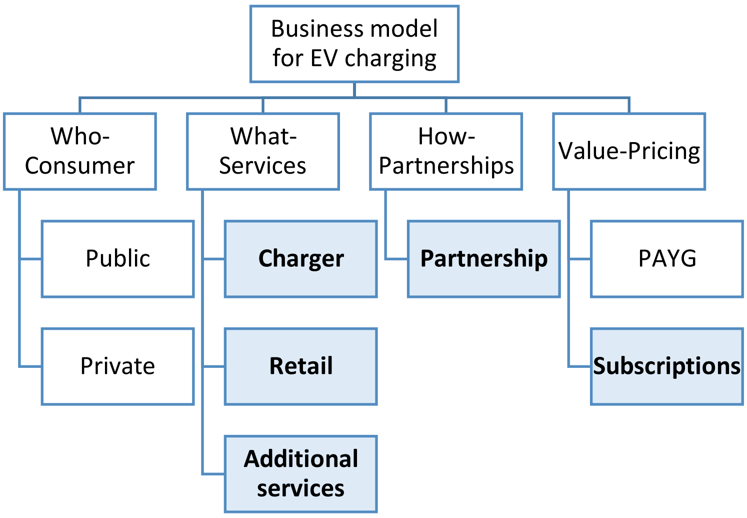


Figure 15: Occurrence of innovation in the business model framework

Service innovation, is observed on two fronts. First, in almost half of the cases assessed, companies explicitly indicate the retail of 'green power' for EV charging as a key differentiator in their business models (see Table 17). Second, in all cases that were assessed, companies provided one or more of the 'additional services' such as the choice between multiple speeds, multiple sockets, multiple power retailers and ICT applications for users in varying degree thus indicating a strong trend.

Table 17: Innovation trends in EV charging

EV charging businesses	Service innovation		Partnership innovation		Pricing innovation	
	Green retailing	**Additional services**	**Access to a wider network**	**Service Specialisation**	**Charging Subscription**	**E-roaming Subscription**
Ubitricity	✓	✓	✓	✓	✓	✓
Plug N Go	✓	✓		✓		
IZIVIA	✓	✓	✓	✓	✓	✓
Nuvve		✓		✓	✓	
Fastned	✓	✓	✓	✓	✓	✓
Share&Go		✓	✓	✓		
Allego		✓	✓	✓		✓
EnelX		✓		✓	✓	✓

Partnership innovation is observed on two fronts. One, to 'increase access to the wider charging network' by partnering with other charging services providers. Five of the eight cases reviewed partner with other charging infrastructure providers to increase access to wider charging network. It is interesting to note that EnelX is following a different approach towards providing access to a wider network by installing its own charging stations across several countries in Europe rather than partnering with other providers. Two, charging service providers are partnering with other companies that provide 'specialised services' (for example, with companies supplying chargers and offering smart contracting, smart billing, data analytics services). All the cases reviewed partner with specialized service or product providers.

Pricing innovation is occurring in the offering of subscriptions, which have two dimensions that can be combined in varying forms. The first is 'charging subscription' in which EV charging service providers are offering subscriptions that provide users with preferential rates and benefits such as booking of chargers. Five cases apply this approach. The second is the 'e-roaming' subscription, where e-roaming can be defined as the provision of access to the wider EV charger network that goes beyond a single provider. Five of the cases reviewed have introduced this subscription model.

2.4 Chapter conclusions and recommendations

EV charging infrastructure business in India is at the introductory stage with a large scope for innovation. Currently, the focus is on kick-starting the market. Utilities and Public sector undertakings (PSUs) are taking the lead in kick-starting and setting up infrastructure with limited but growing private sector involvement. The geographic focus is primarily urban clusters and short to medium range mobility in which the dominant business model is the provision of charging solution to business (B2B) such as bus and taxi fleets. Where charging business targets final consumers (B2C), they are providing multi-socket and multi-speed options.

Case studies of growing markets indicate a trend that charging businesses are shifting from providing basic vehicle charging to incorporating more value-added services in their offerings and how these services are offered. There is greater private sector participation, and the focus is on increasing market share and consumer convenience. The geographic focus is also expanding to include long-range mobility, which is moving beyond urban cluster to intercity. In these markets, innovation in business models is evident in three key areas, namely; services, partnerships, and pricing. Within service innovation, businesses are promoting retailing of green power as well as the provision of additional services such as the choice between multiple speeds, multiple sockets, multiple power retailers, and ICT applications for users. Partnership innovation is focused on ensuring increased access to the wider charging network and partnering with actors that specialise in a particular service; for example, charging supplier, smart contracting, smart billing, data analytics. Pricing innovation is occurring in the offering of subscription. In varying combinations, charging subscriptions provide users preferential rates, while access subscriptions provide priority access to the wider network.

As India increases its EV penetration, business models will evolve as the sector transitions from introductory stage to the growth stage, where the focus could be on incorporating one or more of the innovation attributes as presented in Table 17.

Figure 16 illustrates the relevance of the chapter recommendations and conclusions in the context of the market development phases.

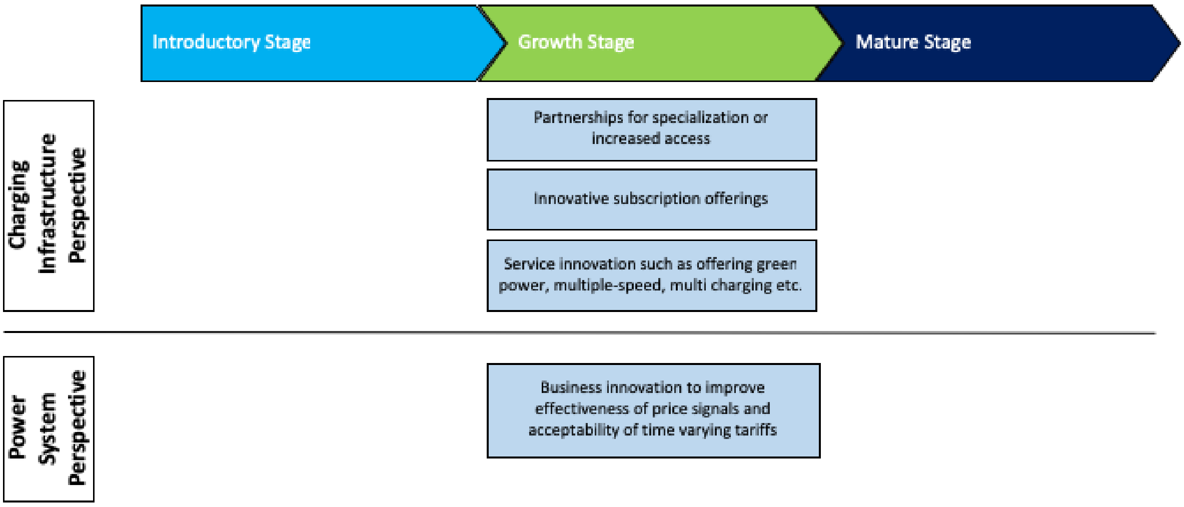
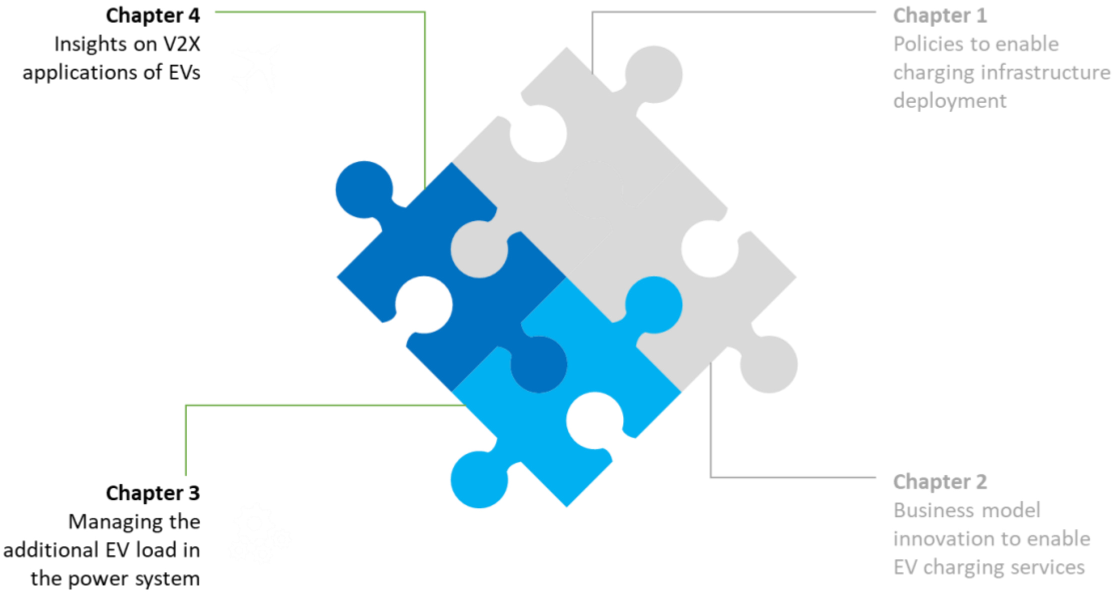


Figure 16: Relevance of chapter recommendation and conclusions in the context of market development stages

PART 2: Power System Perspective



3 Managing the additional EV load in the power system

From the power system perspective, EVs can be considered as an additional load and as a potential source of flexibility with V2X capabilities. In this chapter, the management of the additional load created by EVs is addressed.

EVs create a mobile, power-dense and variable electrical load that is mainly connected to the distribution grid. This is a different type of load that can contribute to the increase in total electricity consumption and the required generation and network capacity. Therefore, it is essential to anticipate and incorporate the growing number of EVs and the location of charging infrastructure in the long-term power system planning.

In India, forecasts indicate that EVs will contribute to the rapidly growing electricity demand in the country. By 2030, it is forecasted that EVs will account for around 3% of the total electricity consumption and this can be accommodated without having a significant impact on the power system (Abhyankar and Sheppard, 2017; Ali and Tongia, 2018) [13]. However, if the charging of EV is not well distributed in terms of time and location, it can lead to an increase in peak demand, which can result in higher energy and system service prices, thereby increasing the cost of electricity supply (Zhang et al., 2014) while grid congestion can lead to grid asset ageing and service interruptions. Consequently, this could increase the cost of ownership of EV and create inconveniences for EV charging (see Figure 17).

Conventionally, utilities would invest in additional new generation and distribution capacity (wire or storage) to ensure adequacy at any time and location of consumption. This way, peaks are accommodated, and the possibility of congestion is reduced. However, ***various solutions are emerging as alternatives to help defer these investments***. These alternative solutions include sending price signals to EV users to shift load from peak hours to off-peak hours and utilizing the distribution grid when it is not at its peak. Similarly, alternative solutions for congestion management allow the DISCOM to have the flexibility to manage congestions proactively or reactively.

[13] Under 30% and 100% EV sales target, the additional load will be 37 and 97 TWh by 2030, respectively (Ali and Tongia, 2018).

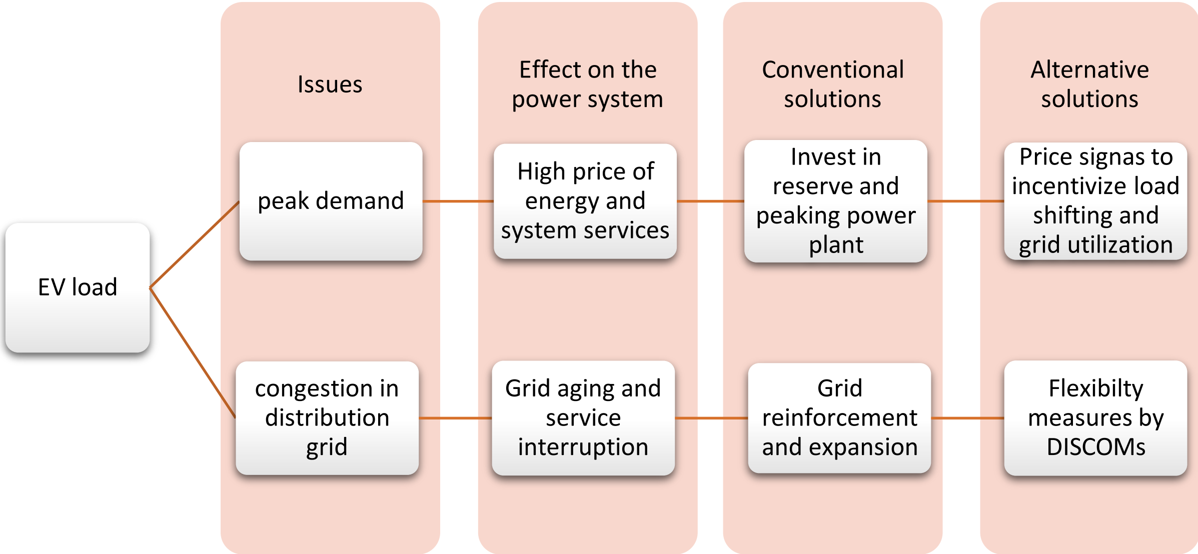


Figure 17: Potential issues caused by additional EV load, effects and solutions

In this chapter, ***we focus on alternative solutions for managing peak demand and distribution grid congestion*** by identifying and discussing various solutions based on the current experiences in India and international practices. This is followed by an assessment of each solution in terms of its applicability in India, given the status of enabling technologies and compatibility with the current regulatory framework. Based on this analysis, conclusions and practical recommendations are put forward.

3.1 Managing EV contribution to peak demand

The contribution of EVs to peak demand can be reduced by sending adequate price signals to EV users, with the aim of incentivizing them to shift charging from high-cost peak hours to low-cost off-peak hours (Collins and Mader, 1983; EDSO, 2018; Eurelectric, 2015; Faruqui et al., 2012; FOR, 2017; IRENA, 2019; King and Datta, 2018; Zhang et al., 2014). In practice, this can be achieved by designing a specific EV tariff that incorporates a time-varying dimension. Note that EV charging can be subject to regulated EV tariff or competitive price depending on the maturity of the electricity market. India currently has regulated price regime, and hence a separate EV tariff can be published, or EVs can be included in the existing tariff category. Hence, the following discussion assumes that a separate EV tariff is published.

Broadly, the final electricity bill of a customer includes the cost of generating, transmitting, distributing and supplying electricity to the point of consumption. Depending on the level of vertical integration of the sector, the costs could be attributed to one or more entities in the electricity value chain. These costs can be recovered from customers in different ways (see Table 18). First, it could be recovered as Rupees per unit of electricity consumed (₹ per kWh), referred to as energy charge or variable charge. Second, it could be recovered as Rupees per the maximum power capacity recorded each month (₹

per kW or kVA). This is commonly referred to as demand charge[14]. Third, it could be recovered as a fixed charge expressed as Rupees per installation per month or simply Rupees per month. Note that the final tariff can be a combination of these components. In the Indian context, we generally have a two-part tariff which combines energy charge with a fixed charge, or a demand charge.

Table 18: Description of tariff design components to recover total cost of electricity

Tariff component	Description	Format
Energy charge	The cost incurred by the customer depends on the level of electricity consumed.	₹ per kWh
Demand charge[13]	The cost incurred by the customer depends on the level of the maximum recorded capacity within each month.	₹ per kW or kVA
Fixed charge	The cost incurred by the customer is fixed and recurring each month regardless of his actual electricity consumption level or capacity usage. That is, if the customer consumes no electricity for an entire month, it still pays this charge.	₹ per month or ₹ per installation per month

In practice, the time varying element of an EV tariff is reflected in the energy and/or demand components of the tariff. In what follows, energy and demand charge components of EV tariffs are first discussed using international practices and then their applicability in the Indian context is presented in terms of technological readiness and regulatory compatibility.

3.1.1 EV energy tariff

The cost of electricity supply depends on the time of consumption during the day. The common approach to reflect this cost is through time-varying energy tariffs, which come in different forms. The simplest and commonly applied form is the time-of-use (TOU) tariff in which the time blocks and prices are determined in advance and revised periodically[15]. The TOU tariff is commonly referred to as *time-of-day (TOD) tariff in India*, hence in the remaining part of the report the term TOD tariff is used.

The most sophisticated form is real-time pricing (RTP) in which prices vary on an hourly basis, reflecting the changes in wholesale electricity price. In between these extremes, there can be other forms, see (Faruqui et al., 2012) for details on time-varying energy tariffs. In practice, we find TOD and RTP being applied to send price signals to EV users, as discussed in what follows.

3.1.2 Time of day tariff for EVs

Time of day tariff is typically applied to usage over large time blocks for several hours where the price for each time block is predetermined and remains constant. The tariff structure can be split into a simple day and night tariff to reflect the peak and off-peak hours or a day can be further split into

[14] A floor could also be introduced, often as a percentage of the contracted capacity. For example, DISCOM takes the highest of the maximum recorded capacity of the month or a percentage of the contracted capacity.
[15] This is sometimes referred to as static TOU (Hledik et al., 2017).

smaller segments. Moreover, seasonality can be incorporated into the tariff structure. However, it is advised that the structure of the tariff should be kept as simple as possible to facilitate understanding and acceptance by consumers (Olmos et al., 2011).

The benefit for the EV user responding to these price signals is savings in its EV charging bill. The power system benefits from a reduction in the cost of generating and supplying electricity due to the better utilization of existing infrastructure, both in generation and networks.

The limitation of TOD tariff is that one cannot be sure about the acceptance and effectiveness of the price signal beforehand because it depends on flexibility, awareness and price sensitivity of the user. On the one hand, if only a few EV users responded to the price signals, the desired reduction in peak demand will not be realized (Eurelectric, 2015; Wu et al., 2011). This is particularly the case for fleet vehicles which are likely to be less responsive to price signals due to their operational constraints; charging points which offer free charging (e.g., charging at workplace and business centres); and public charging stations which could choose to pass the price signals to EV users depending on their business model (see discussion in Chapter 2). In contrast, private charging stations are more likely to be responsive to these prices. That is, depending on their price sensitivity, EV users can program to charge their vehicle during off-peak hours, mostly evenings, to meet their mobility needs of the following day.

On the other hand, if many EVs simultaneously respond to low prices when the off-peak price starts, this can create a new peak (Kim, 2019). This unintentional peak often begins immediately after peak-pricing ends and could coincide with similar shifted loads if they receive the same price signal as the EV. This is more likely to happen if users can program the start time of charging through a software application. To deal with these issues, intermediaries who optimize charging by considering both the price signals and mobility needs of the EV user can directly control the charging.

Furthermore, depending on the time blocks of TOD tariff, the incentive to charge could coincide with the hours when the generation is mainly based on non-renewable generators. In systems dominated by intermittent renewable generation, the tariff could reflect the time of high renewable energy production hours, as a solution for the “duck curve” problem[16] while ensuring that EV charging loads does not increase distribution grid costs (King and Datta, 2018).

Examples of TOD EV tariff can be found in Spain where the supplier Iberdrola, is offering TOD tariff for EV users. The tariff is implemented as a day and night TOD tariff for the energy component of the EV

[16] See (California ISO, 2016)

electricity bill. As can be seen in Figure 17, the off-peak hour tariff is more than 80% lower than the peak hour tariff, sending a strong signal to EVs (Ibedrola, 2019).

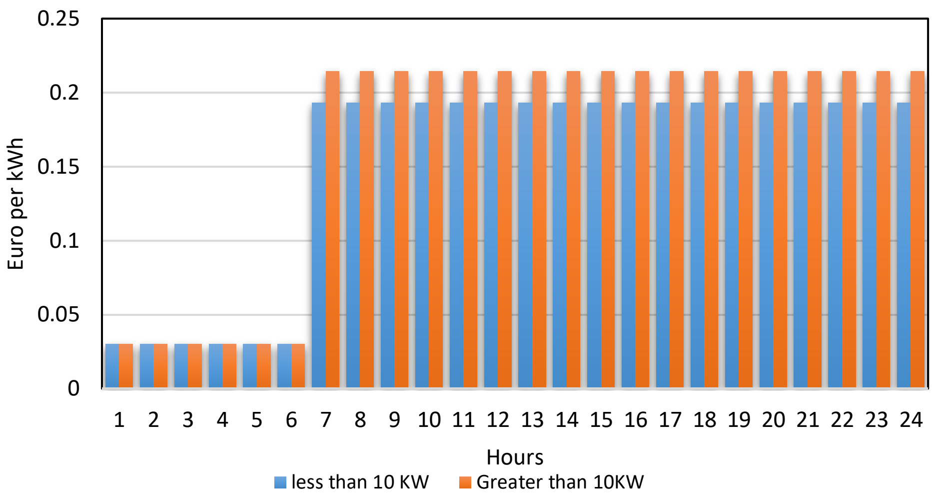


Figure 18: Time-varying energy tariff by Iberdrola in Spain [Based on (Ibedrola, 2019)*]*

Similarly, in the USA, Baltimore Gas and Electric Co. offer residential consumers three tariff options, which include standard flat rate, a standard TOD rate and EV rate (Baltimore G&E Co., 2019). The standard TOD and EV rates are seasonally differentiated time-varying rates except that the EV rate has two, peak and off-peak, rates while standard TOD has three periods (peak, mid-peak and off-peak). The EV rates send a strong signal in which the off-peak rate is 55% lower than the peak in 2019 (Baltimore G&E Co., 2019).

3.1.3 Real-time pricing for EVs

Real-time pricing (RTP) is an approach in which the price level that applies for each time block is not predetermined, but the wholesale electricity prices are passed on directly to the final consumer. The bills are calculated based on at least hourly metering of consumption, or with higher granularity (e.g., 15 minutes). In more mature markets, the price of such offers is composed of the wholesale price of electricity plus the margins of the supplier (i.e., the DISCOM in India).

The benefits of RTP to the power system is that it reflects the actual system condition and cost, resulting in both short-run and long-run efficiency gains (Borenstein, 2005). As a result, it helps reduce the additional peaking capacity requirement and avoid forced outages in time of low system reliability (Asare et al., 1995). The benefit of RTP to EV users is the high potential reward that it offers compared to the other approaches. However, the customer assumes the highest risk due to price volatility. The approach also provides an accurate bill as it reflects the real-time market and system condition, unlike other tariff methodologies which rely on forecasted demand and system condition.

One of the limitations of RTP is that it may face low acceptability due to the price risk and its complexity to implement. In this regard, it has been proposed to offer consumers the possibility to self-select into the appropriate rate design depending on their risk appetite (Faruqui and Palmer, 2011). The second limitation is that, like TOD tariff, the acceptance and effectiveness of the price signal cannot be known beforehand. This can be improved if intermediaries develop business models to optimize charging. The third limitation is that it can also cause distribution grid congestions if many EVs respond to the low wholesale price.

An example of RTP can be found in the UK where an energy supplier, Octopus, introduced a tariff designed for EVs and storage heaters, called Agile Octopus tariff, which offers half-hourly prices that are linked to the half-hourly wholesale market prices and adapted to the mobility profile of the user[17]. Accordingly, there are rates for family homes, users with fixed work timings (i.e., 9 a.m. to 5 p.m.) and night chargers. An example of family home charging rates is shown in Figure 19. These prices are communicated to the customer every day-ahead at 4 p.m. through a smartphone application.

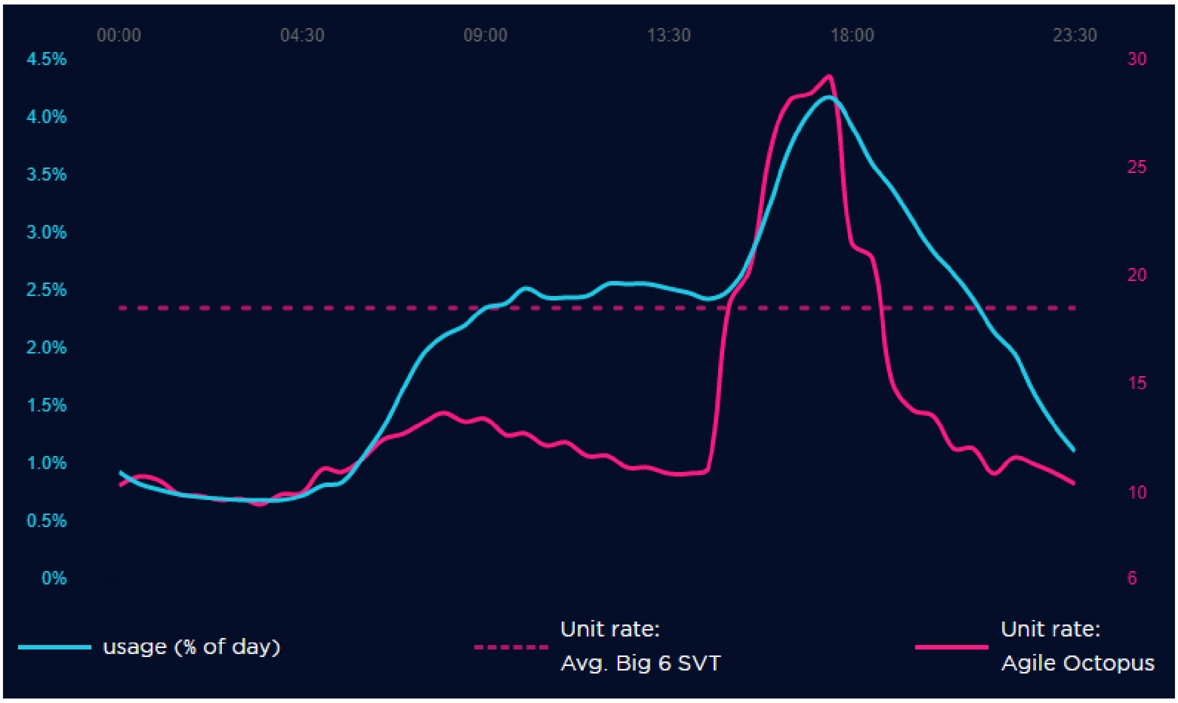


*Figure 19: Octopus Real-time pricing for EV, historical data averaged over all supply regions over twelve months [**'Usage'** refers to percentage of the day the electricity consumption is at different levels during the time of the day. **'Unit rate'** refers to the price per kWh; **'Avg. Big 6 SVT'** refers to the average Standard Variable Tariff of the Big 6 retailers in the UK.]*

3.1.4 EV demand charges

EV energy charges may not send a strong signal to encourage beneficial charging, and they fail to reflect the equally variable nature of grid utilization (Hildermeier et al., 2019). Therefore, an EV

[17] See Octopus Energy, Introducing Agile Octopus [Webpage]. Retrieved from https://octopus.energy/agile/

demand charge could be introduced to reflect the cost of grid usage during charging. That is, the energy tariffs will help reduce the consumption of electricity during peak hours, and the demand charges provide incentives for EV users to reduce their grid capacity requirement, which may, in turn, reduce the peak demand. Demand charges are commonly billed based on local distribution grid peaks, not system peak at state or country level. This is because the peak in the distribution system of a particular city, for instance, may not coincide with the peak hour of the state level load. The billing for demand charges is made monthly by taking the highest capacity usage recorded during the previous month based on a 15 (or more) minutes of consumption.

Demand charges can be designed to include a time-varying dimension, also called peak coincidental demand charges. These charges vary depending on the time the EV user charges its vehicle in which a distinction is made between the EV user's peak and the peak of the distribution system. That is, if the user's peak coincides with the distribution system peak, the user pays higher charges while outside the distribution system peak, prices are lower. This design is relevant for EVs because they are power dense and withdraw large electricity during the charging period, leading to higher bills even if they are charging when the grid is underutilized.

The limitations of demand charges are that they might be complicated for residential consumers to understand and react, and a single spike across the entire month can create a substantial and unrepresentative fee in case of non-peak coincidental demand charges (King and Datta, 2018). This effect can be reduced through time-varying demand charges. Moreover, they are criticized for discouraging the deployment of public charging stations, particularly with fast charging infrastructure, which has higher demand but in a shorter duration (Nelder, 2018). The impact is significant during the early stages of the EV market, in which the charging stations are less utilized. This improves as the utilization of the charging stations increases with the increase in the adoption of EVs. Hence, it is recommended to gradually increase the demand charges as the adoption of EV grows.

An example of time-varying energy and demand charges[18] with a seasonal differentiation is applied by Baltimore Gas and Electric Company of Maryland (Baltimore G&E Co., 2018). While in other cases, mainly in the USA, there is a tendency to redesign or remove demand charges with the aim of reducing the disincentives of demand charges for the investment in DC fast chargers. For example, the Southern California Edison (SCE) introduced TOD tariff for separately-metered EV charging sites by removing demand charges for the next five years, after which they will be phased back in. Similarly, the Pacific Gas and Electric (PG & E) removed demand charges permanently, replacing them with smaller and

[18] In a vertically unbundled sector, as in this example in US, a distinction between energy tariff and network tariff is indicated in the electricity bill of the customer.

more predictable subscription fees, and TOD charges. Other examples include NV energy, which proposed demand charge discounts which gradually increase over a ten-year period; PECO's Pennsylvania uses a five-year demand credit; and National Grid approved an electric transportation plan in Rhode Island to offer a credit to fully offset the demand charges for three years (NC Clean Energy Technology Center, 2018).

3.1.5 Enabling technologies

In this section, the technologies that enable the application of the different tariff designs are presented. This is followed by a discussion on the penetration and readiness of these technologies in India.

3.1.5.1 *Enabling technologies for EV tariffs*

The minimum technology required to enable time-varying EV energy tariffs and demand charges is a smart meter with the capability of recording the timing and level of consumption (see Table 19). For EV only tariffs applied to private (home) chargers, there is a need to have submetering capability to differentiate the consumption of the EV and the rest of the premise with no dedicated meter for the EV charging. If the submeter can record time-differentiated consumption, there may not be a need to have a smart meter for the premise. The submeter is a far less expensive option (King and Datta, 2018).

Table 19: Minimum enabling technology requirements to send price signals to EV users

Solutions		Minimum enabling technology
Energy tariff	Time of day tariff	Smart meter
	Real-time pricing	Smart meter and smart charger
Demand charges	Time-varying demand charges	Smart meter

Besides the smart meter, RTP requires a smart charger, which has networking or communication capability. This capability, on the one hand, allows the charger to receive price signals, programming commands to instruct the EV when and how to charge, and control signals for demand response events sent by the DISCOM, supplier, aggregator or other market operators. On the other hand, it sends data back to the utilities, aggregators and other market parties who will use these data to develop various use cases. A charger with these capabilities can be controlled by utilities, aggregators or other third parties to optimize the charging of fleets of vehicles. This can help improve the effectiveness of price signals by controlling the load. Note that the deployment of such smart technologies will have limited benefit if they are not accompanied by cost-reflective tariffs (Hildermeier et al., 2019).

3.1.5.2 *The readiness of enabling technologies in India*

Currently, the status of smart meter deployment in India is low. At the time of writing this report, only 4% of consumers above 500kWh and 2% of customers between 200 and 500kWh are equipped with a smart meter (MoP, 2019)[19]. This can be a roadblock for the application of time-varying EV tariffs, particularly for residential charging points with no dedicated charger.

As the rollout of smart meters is progressing, the functionality requirements of Advanced Metering Infrastructure (AMI)[20] has already been developed by the Central Electricity Authority in India (CEA, 2016). Accordingly, the AMI shall include core components including smart meters, communication infrastructure, head-end system, meter data management system, web application with updated online data of consumers, and mobile app. The main objective of this infrastructure is to enable two-way communication between smart energy meter and head-end system[21], which enables remote reading, monitoring and control of electrical energy meters (including consumer, feeder and dynamic transformer (DT) meters). The smart meter shall include some minimum basic features including bidirectional communication, load limiting switch, remote firmware upgrade, and measurement of electrical energy parameters.

To improve the adoption of enabling technologies by EV charging points, two measures could be considered. First, increase the penetration of enabling technologies by introducing mandatory standards for charging points to have smart meter capability. Second, encourage innovative business and financial models by suppliers to reduce the high upfront cost of these enabling technologies (e.g., leasing model).

3.1.6 Regulatory compatibility

Time of day tariff is widely practised in India, particularly among industrial and commercial consumers. Various legislations and legal frameworks promote the implementation of the TOD tariff. Article 62(3) of the Electricity Act of 2003 allows differentiation according to 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 geographical position of any area, the nature of supply and purpose for which the supply is required (MoLJ, 2003). In addition, the national tariff policy states that two-part tariffs featuring separate fixed and variable charges and time-differentiated tariff shall be introduced as priority for

[19] Data does not include data of Mizoram, Nagaland, Andaman and Nicobar Islands, Lakshadweep

[20] AMI has core components including smart meters, communication infrastructure, head-end system, meter data management system, web application with updated online data of consumers and mobile app (CEA, 2016)

[21] A head-end system is hardware and software that receives the stream of meter data brought back to the utility through the AMI.

large consumers. Note that India currently has regulated prices, and hence regulated EV tariff could be implemented as a transitional measure until an open and competitive retail market is in place[22].

A number of states have introduced tariff for EV charging as either a separate tariff category or as part of the existing tariff categories. As shown in Table 20, Delhi, Punjab, Maharashtra, Uttar Pradesh, Madhya Pradesh and Chandigarh have introduced separate categories for EV charging. With respect to the energy charges, most of the states apply flat energy tariff without price signals. The exceptions in this case are Delhi, Maharashtra, Uttar Pradesh and Telangana, which have introduced time of day tariff and with seasonal differentiation in Delhi and Uttar Pradesh. In these states, the off-peak prices are between 15% to 25% less than the peak prices (Pillai et al., 2019). Compared to the international case with TOD tariffs, such as in Spain and the USA, the price signals are not very strong (see section 3.1.2). Therefore, the effectiveness of these tariffs should be evaluated, and required revision should be made accordingly.

In addition to the energy charges, a few states have also adopted demand charges, namely Maharashtra, Haryana, Karnataka, Gujarat and Chandigarh. Since fast charging stations are likely to be connected to the high-tension grid (medium voltage) or higher, the demand charges may have a negative effect on the business case for this infrastructure at the early stages of the EV market development (see discussion in section 3.1.4). Hence, these charges can either be increased gradually with the development of the market or embedded in the time of day tariff to send stronger price signals.

Other components of the EV tariff include fixed charges in which the user or charging station pays per connection or installation. These are introduced in Jharkhand and Gujarat. In Jharkhand, it is applied for rural and urban charging points regardless of their voltage level, in combination with a flat energy charge. In Gujarat, the fixed charge applies for EV users charging in the low-tension grid, in combination with TOD energy tariff.

While differentiations across voltage levels is common among the states, differentiation across social geographies (e.g. urban and rural) is only applied in Jharkhand where charging in rural area costs 110 Rupees per connection per month and 0.5 Rupees per kWh less than the cost of charging in an urban area. This is an important tariff design consideration, especially in states where the distinction between urban and rural settlement is relevant.

[22] There might also be a need to establish EV tariff in markets with deregulated price if the market fails to deliver due to lack of competition. Such a solution should be applied as a transitional measure while, in parallel, focusing on removing any obstacles to the creation of an open and competitive retail market.

Table 20: EV charging tariff design in the different Indian states (Based on (Pillai et al., 2019) *and state tariff orders)*

State	Separate EV tariff category	Energy charges			Demand charges	Fixed charges	Voltage level differentiation	Geographic differentiation (urban- rural)
		Flat tariff	TOD tariff	Seasonal differentiation				
Delhi	✓		✓	✓			✓	
Punjab	✓	✓						
Maharashtra	✓		✓		✓			
Jharkhand		✓				✓		✓
Andhra Pradesh		✓						
Haryana		✓			✓		✓	
Karnataka		✓			✓		✓	
Uttar Pradesh	✓*		✓	✓			✓	
Gujarat		✓			✓***	✓ **	✓	
Telangana		✓ **	✓ ***				✓	
Chhattisgarh		✓						
Madhya Pradesh	✓*	✓						
Chandigarh	✓*	✓			✓			
**** Only for public charging stations ** Only for LT *** Only for HT***								

In conclusion, given the current regulatory context in India, time of day tariffs can be a practical solution to communicate peak and off-peak prices. More sophisticated tariff designs, including RTP, can be considered, depending on the penetration of EV and enabling technologies as well as the maturity of the electricity market. Moreover, as the EV market matures and the share of intermittent renewable energy generation such as solar and wind increases, it is essential to revisit the tariff design to ensure that charging during high renewable energy production is encouraged. In addition, depending on the development of self-consumption (e.g., rooftop PV), the impact of tariff design on EV users and other users should be anticipated. In this regard, studies have already started to indicate that there are winners and losers, depending on the tariff design. In Hoarau and Perez, (2018), it is claimed that the concerns of load defection can be counterbalanced by EVs, and the tariff design can give conflicting incentive to EV and distributed energy resources. Similarly, a case in the UK studied in Küfeoğlu and Pollitt, (2019) shows that two-part tariff leads to unfair cost allocation for consumers who do not own solar PVs while higher penetration of EV can lead to lower distribution tariff for all customers.

Therefore, the application of these solutions should start by profiling the EV ecosystem of the specific territory it is applied, including the driving patterns, location and utilization of the available charging points. As these factors change over time, and the power system transitions, it is important that the tariff design evolves as well, moving towards a more open and competitive way of pricing.

It should also be noted that introducing time-varying energy tariffs and/or demand charges does not necessarily avoid distribution grid congestion; it may even create it. Therefore, congestion management solutions should be considered.

3.2 Managing distribution grid congestion

Besides sending price signals to reduce the charging of EV during peak hours, the DISCOM can take proactive measures to reduce potential grid constraints (see Figure 20). These include, first, publishing accurate information regarding locations with grid constraints to guide the decision of charging infrastructure developers. This could be less relevant in cases, such as India, where the DISCOM is legally bound to provide firm connection where any potential grid constraints are avoided by investing in an oversized grid; i.e., a fit and forget approach. Second, incorporating the growth in EV adoption and the location of charging infrastructure in the grid planning process.

Theoretical solutions, perhaps first-best solutions, include congestion pricing (nodal or zonal) which incorporates grid constraints in the day-ahead electricity market prices. This solution is common at the transmission level, but at the distribution level, it remains theoretical (Hadush and Meeus, 2018; Pérez-Arriaga and Knittel, 2016).

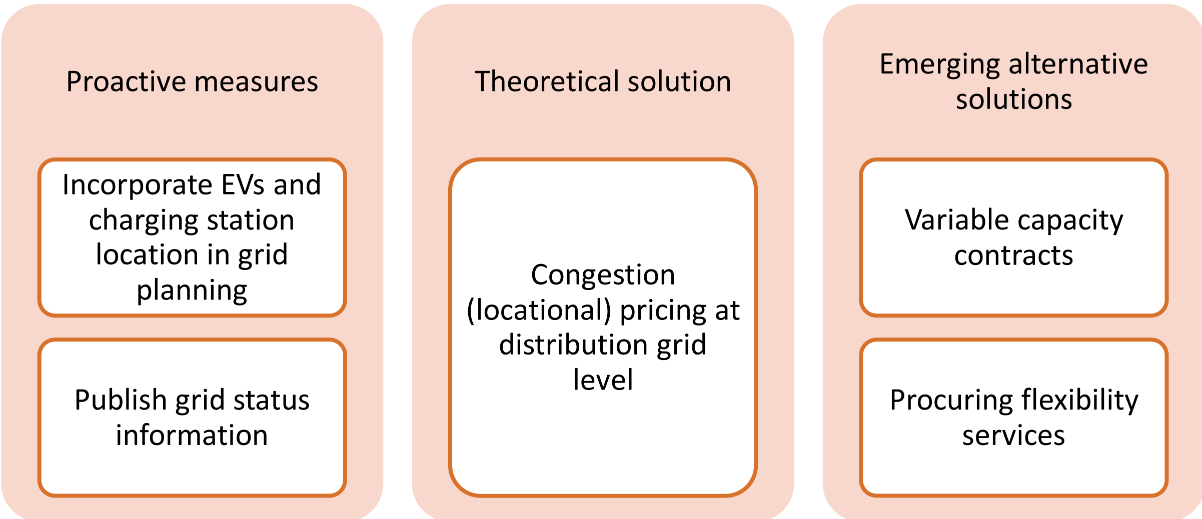


Figure 20: Alternative solutions to manage congestions in the distribution grid

In the absence of these proactive measures and advanced congestion pricing approaches, the DISCOM should have to take flexibility measures to relieve possible distribution grid congestion. ***Two approaches are currently emerging in practice***: 1) variable capacity contracts and 2) procurement of congestion management flexibility services.

3.2.1 Variable capacity contracts

Variable capacity contracts (VCC), also known as smart, non-firm or interruptible connections, is a contract between the DISCOM and the EV user or charging point operator, allowing the DISCOM to manage the grid connection within the limits of the agreed variable capacity, rather than a fixed capacity contract. VCC involves a direct control of load by the DISCOM or charging point operator based on the information from the DISCOM. The solution is more viable when the EV charging point or station wants to be connected in an area where the distribution grid is constrained, and hence, a firm connection cannot be provided without reinforcing the grid.

The application of this solution for EVs is limited. However, its relevance is increasing as more and more distributed generators and other energy resources such as EVs are connected to the distribution grid. One example is the active control of charging in Germany, where EV is considered a controllable load by legislation (Bundesministerium für Justiz und Verbraucherschutz, 2005). This legislation enables DISCOMs and suppliers to set discounted network charges for EV charging, and in return, DISCOMs are granted the right to adjust the demand of EV charging point during predetermined peak hours if the distribution network is stressed. That is, this arrangement allows the DISCOM to interrupt the EV charging to manage congestion.

Another example where VCC has been applied is for managing the impact of distributed intermittent generators on the distribution grid. A prominent example includes the smart connection practice by the DISCOM of Orkney Isles[23] in Great Britain (Anaya and Pollitt, 2017; Macleman et al., 2013). There are different commercial arrangements to settle the curtailment of the output of renewable energy generators, particularly when multiple generators are bound to the VCC scheme. These include Last-in First-out (LIFO), Pro Rata, and Market-Based approaches (Anaya and Pollitt, 2014).

VCC can help defer or avoid expensive investments in grid reinforcement. However, it creates constraints on the availability of charging when the EV users need it. Furthermore, as the penetration of EV grows and congestion becomes structural, this may not be a viable solution, and grid reinforcement can become more economical.

[23] The Orkney Active Network Management (ANM) project was *"implemented as an alternative solution to network reinforcements. These reinforcements would have been in the form of a new 33 kV subsea cable linking Orkney to mainland GB grid, which would have cost an estimated £30 million"* (Kane and Ault, 2014).

3.2.2 Procuring flexibility for congestion management services

A market-based solution for managing grid congestion includes procurement of flexibility services[24] from a 'flexibility market place' where customers can offer their flexibility directly or through a third-party market actor (e.g., aggregator). In this market place, the DISCOM places its request, and it is matched with the offer of the flexibility service provider. In this case, the flexibility service can come from EVs or other non-EV resources, including dispatchable loads, distributed generators, and energy storage. Where EVs are participating, they can provide this service by charging or not charging at the requested time and location (Knezović et al., 2015b). They can also provide the service by injecting power back into the grid if they have the V2G capability (see Chapter 4 for detail discussion on V2G grid services).

The procurement of system flexibility services by DISCOMs is still in the early stages of development. Currently, there are several pilot projects running; some of the pioneering projects have been reviewed by Schittekatte and Meeus (2019).

This solution can help the DISCOM to optimize investment in distribution network capacity, increasing the hosting capacity of the grid and reducing curtailment and outage times. Moreover, it provides an additional revenue stream for the EV owner. However, it has limitations that need to be considered in designing the flexibility market. It is also prone to market power abuse and gaming by market players by creating peaks in an area to sell flexibility at a high price (Joskow and Tirole, 2000). To avoid this, a safeguard should be introduced. In addition, it is complex to implement in practice.

3.2.3 Enabling technologies

In this section, the technologies that enable the application of variable capacity contracts and procurement of congestion management services are presented. This is followed by a discussion regarding the penetration and readiness of these technologies in the context of India.

3.2.3.1 *Technology requirements for congestion management solutions*

Implementing the variable capacity contract solution requires technological capabilities that enable the DISCOM to receive information regarding the loading status of the grid at a different level, including feeders and transformers. This can be achieved by installing sensors and meters on these components. Another technology that is required is the capability to process this information and take

[24] Flexibility services for congestion management can be defined as the service offered by generators and loads or third-party aggregators to the DISCOM in which generation injection and/or consumption patterns are modified to relieve congestion in the grid.

measures remotely. To do this, smart chargers that can adjust the level of charging in response to the situation on the grid are required.

Similarly, the technological requirements for procuring congestion management flexibility services provide the DISCOM with the capability to receive real-time information on the status of the grid, locate congestion area, and procure flexibility services to alleviate the congestion. In this case, the DISCOM may not require direct control capability as in the VCC; i.e., an aggregator or individual flexibility service provider can carry out the activation of the procured flexibility. Furthermore, fully unlocking the potential of flexibility services at the distribution grid would require advanced metering infrastructure (AMI) with Active Network Management[25] by the DISCOM.

3.2.3.2 *The readiness of enabling technologies in India*

Smartening the distribution grid is an ongoing process in India. There are initiatives to increase the visibility of various network components in the distribution grid, introduced as measures to reduce network losses and theft. According to UDAY dashboard, all DISCOMs have introduced feeder meters both in urban and rural areas, and around 80% of the urban and 60% of rural dynamic transformer (DT) meters have also been installed (MoP, 2019)[26].

As the technological readiness in India to fully introduce the variable capacity contracts and flexibility markets is still at early stages, deployment of enabling technologies such as smart chargers and sensors can be prioritized in areas where there is frequent congestion.

3.2.4 Regulatory compatibility

Under the current regulatory framework, the conventional fit and forget approach is applied. In case suppliers cannot deliver electricity, and consumers' demand cannot be satisfied due to distribution grid constraint, curtailment is the default solution. However, there are proactive measures to limit consumers on their capacity usage through demand contracts or sanctioned load. Any usage above the contracted capacity is considered unauthorized usage, and the different states take different measures when this happens. These include the DISCOM sending notice to the customer to enhance the contracted capacity with or without penalty, the DISCOM adjusting the contracted capacity, or the DISCOM disconnecting the service. Table 21 shows this implementation difference.

Table 21: Regulation regarding unauthorized demand

States	Measures in case of an unauthorized demand
Delhi	Contracted capacity is adjusted by the licensee (the DISCOM)

[25] Active Network Management (ANM) is defined as "using flexible network customers autonomously and in real-time to increase the utilisation of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs."(ENA members, 2015)

[26] Does not include data of Mizoram, Dadra and Nagar Haveli, Nagaland, Andaman and Nicobar Islands, Lakshadweep

Karnataka	Consumer pays double the applicable tariff in case of excess load
Kerala	DISCOM gives notice of 30 days to enhance capacity, otherwise average of top three recordings
Andhra Pradesh	DISCOM sends a one month notice or billed at high tension schedule for LT customers, otherwise disconnected
Uttar Pradesh	Consumer pays double the prescribed charges for excess load
Source: Electricity supply code of Delhi (DERC, 2017)*, Karnataka* (KERC, 2008)*, Kerala* (KSERC, 2014)*, Andhra Pradesh* (APERC, 2018)*, Uttar Pradesh* (UPERC, 2018)	

This practice can serve as a basis to consider variable capacity contracts for areas where there are critical capacity constraints. As the market matures, a market-based solution including procurement of congestion management flexibility services can be considered. The first step to prepare the system to accommodate these advance congestion management solutions would be to introduce regulatory sandboxes and fund pilot projects for proof of concept and testing.

3.3 Chapter conclusions and recommendations

EV creates a unique additional electrical load that is mobile, power-dense, variable and mostly connected to the distribution grid. Therefore, starting from the introductory stage of EV market development, the long-term power system planning should include the growth of EV adoption and deployment of charging infrastructure considering the unique characteristics of this load.

Even if forecasts indicate the total energy consumption of EV in India can be accommodated, it could have a significant impact on the power system if the charging time and location is not well distributed. This could lead to high cost of electricity supply due to the increase in peak demand, grid ageing and service interruption due to congestion in the distribution grid. Conventionally, these issues are addressed by investing in peaking generation capacity and reinforcement of the distribution grid. However, alternative solutions are emerging with the aim of deferring expensive investment. This chapter identifies various alternative solutions for addressing the contribution of EVs to the peak demand and distribution grid congestion. The solutions are then analysed in term of the readiness of enabling technologies and compatibility with the regulatory framework in India.

The peak demand contribution of EVs can be reduced by sending price signals for EVs to shift charging to off-peak hours through time-varying energy and demand tariffs. However, the application of such tariff designs in India is, on the one hand, challenged by the low penetration of enabling technologies such as smart meters, even though solutions such as TOD tariff are compatible with the current regulatory framework. This can be addressed by introducing mandatory standards for charging stations to be equipped with the required technologies and encouraging business model innovation to reduce the upfront cost of enabling technologies. On the other hand, the effectiveness and acceptance of these price signals depend on the flexibility and price sensitivity of the EV user. This can be improved by encouraging innovative business models where intermediaries (e.g., aggregators) play a role of optimizing and directly controlling EV charging by considering price signals and the mobility needs of the EV user.

Since price signals aimed at reducing peak demand do not necessarily avoid congestion in the distribution grid, unless they are spatially differentiated, it is important also to consider congestion management solutions suited to the distribution system. Accordingly, it is recommended that proactive measures that include the publication of grid information to guide siting decision of investment in charging infrastructure as well as the incorporation of EV adoption and location of charging infrastructure should be prioritized. With the increase in EV adoption and penetration of enabling technologies, more sophisticated solutions, such as variable capacity contracts and flexibility markets, can be considered.

The choice of appropriate solutions will depend on key developments in the EV and power sectors. These include the growth in EV adoption, penetration of enabling technologies, the maturity of the wholesale and retail market, and the severity of congestion in the distribution grid. Some of the solutions discussed in this report, and the lessons that can be learned from growth stage EV markets could become relevant as the EV market in India develops. Allowing regulatory sandboxes to pilot and test these solutions can be useful to gain insights on the application of these solutions in the Indian context.

Figure 21: illustrates the relevance of the chapter recommendations and conclusions in the context of the EV market development phases.

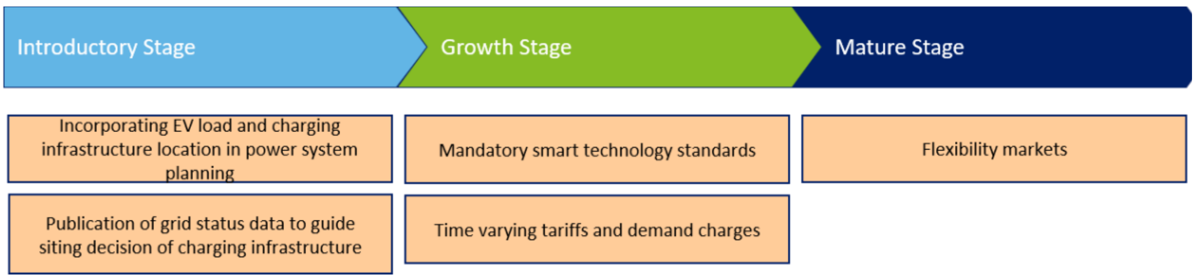


Figure 21: Relevance of chapter recommendation and conclusions in the context of market development stages

4 Insights on V2X applications of EVs

Apart from being an additional load on the power system, EVs are possible distributed energy resources (Eid et al., 2016; Nelder et al., 2016)[27]. The EV market in India is currently at a nascent stage. V2X services will only become relevant once the EV market has reached a significantly higher level of maturity due to economy scale. Currently, V2X resources are considered in only one state (AP) policy. However, India is already gaining experience with distributed generation (rooftop solar) and net-metering, where excess power is fed back into the system (Roux and Shanker, 2018).

One of the key enablers for V2X services to enter the market would be the structure of the regulatory framework that governs them. The main aim of this chapter is to analyse and present regulatory enablers for unlocking the full potential of V2X services.

To understand the future relevance of V2X service, it is important to first understand two other crucial dimensions of V2X, namely, V2X applications and V2X costs. On the one hand, V2X applications translate into potential revenue streams for such service providers. On the other hand, provision of any V2X service would entail some costs, which would eventually dictate the viability of providing the particular V2X service. Finally, apart from regulatory enablers, there are also technological enablers. (See Figure 22).

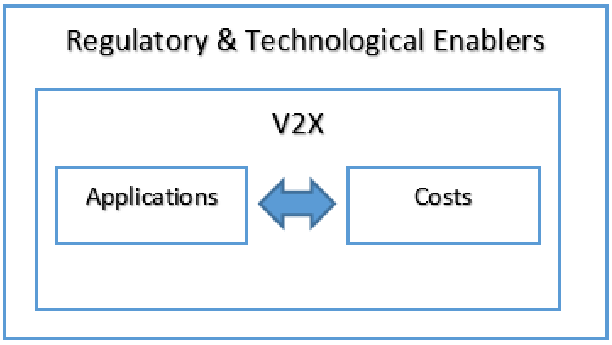


Figure 22: Illustration of the V2X fundamental dimensions

Therefore, in the first two sections of this chapter, we identify and discuss different applications and costs related to V2X services. In the third section, the technological enablers are discussed briefly[28] followed by a detailed discussion on regulatory enablers from the perspective of the identified applications and their relationship with the costs.

[27] In this chapter, the research premise for V2X application is the view of individual EVs.
[28] Detailed discussion on these technological enablers are outside the scope of this report

4.1 V2X Applications of EVs

An EV can participate and earn revenue from providing V2X services by carrying out three different actions, namely**, injecting electricity into the grid by discharging the EV battery, extracting electricity from the grid by charging the EV battery, and abstaining the consumption from the grid by ceasing to charge the EV**. Based on these actions and a literature review, the V2X applications of EVs can be categorised as wholesale energy trade, self-consumption, and grid services provision (see Figure 23).

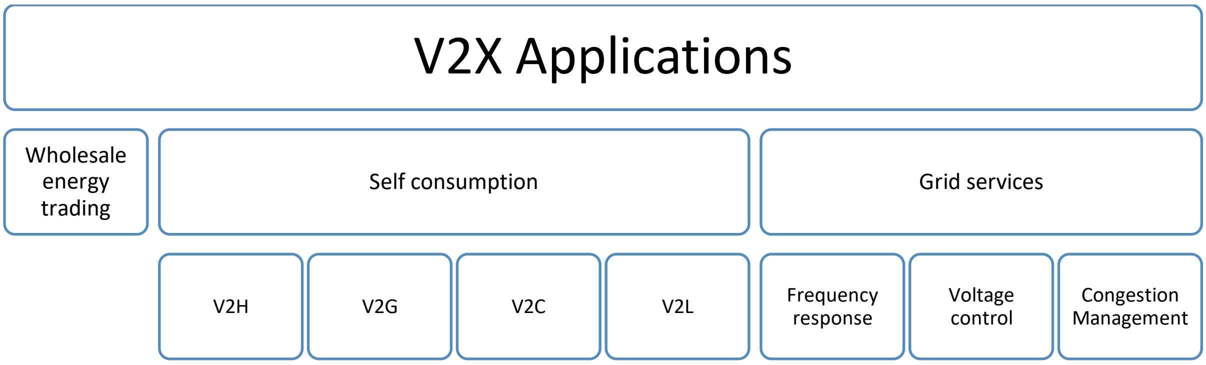


Figure 23: V2X applications

Wholesale energy trade can occur through bilateral contracts between suppliers and demand or through organised markets such as day-ahead markets and intraday markets. Electric Vehicles can participate in this market as a virtual generator or as Demand Response. Depending upon the market structure, the participation can be in the day-ahead market, intra-day market or as bi-lateral contracts. The customers in this context would load-serving entities and large consumers (See (Pearre and Ribberink, 2019; Weiller and Neely, 2014))

Self-consumption is a decentralised services where the EV acts as back-up generation during a scarcity period or used for reducing consumption from the grid. These services can be further categorised into four types:

- **Vehicle to House (V2H):** This is a decentralised service that a vehicle can provide to an individual house by acting as a back-up supply providing electricity during scarcity periods or times when the cost of electricity is high (See: (Guo and Zhou, 2016; Pearre and Ribberink, 2019; Weiller and Neely, 2014)).
- **Vehicle to Load (V2L):** V2L is a decentralised application where the EV can act as a back-up supply for isolated loads as well as reduce dependence on expensive diesel generators (See: (Tuttle and Baldick, 2012).
- **Vehicle to Building (V2B):** This is similar to the service provided to a house, however in this case instead of an individual house EVs can provide back-up supply to a full apartment complex or a large commercial building (See: (Guo and Zhou, 2016; Pearre and Ribberink, 2019)).

- **Vehicle to Community (V2C):** This application can provide a back-up supply for a micro-grid (and off-grid) communities (See: Pearre and Ribberink, 2019).

Grid services: The system operators are required to ensure operational security by keeping the frequency and voltages within the prescribed limits. Furthermore, in case of congestion in the grid, they have to apply congestion management measures. It is possible that EVs could provide all three services to the network operator (See Knezović et al., (2015b)).

- **Frequency Response:** EVs can respond rapidly to a signal for providing either upward or downward balancing services. Thus, EVs can be used to provide frequency response services such as primary, secondary, tertiary reserve, and black start at a system-level via injecting or withdrawing power or by abstaining from charging. Transmission system operators usually procure these system services. However, with increasing DER, balancing might even become more local in the future (See: Andersson et al., (2010); Codani et al., (2016, 2015); Knezović et al., (2014); Pearre and Ribberink, (2019)).
- **Voltage Control:** Similar to frequency response, the EV can also provide voltage control solutions. The main difference between the two services is that frequency response is at a system level, while voltage control is location-specific. The mobile nature of EVs in this context can thus be advantageous. This service is procured by the network operators (see: (Carradore and Turri, 2010; Knezović et al., 2015a, 2015b; Pearre and Ribberink, 2019).
- **Congestion Management:** EVs can act as a measure for network congestion management by adjusting their usage patterns. The EVs can reduce congestion by lowering their load or act as virtual power plants when the injection is required due to a re-dispatching action. Congestion management is required at the TSO level. However, as the power system is becoming increasingly decentralized, DISCOMs will need to manage congestion locally in their distribution grids in the future (Knezović et al., 2015b; Romero-Ruiz et al., 2016; Van ’t Wel, 2019).

4.2 Costs from V2X applications

There are two types of costs incurred by the EV user while providing V2X services. These costs can be classified as explicit costs or implicit costs (see Figure 24).

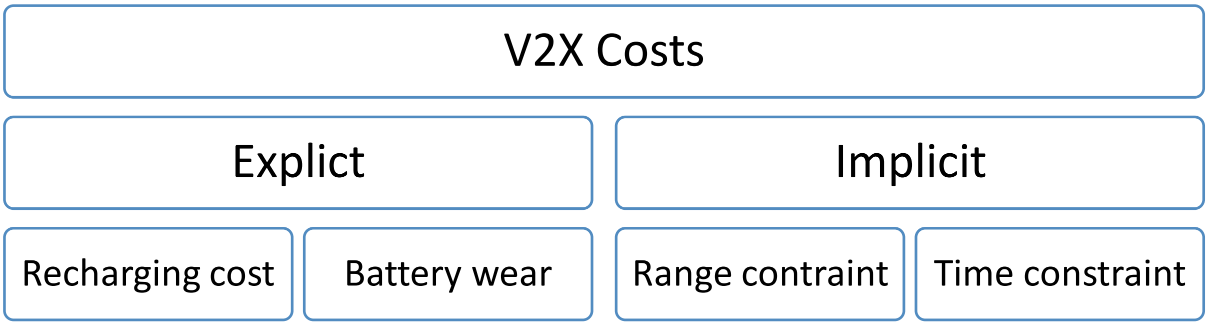


Figure 24: Illustration of V2X cost classifications

Explicit costs are those for which the value can be quantified in monetary terms. The first explicit cost identified is incurred when the EV is used for injecting power. This can be defined as the cost incurred for recharging the battery to the same level as before the power injection to provide the V2X service. The second cost arises from degradation of the battery life due to additional charging cycles (See: Lunz et al., (2012); Ribberink et al., (2015); Noel et al., (2019)).

Implicit costs: There is an inherent trade-off between the two services that the EV can provide namely mobility and V2X, as doing one limits the ability to do the other as the EV has to be connected to the charging station to provide V2X services. This trade-off while the EV provides V2X services can be defined as two constraints for mobility, namely, range constraint and time constraint (See: Noel et al., (2019)).

- **Range constraint:** If the EV has committed to providing a particular V2X service, the EV user would have to ensure that at all times, there is sufficient capacity in the battery to provide this service. This, in turn, would lead to a reduction in the driving range of the EV for the given charging level. In the context of location-specific services, the range constraint would arise from the need for the vehicle to be near the location for service provision.
- **Time constraint**: When the EV provides V2X services, it would have to be connected to the charger. Thus, during the time of the day and time period that the EV is committed to providing the V2X services, it will be unavailable to provide mobility.

4.3 Enablers for V2X Services

To facilitate the use of V2X services, certain enablers would be required. These enablers can be sub-categorized into either technological enablers or regulatory enablers.

4.3.1 Technological enablers

The technological infrastructure can be further sub-divided into the hardware infrastructures and the Software infrastructure required for running the system. In this section, the technological enablers are discussed briefly.

4.3.1.1 *Hardware Infrastructure*

To enable the rollout of V2X services, it is essential to ensure that the hardware required to provide these services is compatible. Two key components form the basis of this hardware infrastructure. Firstly, bi-directional chargers that can both withdraw and inject electricity into the system are needed. Bi-directionality is the minimum requirement but there is further scope for smartening chargers (Das, 2016; Ferreira et al., 2011; Mwasilu et al., 2014). Secondly, sophisticated smart meters would be required to measure the V2G services provided by an EV (Rua et al., 2010). Further discussion on the technology is outside the scope of this research.

4.3.1.2 *Software Infrastructure*

Information and communication infrastructure would play a pivotal role in valorising the full potential of V2X resources (Noel et al., 2019). There can be two minimum dimensions of software infrastructure. The first is the software that would run the bidirectional (smart) chargers and smart meters. The second is the interface and interaction between the service providers: EV and service consumers. This includes apps, market platforms, systems for certifying proof of origin, advanced dynamic learning algorithms to optimise the service provision and provisions to protect consumer data privacy and security (Han and Xiao, 2016; Noel et al., 2019). Further discussion on the technology is outside the scope of this research.

4.3.2 Regulatory enablers

Noel et al., (2019), state *"However, above all, V2G needs to be integrated in the regulatory system in a manner that is non-discriminatory and guarantees equitable access to the variety of electricity markets that V2G can participate in".* Thus, regulatory enablers for V2X integration can be defined as the actions taken to modify the regulatory environment to eliminate or minimise the barrier to market entry, provide a level playing field for V2X service providers and a fair value for V2X services.

A crucial element for such integration is the definition of different V2X products and services. This research provides insights on fundamental product and service definitions that would be pertinent for the different V2X applications[29]. In the existing literature, Pérez-Arriaga (2013) provides a detailed understanding of the regulatory and market design fundamentals. Borne et al. (2018) present a review of the barriers for new resources such as EVs to enter the frequency regulation market. Key market design parameters for balancing mechanisms is discussed by Schittekatte and Meeus (2018). Bhagwat et al. (2019) assess balancing market design parameters in the context of offshore wind. Bessa and

[29] However, before delving deeper into this topic, note that V2G is still at a conceptual stage (although several pilots are underway (See: Perez, 2018)). No trade in several identified V2X services that the EVs can provide exists. Thus, this analysis keeps the discussion market design neutral.

Matos (2012) provide a detailed literature review on the economic and technical management role of EV aggregators. Codani et al. (2014) assessed the impact due to TSO rules on the ability of EVs to provide ancillary services.

Therefore, based on the review of existing literature, six fundamental product and service attributes are identified. The six attributes are volume, contract period, lead-time, service location, product symmetry, and reservation period.

In the context of the V2G, the design of these six attributes would have an impact on the overall cost of ownership for the EV user. From the context of V2X costs identified in Section 1.2, several studies exist on the explicit costs and its recovery from the revenues provided by the V2X services (See: (Andersson et al., 2010; Codani et al., 2016; De Los Rios et al., 2012; Kempton et al., 2008; Kempton and Tomić, 2005; Noel et al., 2019). However, the implicit costs for the EV user from the inherent trade-off between mobility and V2X have the potential to become a significant roadblock for the development of V2X services.

In the remainder of this section, the interrelationship between each product and service attribute and implicit costs in terms of time and range constraints is assessed. Subsequently, possible solutions to ensure the minimisation of these constraints are proposed. This leads to a set of recommended practices for regulators on product definitions to keep in mind while designing frameworks for procurement of various V2X services.

4.3.2.1 *Volume*

This can be defined as the quantity (for instance in kW or kWh) of the service that has been committed by the V2X service provider. This attribute is relevant for all V2X services.

The main barrier in the context of the volume is the range constraint. The EV would require having sufficient charging level to either inject or absorb the committed power. Therefore, the larger the volume committed, the greater would be the range constraint. Furthermore, the capacity of individual EVs is significantly small compared to large power plants. Therefore, large minimum volume requirement can be a barrier to entry. For instance, in the Indian Energy Exchange (IEX) day-ahead market, the minimum bid size is 0.1 MWh while in comparison, the TESLA model 3 long range pack can supply up to 74kWh (equivalent to 0.074MWh).

Aggregation of EV resources can be a solution to this issue. In the context of volume, the benefits from aggregation are two folds. Firstly, it would allow participation of this aggregate reserve in the provision of service where the minimum entry threshold for volume is higher than the service volume of an individual EV can provide. Secondly, it can limit the volume constraint, as an aggregator can source smaller volumes from several EVs in its portfolio, thus reducing the risk from the unavailability of a single EV and minimising the range constraint issue for EV individual owners.

A second approach to minimising the range constraint from a volume perspective is to allow as small as possible volume to offer the service. This will allow individual EVs to decide the fraction of the battery volume that it would want to offer (like in the case of an aggregator). This will minimise the range constraint issue for EV individual owners.

4.3.2.2 *Contract Period*

This can be defined as the time period (for instance, in minutes or hours) for which the service is committed to be consistently provided by the V2X service provider. This attribute is relevant for all identified V2X services.

The main barrier in the context of the contract period is identified to be the time constraint. The EV would be required to provide the service for a committed timeframe without interruption. The longer the contract period, the higher the time constraint would be.

Firstly, aggregation can be a solution for minimising the time constraint that arises. By interlinking several EVs while offering a service, an aggregator can provide the necessary level of service continuously for the required contract period utilising multiple EVs depending upon their availability. For instance, if a service needs to be provided consistently for a period of 15 minutes, an aggregator can provide this service from 3 EVs for 5 minutes each. Furthermore, in case an EV cannot provide the given service due to an unforeseen event, then the aggregator can use another EV from its pool as back up, thus reducing risks of failure to provide the service. Thus, aggregation can aid in mitigating the time constraint issue.

Secondly, reducing the minimum threshold for contract periods to as short as possible can aid in minimising the time constraints for EVs. Short contract periods would provide greater flexibility to the EV to choose the duration of service provision depending upon the EV user’s willingness.

4.3.2.3 *Lead time*

This is defined as the time between when the service is procured (gate closure) and when it is actually delivered. This attribute is relevant for all V2X services.

The main barrier in the context of lead-time is identified to be the time constraint. Firstly, it would be necessary for the EV to be plugged in at the committed specific time to provide the given service, thus constraining its ability to use the EV for mobility at that time. Secondly, there is a risk that the ability or willingness of the EV user may change due to external circumstances from the time that the service is sold and when it is to be delivered.

The primary solution for this barrier is to make the lead times as short as possible (in the context of organised markets – close to real-time gate closure). This will allow better predictability of availability by the EV user while offering any V2X service, thereby minimising the issue of time constraint for the EV owner.

Aggregation can again be useful as the aggregator can optimise its V2X service offering to ensure an adequate number of vehicles (and back up) is available to service its V2X commitment, thereby reducing the risk of unavailability even in case of long lead times and minimising the time constraint for individual EV owners.

4.3.2.4 *Service Location*

This is defined as the specific location at which the particular service is required to be provided. This attribute is critical for location-specific services system services such as voltage control and congestion management, and local self-consumption.

The main barrier in the context of location is identified to be the range constraint. It would be necessary for the EV to be plugged in at a specific location to provide the service. Thus, the EV that promises these location-specific services can be used only near the location or have the ability to get to the specific location at the given time (alternately risking service default).

An aggregator can optimise the location-specific V2X services that it offers depending upon the forecast of the number of vehicles from its portfolio that would be near to the given location thus minimising the risk and reducing the range constraint barrier for individual EV user. Shorter lead times that are close to real-time of service delivery can also reduce the uncertainty of locational availability for the EV by enabling more accurate estimation of service provision.

4.3.2.5 *Product symmetry*

This attribute describes whether upward and downward capacity/energy should be procured jointly, as 'symmetric products', or separately, as 'asymmetric products'. This is of relevance for providing system services.

The main barrier in the context of product symmetry is identified to be the range constraint. Most EVs can provide symmetric services. However, a problem may arise in either of the two extreme cases when the EV would be fully charged and unable to absorb or when it is very low on charge and unable to inject power to the grid. Thus, the EV would require its battery to have enough resources to inject or absorb the required level of energy, thereby limiting its use for mobility. This can be a significant entry barrier for EVs in providing V2X services.

There are three avenues to mitigate the range constraint arising from a symmetric product. Firstly, allow trade of asymmetric products. Thus, the EV user can then choose the type (upward / downward / both) services that it wants to provide. Secondly, as discussed earlier, individual EV constraints due to the need for the provision of symmetric products can be resolved using aggregation. Consequently, the aggregator will offer symmetric service optimised over its entire EV portfolio. Finally, close to real-time trade can aid the EV user in more accurately estimating the amount of symmetric service they are willing to provide and thereby minimising the impact of the range constraint.

4.3.2.6 *Reservation Period*

This attribute is very specific for grid services and relevant in the context of capacity reservation markets. It is defined as the time block in the future for which capacity is reserved.

The main barrier in the context of reservation period is identified to be the time constraint. It would be necessary for the EV to be plugged in at a specific time of the day to provide the service and it may or may not be called upon. For instance, if the capacity of an EV is reserved for six hours between 06:00 to 12:00 on a Saturday morning, the EV will have to be available to provide this service when called upon during this period thus curtailing its time of use (time constraint).

The time constraint due to the reservation period can be dealt with in the same way as is the case with lead-time and location. Firstly, aggregation of EVs can resolve this issue by netting out any uncertainties of EV availability that may arise. Secondly, short lead times and trading as close to real-time as possible would enable a more accurate forecast of the service that the EV can or cannot provide thus minimising time constraint.

4.3.2.7 *Summary of the assessment*

From this assessment, it can be observed that the impact of the two constraints on the six service attributes can be addressed with five solutions. Table 22 provides an overview of each solution and the constraints that can be addressed by it. In general, allowing aggregation of resources has the potential to act as a robust enabler for V2X service provision by eliminating the natural implicit constraints of individual EVs. Nevertheless, providing smaller min volume and contract periods along with shorter lead times and the inclusion of asymmetric products will act as positive reinforcement in terms of regulatory enabling.

Table 22: Summary of the assessment

Service Attributes →		Volume	Contract Period	Product Symmetry	Location	Lead time	Reservation Period
Constraints	Range	✓		✓	✓		
	Time		✓			✓	✓
Solutions	Smaller min volume	✓					
	Smaller min contract period		✓				
	Shorter lead time			✓	✓	✓	✓
	Asymmetric products			✓			
	Aggregation	✓	✓	✓	✓	✓	✓

4.4 Chapter conclusions and recommendations

V2X services are still in their early stage of development globally. In the context of India, where the EV sector itself is at a nascent stage, V2X services would become relevant in the future when the market is at a more advanced (mature) stage of development. Facilitation of V2X services will require technology enablers in terms of the hardware and software, and regulatory enablers. Proactive policy-making will aid in ensuring that the full potential of the V2X services can be utilised. This chapter provides four recommendation on key regulatory enablers for unlocking this full potential of V2X services.

- Individual EVs is a distributed resource. Therefore, enabling aggregation of EVs to provide V2X resources is recommended. Such aggregation would lead to greater predictability of aggregated resource availability as well as optimisation of resource utilisation over the entire portfolio of the aggregator. This would consequently minimise implicit time and range constraints that are associated with individual EVs.
- Market entry barriers for such resources can be minimised by allowing smaller minimum bid volumes and minimum contract periods. Thus, even individual EV user too could provide V2X service and have greater participation flexibility by choosing the trade volume and contract period based on the value they attach to the time and range constraints.
- Furthermore, having a lead time that is as short as possible between the time of commitment to the time of provision of the resource will allow better forecasting of resource availability at the required time and location. Thus, minimising the risk of the resource not honouring its commitment due to incorrect forecasting.
- Finally, allowing trade of asymmetric products (for instance upward and downward balancing products for frequency response) would also reduce entry barriers for EVs. It would allow the V2X service providers to optimise its actions based on the value they attach to the time and location constraints from V2X service provision.

Figure 25 illustrates the relevance of the chapter recommendations and conclusions in the context of the market development phases.

Figure 25: Relevance of chapter recommendation and conclusions in the context of market development stages

5 Recommendations

The objective of this study is to assess the current state and provide a vision for the future of EV charging infrastructure deployment and power system integration. It presents a ***toolbox*** consisting of solution choices and recommendations for addressing two challenges: 1) the deployment of charging infrastructure and 2) the planning and management of the power system to accommodate the influx of EVs. The summary of key insights and recommendations arising from this research on the two challenges are as follows:

1. Policies for EV charging infrastructure deployment

- **Recommendation to enable EV charging on the supply side:**
  - Reduce entry barriers, mandate a time-bound, single-window clearance for permissions required to install charging stations.
  - Foster competition and eliminate market power concerns, clarify the long-term role of state-owned utilities that are at the forefront of EV charging station deployment.
  - As EV market enters the growth stage, a good practice is to reassess the approach to EV charging tariff structure periodically.
  - As EV charging market takes off and starts to follow demand, incentives for installing EV chargers should be recalibrated to ensure coverage in remote or low demand areas.
  - The EV policy must include some provisions for the development of frameworks to ensure ethical handling and use of user data and privacy.
  - Develop a regulatory framework for the utilisation of V2X capabilities, which can be a valuable resource. A cost-benefit analysis can become the basis for deciding the extent to which V2X should be enabled and incentivised.
- **Recommendation to enable EV charging on the demand side:**
  - Specify a comprehensive set of minimum payment methods that should be made available to the consumer at a charging station.
  - Develop provisions for minimum facilities required at the public charging station based on the Government of India guidelines.
  - Develop a harmonised Intra/inter-state registration process for using charging infrastructure, thus allowing the use of the wider network.
  - Policymakers should proactively take a step within the EV policy by mandating minimum standards for a mechanism to address consumer complaints.

2. Business model innovation to enable EV charging services

- The EV charging infrastructure business in India is at the introductory stage with a large scope for innovation. The market is at an introductory stage with public sector undertakings (PSUs) taking the lead in setting up infra with limited (but growing) private sector involvement. Moreover, the dominant business model is private B2B with a geographic focus on urban clusters with some B2C businesses that are offering multi charger and multi speed options.

- EV charging business model trends from EV markets in the growth state indicates that there is greater competition in the market arising from higher private sector participation. The focus shifts from providing basic vehicle charging to innovation in incorporating more value-added services in their offerings and how these services are offered. This Innovation in business models is evident in three key areas - service, partnership and pricing.
  - **Service innovation**: businesses are promoting retailing of green power, providing a choice between multiple speeds, multiple sockets, multiple power retailers, and developing software applications for users.
  - **Partnership innovation** is focused on ensuring increased access to the wider charging network and partnering with actors that specialise in a particular service.
  - **Pricing innovation** is occurring in the offering of subscriptions. In varying combinations, charging subscriptions provide users preferential rates, while access subscriptions provide priority access to the wider charging network.

3. Managing the additional EV load in the power system

- EV as load can lead to two potential issues: 1) increase in peak load leading to increase in costs from higher prices for energy and system services; 2) increase in congestion leading to faster ageing of the grid and service interruptions. Conventionally, utilities would invest in physical infrastructure to eliminate these issues. However, alternative solutions are now emerging.

- **The peak demand contribution of EVs** can be reduced by sending price signals to EVs to shift charging to off-peak hours through time-varying energy (e.g., time of day tariff and real-time pricing) and demand tariffs.

- The low penetration of enabling technologies could become a barrier to the application of time varying EV tariff in India. In this case, introducing mandatory standards for charging stations to be equipped with the required technologies and encouraging business model innovation to reduce the upfront cost of enabling technologies can mitigate this issue.

- The effectiveness and acceptance of these price signals depend on the flexibility and price sensitivity of the EV user. Encourage innovative business models where intermediaries (e.g., aggregators) play a role of optimizing and directly controlling EV charging by considering price signals and the mobility needs of the EV user can mitigate this issue.

- **To deal with congestions,** prioritize proactive measures such as encourage optimal siting of charging infrastructure by publishing state of the grid information and integrate the anticipated EV adoption and charging infrastructure development into the grid planning process.

- With the increase in penetration of enabling technologies and EV adoption, more sophisticated solutions such as variable capacity contracts and flexibility markets can be considered.

4. <u>Unlock the potential of Vehicle-to-X (V2X)</u>

- Currently, the concept of V2X is still in an early stage of development globally but would become relevant in the future as the market matures.
- Following four recommendations on the regulatory aspects are provided to improve the accuracy in predicting availability of V2X resource at a given time and location and to minimise market entry barriers for V2X service provision:
  - Enable aggregation of EVs to provide V2X resources.
  - Allow smaller minimum volume and minimum contract period for trade.
  - Allow trade of asymmetric products (for instance upward and downward balancing products)
  - Have a lead time that is as short as possible, between the time of commitment to the time of provision of the service.

A summary indicating the relevance of the various elements within the toolbox in the context of market development stages is presented in Figure 23. Although the issues addressed in this study appear to be modular, there exist interdependencies. While some proposed measures are focused on enabling solutions to address these two challenges, some are future measures that need to be factored in while the EV market in India moves from introductory to growth to mature stages.

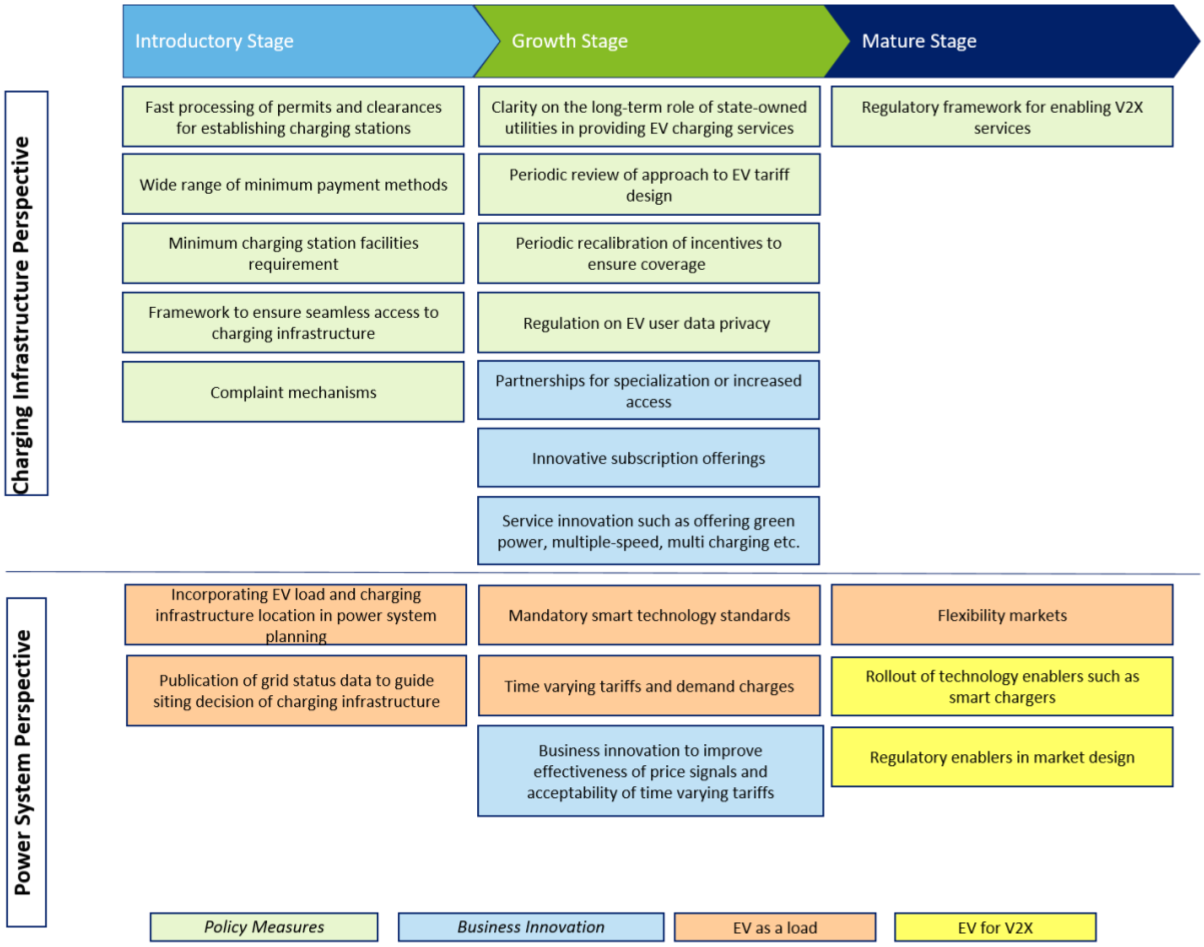


Figure 26: Relevance of the various elements within the toolbox in the context of market development stages

Finally, the EV challenges discussed in this study should be viewed in the context of the overall energy transition and disruptive innovations that are shaping the power sector of the 21st century. This calls for the development of smart infrastructure alongside smart users and smart use of data to capture values through innovative business models. Thus, the search for the most appropriate solutions in this time of change should also be supported by regulatory sandboxes both at the national and state level that help in testing different solutions to gain better insights.

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