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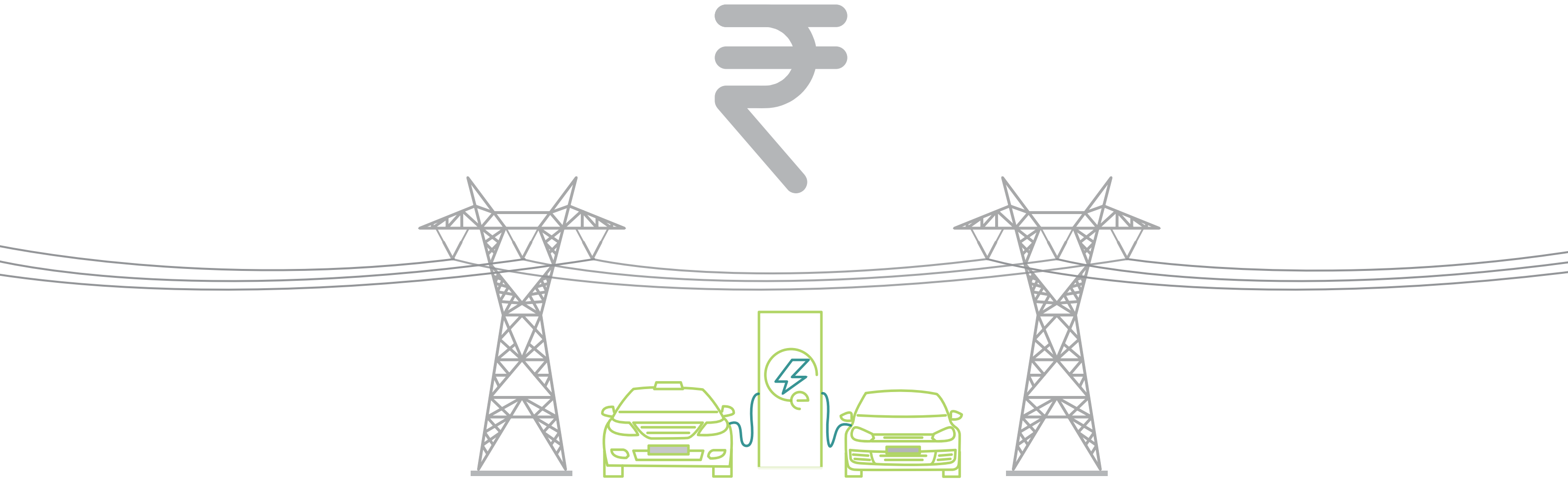
EV

A New Entrant to India's Electricity Consumer-basket



Impact on Utility Cost of Supply and the Need for a New Approach for Tariff-Setting

Shyamasis Das, Bhawna Tyagi

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July 2020

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Impact on Utility Cost of Supply and the Need for a New Approach for Tariff-Setting

Suggested citation:
Das, S. & Tyagi, B. (2020). EV – A New Entrant To India's Electricity Consumer-Basket: Impact on Utility Cost of Supply and the Need for a New Approach for Tariff-Setting. New Delhi: Alliance for an Energy Efficient Economy.

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Alliance for an Energy Efficient Economy (AEEE) is a policy advocacy and energy efficiency market enabler with a not-for-profit motive.

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

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Acknowledgement:
The authors express sincere gratitude to Abhishek Ranjan, AVP of BSES Rajdhani Power Limited, Ajit Pandit, Director of Idam Infrastructure Advisory Pvt Ltd., Dr. Pramod Deo, Former Chairperson of CERC, and Sanjiv Agarwal, Partner, Actis for their critical feedback on the report. In addition, the study has immensely benefited from the valuable inputs from Chandana Sasidharan, Senior Research Associate, AEEE.

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

2-W	Two-wheeler
3-W	Three-wheeler
4-W	Four-wheeler
A	ampere
ACEEE	American Council for an Energy-Efficient Economy
ACoS	Average Cost of Supply
APERC	Andhra Pradesh Electricity Regulatory Commission
ARR	Aggregate Revenue Requirement
BaSce	Baseline and Scenario
BERC	Bihar Electricity Regulatory Commission
BEV	Battery Electric Vehicles
BRPL	BSES Rajdhani Private Limited
BYPL	BSES Yamuna Private Limited
CAGR	Compound Annual Growth Rate
CCS	Combined Charging System
CHAdeMO	CHArge de MOve
CO	Carbon monoxide
CO_2	Carbon dioxide
CoS	Cost of Supply
DC	Direct current
DHI	Department of Heavy Industries
DISCOMs	Distribution Companies
DoD	Depth of Discharge
DT	Distribution Transformer
e-bus	Electric Bus
e-mobility	Electric Mobility
EPRI	Electric Power Research Institute
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles
FoR	Forum of Regulators
FY	Fiscal Year
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoI	Government of India
GW	Gigawatt
HERC	Haryana Electricity Regulatory Commission
HC	Hydrocarbons
HT	High-Tension
HV	High-Voltage
IEX	Indian Energy Exchange

JERC	Joint Electricity Regulatory Commission
km	kilometre
KSERC	Kerala State Electricity Regulatory Commission
kWh	kilowatt-hour
ktoe	kilotonnes of oil equivalent
LBNL	Lawrence Berkeley National Laboratory
LPSC	Late Payment Surcharge
LT	Low-Tension
LV	Low-Voltage
MERC	Maharashtra Electricity Regulatory Commission
MoP	Ministry of Power
Mtoe	million tonnes of oil equivalent
MWh	megawatt-hour
MYT	Multi-Year Tariff
NDMC	New Delhi Municipal Council
NEMMP	National Electric Mobility Mission Plan
NO_x	Nitrous oxides
O&M	Operation and Maintenance
PCS	Public Charging Stations
PEV	Plug-in Electric Vehicles
PEVI	Plug-in Electric Vehicle Infrastructure
PHEV	Plug-in Hybrid Electric Vehicles
PJ	petajoules
PM	Particulate Matter
PPAC	Power Purchase Adjustment Cost
RE	Renewable Energy
REC	Renewable Energy Certificate
RoCE	Return on Capital Employed
RPO	Renewable Purchase Obligations
SERC	State Electricity Regulatory Commission
SLDC	State Load Dispatch Centre
SNA	State Nodal Agency
SO_x	Sulphur oxides
SRP	Salt River Project
TPDDL	Tata Power Delhi Distribution Limited
ToD	Time-of-Day
ToU	Time-of-Use
TWh	terawatt-hours
UPERC	Uttar Pradesh Electricity Regulatory Commission
UT	Union Territory
V	volt
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant
WHO	World Health Organisation
y-o-y	year-on-year

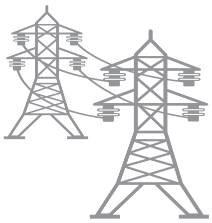
1. Introduction

Road transport continues to be an oil guzzler in India. Presently, it accounts for about 59% of total energy consumption (~ 52,296.54 kilotonnes of oil equivalent (ktoe)) in the transport sector (Central Statistics Office, 2019). The sector's continued dependence on oil has a significant impact on the environment through the resulting emissions of greenhouse gases (GHG) and criteria pollutants such as nitrous oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC), particulate matter ($PM_{2.5}$), etc. According to World Health Organisation (WHO) Ambient Air Quality Database, 15 out of the 20 most polluted cities were in India in 2016 (IQAir, 2018). Other Indian cities are also showing similar signs of continued deterioration of ambient air quality.

As the Indian economy is rapidly growing, transport demand is expected to further increase over the next several decades. To reduce oil dependence and address the issues of climate change and local air pollution, electrification of vehicles has been identified by the Government of India (GoI) as a potential opportunity. In 2012, India released its National Electric Mobility Mission Plan (NEMMP) 2020, which aimed to promote hybrid and electric vehicles (EVs) to enhance national energy security, mitigate adverse environmental impacts (including carbon dioxide (CO_2) emissions) from road transport, and boost domestic EV manufacturing capabilities (Government of India, 2012). Following this, the GoI launched the Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) scheme in April 2015. FAME is an incentive scheme that aims to reduce the upfront purchase price of hybrid vehicles and EVs to stimulate their early adoption and market creation (Government of India, March 2015).

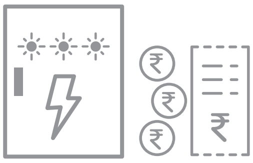
GoI has expressed its intent to achieve 100% EV sales by 2030 to promote zero-emission technologies (The Economic Times, 2017). On 8th March 2019, the second phase of the FAME scheme was launched. The scheme is proposed to be implemented over a period of three years (Government of India, March 2019). Vehicles eligible under the FAME II scheme are expected to cumulatively reduce 5.4 million tonnes of oil equivalent (Mtoe) of oil demand, resulting in a net decrease of 170 petajoules (PJ) of energy and 7.4 million tonnes of CO_2 emissions over the vehicles' lifetime (NITI Aayog and Rocky Mountain Institute, 2019).

At the sub-national level, several states and one union territory (UT) have announced EV policies specifying fiscal, non-fiscal, and other incentives to boost EV adoption. However, vehicle electrification in India is still at its nascent stage, with EVs (both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)) only getting 0.06% of the car market share through 2017 (International Energy Agency, 2018). The sale of electric two-wheelers (2-W) is less than 1 percent of the vehicle market share (International Energy Agency, 2019). There are several factors that pose significant barriers to EV adoption, such as high EV cost, range anxiety (primarily due to lack of charging stations), and EV charging time (Das, Sasidharan, & Ray, Charging India's Bus Transport, 2019).



The interlinkage of mobility and the electricity grid presents a challenge for power distribution companies.

To increase EV adoption, the availability of charging infrastructure is a major requirement. It is the backbone of electric mobility and has been the most difficult issue to address. Charging infrastructure closely binds mobility to the electricity sector and has the potential to bring about major transformations in electricity distribution. The interlinkage of mobility and the electricity grid presents an opportunity as well as a challenge for power distribution companies (DISCOMs).



EV charging has two major implications for DISCOMs. While additional electricity sales due to EV charging would help increase a DISCOM's revenue, the charging demand may increase the peak load in the DISCOM's service area, which could have a significant impact on its cost of power procurement and network management. Hence, the DISCOM has to factor in future EV charging demand in its resource and investment planning. This makes the understanding of when, where, and how much EV charging would add demand to the grid very crucial. EV charging tariffs become a critical fiscal and regulatory tool in this regard. The tariffs need to be designed in a way that would allow the DISCOM to recover its costs, while making EV charging cost-effective for users and provision of EV charging services a commercially viable business. Therefore, it is crucial to first understand how consumer tariffs are fixed in India and how EV charging tariffs are linked to EV adoption. The following subsections cover these topics and highlight the current relevant policies and guidelines in this context.

The tariffs need to be designed in a way that would allow the DISCOM to recover its costs, while making EV charging cost-effective for users and provision of EV charging services a commercially viable business.

1.1 How EV Tariffs Are Linked to EV Users

In the electricity sector, "tariff" can be defined as the cost or charge incurred by a consumer class to avail of electricity for its use. In India, consumer electricity tariff is a state-subject i.e. it is set by an appropriate commission at the state level called the State Electricity Regulatory Commission (SERC). The process of tariff-setting is based on the provisions contained in Sections 61 and 86 of the Electricity Act 2003 and the Tariff Policy notified by the GoI from time to time. EV charging is a new consumer category, recently added to the existing list, for which the tariffs have to be fixed by the commission of the respective state or Union Territory (UT).

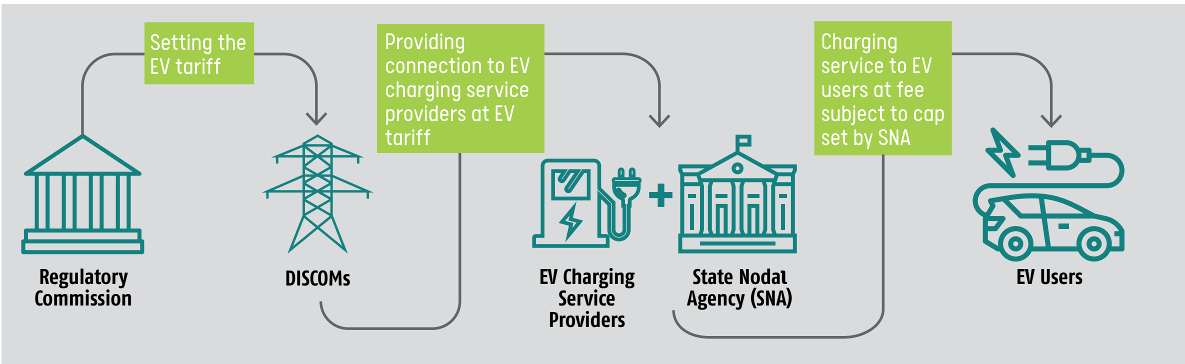


FIGURE 1: TARIFF LINKAGE WITH EV USERS

Source: AEEE Analysis

Figure 1 shows how electricity tariffs are linked to EV users. The process followed in notifying tariffs for EV charging is the same as for the rest of the consumer categories in a state or UT. The DISCOM files the tariff petition with the regulatory commission of the respective state/UT for approval, which is subsequently discussed and debated in an open stakeholder consultation forum. Following the set regulatory procedures, the regulatory commission approves EV tariff rates, based on which a DISCOM provides connections and supplies electricity to the EV charging service providers and retail EV users. For an EV charging service provider, the cost of electricity is a major operating expense. However, they also incur considerable infrastructure-related costs in establishing the charging station. Therefore, to recover both variable and fixed costs, the EV charging service provider charges EV users a fee, commonly known as the "EV charging service fee". This is what EV users pay when they charge their vehicles at EV charging stations. To ensure that the service charge is not too high, the designated State Nodal Agency/State Government/appropriate commission has the discretion to fix a ceiling for the service charge, which is applicable for the public charging stations (PCS) set up with government incentives, financial or otherwise (Ministry of Power, 2019).

1.2 Current Relevant Guidelines and Policies for EV Tariffs in India

Initially, there were apprehensions among the charging service providers regarding whether the charging of EV batteries at a charging station would require a licence or not. As per Section 12 of the Electricity Act 2003, a licence needs to be obtained for the activities of trading, transmission, and distribution of electricity. To address this, the Ministry of Power (MoP) issued a clarification on 13th April 2018 in which EV charging was recognised as a "service" (Ministry of Power, 2018). The ministry further clarified that the charging activity does not entail resale of electricity, as the energy is consumed within the premises, which satisfies the definition of consumer as per the Act.

To boost EV adoption in India, various policies and guidelines have been announced by GoI, states, and UTs. To provide guidance concerning tariff-setting for EV charging, MoP issued a set of guidelines on 14th December 2018 on "Charging Infrastructure for Electric Vehicles" (Ministry of Power, 2018). The guidelines covered tariffs for electricity supply to PCS. As per the guidelines,

- The tariff will be determined by the appropriate commission; however, the tariff shall not be more than the average cost of supply (ACoS) plus 15 percent.
- The tariff applicable for domestic consumption shall be applicable for domestic charging.

On 1st October 2019, the MoP revised the guidelines, and the following provisions were specified in the case of EV tariffs (Ministry of Power, 2019):

- The tariff will be determined by the appropriate commission in accordance with the Tariff Policy issued under Section 3 of Electricity Act 2003, as amended from time to time
- The tariff applicable for domestic consumption shall be applicable for domestic charging.
- Separate metering arrangements shall be made for PCS.

The ceiling of ACoS plus 15% was done away with. As per the revised guidelines, the Tariff Policy as per the Electricity Act 2003 would be the guiding document for the appropriate commission in determining the tariff. However, the threshold of ACoS plus 15% has been brought back into the guidelines through an amendment dated 8th June 2020 (Ministry of Power, 2020).

In this context, it is interesting to note that the Tariff Policy 2016 mentions that the consumer tariff needs to progressively reflect the cost of supply (CoS) of electricity and allows for a wider range of tariffs within ±20% of the ACoS (Ministry of Power, 2016).

Since the first set of guidelines was introduced on 14th December 2018, the clause on EV tariffs has undergone two major revisions.

Since the first set of guidelines was introduced on 14th December 2018, the clause on EV tariffs has undergone two major revisions, indicating that developing guidelines on tariff-setting for EV charging is not a straightforward task.

1.3 Need for Investigation – Tariff Framework for EV Charging

EV charging is an addition to the existing list of consumer categories. The non-EV categories have been there for a long time, and their energy consumption and demand patterns are fairly well understood and have already been accounted for to a certain extent in the tariff framework. However, EV charging as a consumer category is distinct from other categories in three major ways:

First, EVs are a mobile source of electricity requirement. As a result, the possible energy requirement and power demand at the charging points could be hard to predict during the initial phase.

Second, the EV charging load is anticipated to be intermittent, with spikes in the demand curve. This could have a significant impact on the local distribution network, especially in distribution areas with limited available hosting capacity[1].

Third, EVs can potentially act as prosumer due to possibility of bi-directional energy flow. They are a potential distributed energy resource and could be leveraged to feed electricity back into grid using Vehicle-to-Grid (V2G) functionality.

Regulators have to take these factors into account when framing the EV tariff schedule. Presently, there is no existing literature that deals with the key aspects of the EV charging tariff framework, considering the uniqueness of the EV charging consumer category. A study by India Smart Grid Forum provides a comparison of EV policies and tariffs in different states and briefly discusses global EV promotion initiatives (Pillai, Suri, Dhuri, & Kundu, 2019). With respect to EV tariffs, the study broadly suggests that there should be no fixed charge in the initial years and advocates Time-of-Day[2] (ToD) tariffs to discourage charging during peak hours. A study by The Energy and Resources Institute briefly touched upon the aspect of EV tariffs and recommended that lower rates could be introduced to encourage EV adoption (TERI and Yes Bank, 2018). In its report on EV charging infrastructure in India, Florence School of Regulation delves into two aspects –deployment of charging infrastructure and integration of EVs into the power system (Bhagwat, Hadush, & Bhagwat, 2019). The study assessed the impact of EVs on the grid in terms of peak power demand and grid congestion, with a brief discussion on EV tariffs, and provided recommendations on how to reduce peak power demand and congestion. None of the studies considered the impact of EV charging on the CoS of DISCOMs (which is the basis for setting tariffs) or examined the key aspects to consider when designing the EV tariff framework.

1 Hosting capacity is defined as the amount of new power generation or consumption sources that can be connected to the grid without adversely impacting the reliability or power quality for other customers.

2 The term "Time-of-Day (ToD) tariffs" refers to electricity tariffs that vary by time period, being higher in peak periods and lower in off-peak periods. A rebate is provided and a surcharge levied for electricity consumption in off-peak and peak periods, respectively.

Thus, there is a need for clarity regarding the framework for tariff-setting, which would allow DISCOMs to recover their costs, while making EV charging cost-effective for users and EV charging service provision a commercially viable business. This will help in sending clear price signals to the DISCOMs and charging service providers, as well as EV users. It will also facilitate faster EV adoption and effective EV-grid integration.

2. Objective, Scope, and Approach

The present study intends to analyse the different elements of an EV tariff framework, educate concerned stakeholders about the implications of EV tariff design, and encourage them to participate in informed discourse on this subject. This will provide further support in bringing about necessary regulatory changes to enable the establishment and operation of charging stations as commercially viable business ventures in the Indian context. Moreover, the assessment will help prepare the DISCOMs to provide service efficiently and cost-effectively through better EV charging load management and predictive infrastructure augmentation.

Therefore, the study has two broad objectives:

To evaluate the impact of the additional load from EV charging on a DISCOM's CoS

To facilitate the development of a framework for determining appropriate tariffs for EV charging

To achieve the abovementioned objectives, it is essential to estimate the potential electricity demand due to EV adoption, anticipate the possible charging patterns, and evaluate the contribution of EV charging to the base and peak load, along with reviewing the current tariff schedules adopted by different states and UTs. Thus, the investigation entails the following major steps:

- Undertaking a review of the existing studies done on the impact of EV integration on the distribution network, both in the context of India and other countries
- Assessing the EV population and its possible charging patterns, energy requirements, and contribution to the peak and off-peak loads in a DISCOM's service area
- Evaluating the impact of EV charging on the various components of a DISCOM's CoS
- Undertaking a case study focusing on a state and its DISCOMs
- Reviewing the current EV tariff schedules adopted by different states and UTs in India
- Identifying the key considerations for developing an EV tariff framework
- Carrying out stakeholder consultation on the issue of EV tariff frameworks
- Formulating recommendations on the determination of appropriate tariffs for EV charging

3. Review of Select Indian and International Studies on the Impact of EV Charging on the Grid

In this section, the report analyses both India-specific and international literature publicly available as on November 2019 about the impact of EV charging on the electricity grid. The literature review divides the existing studies into four areas – EV sales estimation, applied models for energy requirement evaluation, assessment of the peak power demand and energy requirement from EV charging, and the potential application of EVs to flatten the load curve. Overall, there is a dearth of such assessments in the Indian context.

3.1 EV Sales Estimation

The fundamental information required to estimate the electricity demand from EVs in any country is the projection or estimation of the number of EVs sold. A study by Lawrence Berkeley National Laboratory (LBNL) considered the GoI intent of achieving 100% EV sales by 2030 in their assessment of the system-level techno-economic impact of battery electric vehicles (BEVs) in India (Abhyankar, Gopal, Sheppard, Park, & Phadke, 2017). The study assumed that the annual sales of 2-W BEVs and four-wheeler (4-W) BEVs would have to be 32 million and 10 million units, respectively, to achieve purely EV sales in the light-duty passenger segment by 2030. The annual growth rate of car sales is assumed to be constant, with sales nearly quadrupling in about 15 years. In the case of 2-Ws, the study expected a slowdown in sales due to increased income, especially in urban areas, and, hence, the 2-W sales might only double between 2015 and 2030. A study by the Forum of Regulators (FoR) took a different approach, assuming 100 EVs in the baseline scenario to evaluate the impact of EVs on the grid (Forum of Regulators, 2017). In their analysis of the EV sector, Ali and Tongia (2018) considered EV impact under two scenarios: an ambitious scenario with the GoI target of 100% sales by 2030 and a more modest scenario with approximately 33% EV sales by 2030 (Ali & Tongia, 2018). Most studies focusing on India have considered the GoI target in their analyses, whereas global studies have considered the actual penetration of EVs in their assessment [(EPRI, 2018); (Sheppard, Waraich, Campbell, Pozdnukhov, & Gopal, 2017); (Schey, Scoffield, & Smart, 2012); (Jain, 2018)].

Most studies focusing on India have considered the GoI target in their analyses, whereas global studies have considered the actual penetration of EVs in their assessment.

3.2 Models Used for Energy Requirement Evaluation

Most of the studies have used a variety of different models to determine the contribution of EVs to electricity demand. LBNL (2017) used three simulation models for estimation: (a) Plug-in EV Infrastructure (PEVI) model to simulate driving or charging behaviour; (b) PLEXOS, for simulation of least-cost investment planning and economic dispatch of the power system, and (c) the Economic and Environmental Impacts model to assess the impact on emissions, oil imports, and DISCOM finances (Abhyankar, Gopal, Sheppard, Park, & Phadke, 2017). FoR's study used Matlab to calculate the EV charging load. The study used the library model with certain modifications (Forum of Regulators, 2017). McKinsey studied the potential impact of EVs on global energy systems, particularly in the German context, using the Monte Carlo simulation for the analysis (Engel, Hensley, Knupfer, & Sahdev, 2018). In another study, LBNL (2017) modelled plug-in EV charging demand for San Francisco using the Behaviour Energy Autonomy Mobility (BEAM) model. BEAM is an extension of MATSim, an open-source transportation system modelling framework (Sheppard, Waraich, Campbell, Pozdnukhov, & Gopal, 2017). The study updated and improved the Plug-in Electric Vehicle (PEV) benefits analysis developed initially by Baseline and Scenario (BaSce) analysis. One of the crucial assumptions of the BaSce analysis is that large-scale deployment would not significantly alter the electric power system or change the benefits and costs associated with fuelling infrastructure (both for electricity and petroleum).

3.3 Estimation of Peak Power Demand and Energy Requirement

There are only a few studies that estimated the impact of EVs on the peak power demand and energy requirement in India.

There are only a few studies that estimated the impact of EVs on the peak power demand and energy requirement in India. If India achieves 100% EV sales by 2030, LBNL (2017) estimates that the increase in additional electricity requirement due to BEV charging by that period would only be 3.3% of the total electricity demand in the country, i.e. 82 terawatt-hours (TWh)/ year (Abhyankar, Gopal, Sheppard, Park, & Phadke, 2017). However, the contribution of BEV charging to peak load was estimated to be about 6% of the total peak load by 2030, i.e. 23 gigawatts (GW). When the investigation performed a sensitivity analysis by varying the parameters by ± 25%, the overall BEV energy consumption in 2030 was found to range between 62 and 103 TWh/annum (which corresponds to 2-4% of the non-BEV energy requirement), whereas the peak load was anticipated to vary from 19 to 39 GW (i.e. 5–10% of the non-BEV peak load). The study also calculated that BEV charging could earn utilities about ₹ 700 billion/ year in additional revenue by 2030, assuming a marginal tariff of ₹ 9/kWh. The crucial assumption made by the study was that the travel demand would remain constant until 2030 and all BEV owners would have access to public charging infrastructure.

The study by FoR (2017) estimated that a baseline 50% loaded commercial feeder can absorb up to 20% of additional EV load from fast charging (Forum of Regulators, 2017). Similarly, the residential feeder can safely handle a ratio of 60:40 from the residential load and EV load (fast charging), respectively. However, they estimated that the threshold for additional EV load should be 20% in the case of a peak co-incident charging scenario. The impact of slow charging on both feeders was negligible. They considered Multi-Year Tariff regulations issued by Maharashtra Electricity Regulatory Commission (MERC) as the basis for the calculation of tariffs. The study calculated that if the investment in the EV charging stations is socialised with all consumer categories, then the tariff increase may vary from ₹ 0.0007/ kWh to ₹ 0.0040/kWh. However, the impact on tariff increase would be substantial if the entire cost was passed on exclusively to EV users. In that case, the tariff would vary from ₹ 0.1790/kWh to ₹ 0.2810/kWh. The library model FoR used includes three major components: power stations (solar PV farm, wind farm, and diesel generator), distribution lines, two 3-phase transformers, and loads (EV and residential loads). However, the model is not representative of existing distribution feeder systems and instead presents the results of a study on a controlled microgrid. Furthermore, the study assumed that the generators are located at different points, with wind generators placed at a maximum of 25 km away from the load, whereas in the grid-based scenario, the distance is typically greater than 200 km. Therefore, results may not be representative of grid-based scenario.

The impact of EVs on energy requirement is also discussed in the study by Ali and Tongia (2018), although they did not specify their methodology for calculating the impact. The d7-study concluded that EVs could add up to 50% of peak power demand and contribute 3 percentage points to peak power demand growth between 2017 and 2030 (Ali & Tongia, 2018). The research projected that the total electricity demand for EV charging might vary between 37 and 97 TWh by 2030 under the 33% and 100% EV sales scenarios, respectively, considering only intra-city (urban) passenger travel. Vehicle category-wise electricity consumption projections in 2030 are given below:

- 2-Ws: 5-16 TWh with mileage of 54.4 kilometres (km)/kilowatt-hour (kWh);
- 3-Ws: 8-16 TWh with mileage of 19.2 km/kWh;
- 4-Ws: 9-26 TWh with mileage of 9.4 km/kWh
- Taxis: 4-10 TWh with mileage of 9.4 km/kWh
- Buses: 11-28 TWh with mileage of 0.8 km/kWh.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) also carried out an impact assessment study on integration of EV charging on the electricity distribution system (GIZ, 2019). They considered certain feeders in the service area of BSES Yamuna Power Limited (BYPL) and forecasted the impact of EV integration on the distribution network through 2030. As per the EV projections and charging patterns presented in the methodology, uncontrolled EV charging may account for around 13.8% of the DISCOM's total energy sales and about 12.3% of peak power demand in 2030. The study envisages that the additional peak power demand in the system could be met by upgrading the grid infrastructure, which would require additional investment equivalent to 12.3% of BYPL's total worth. Therefore, the study recommended adopting controlled charging and/or ToD or Time-of-Use[3] (ToU) tariffs to minimise the impact on peak load. This is the only study that considered the impact at the feeder level for DISCOMs. However, the study did not evaluate the impact on the DISCOM's CoS and limited its analysis to only one DISCOM, in Delhi.

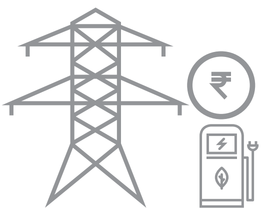
EV charging patterns in India are only discussed in one study, by OLA Mobility Institute, which studied the operational challenges faced in OLA's electric mobility pilot project in Nagpur (Arora & Raman, 2019). The study observed that the power demand from electric cab charging at the charging stations peaked during the afternoon (12 PM – 4 PM) and at night (8 PM - 12 AM) - with 63.5% of charging happening at these times. As there is no other publicly available study on EV charging patterns, there is a lack of information available on the patterns for other EV segments.

Several international studies have analysed the charging patterns and EV contribution to peak power demand in other countries. The Electric Power Research Institute (EPRI) studied the charging patterns of the Salt River Project (SRP) service territory in Arizona (EPRI, 2018). The study considered both BEVs and PHEVs in the analysis. Vehicle data logging devices were used to track 100 EVs during driving and charging events to acquire minute-level, high-resolution data. It was expected that long road trips would be limited to Tesla cars, as there is no charging network supporting other vehicle types.

3 The term "Time-of-Use (ToU) tariffs" refers to electricity tariffs that vary based on the time of the day and season in which electricity is used. Similar to ToD tariffs, ToU rates provide the opportunity to reduce the electricity bill by shifting electricity consumption to partial-peak or off-peak hours throughout the day, when rates are lower.

The study estimated that EVs would use approximately 2,700 – 3,300 kWh of electricity per year. On average, power demand ranged from 20 to 70 kW, with spikes of up to 120 kW. The crucial finding of the study was that peaks of 120-140 kW were observed, even when there were only 0-10 vehicles being charged; in other words, the upper bound of peak power demand in a service territory is not impacted much by the number of vehicles charging simultaneously. It was observed that while DC fast charging accounted for less than 3% of the total energy consumption, it was the cause of most of the peaks in the total project load. Another finding was that approximately 81% of charging occurred at home, while only ~3% of charging occurred at public charging locations. Factors that affected EV charging consumption included driving habits, as well as the ambient temperature, which could affect the battery chemistry and auxiliary power needed for air conditioning and heating. They also found that temperature variation did not significantly alter the load profiles significantly.

An analysis by McKinsey (2018) suggests that projected growth in electric mobility (e-mobility) will not drive a substantial increase in total grid-based power demand in the near to medium term. In the case of Germany, the study found that EV growth is not likely to cause large increases in power demand through 2030 (Engel, Hensley, Knupfer, & Sahdev, 2018). It could potentially add about 1% to the total and require about 5 GW of extra generation capacity. They expect peak load to increase by 1% and 5%, respectively, for 2030 and 2050, which could be easily absorbed by the system. For a typical residential feeder circuit of 150 homes at 25% local EV penetration, the analysis indicated that the local peak load would increase by approximately 30 percent. They found that aggregation across many households (those with and without EVs) reduces the relative increase in peak load at a substation. Load profiles for fast charging stations fluctuate widely but still follow a weekday and weekend pattern. Unmanaged substation peak load increases from EV charging power demand will eventually push local transformers beyond their capacity, thereby resulting in required upgrades. Combining data on the distribution of EV penetration per zip code from McKinsey's geospatial analysis with data on the current utilisation of transformers revealed that capital expenditure requirements as a function of national-level EV penetration follow an S-curve shape. As the cost of batteries continues to rapidly decline, using energy storage to smooth load profiles will become increasingly attractive.



3.4 EVs: An Instrument to Flatten the Load Curve

EVs are an additional source of revenue for DISCOMs, and proper planning can result in the more efficient and less costly grid operation.

EVs are an additional source of revenue for DISCOMs, and proper planning can result in the more efficient and less costly grid operation. They could be used as a "flexible load," i.e. their charging times could be coordinated to flatten the load curve and increase the offtake of renewable energy. The BEV charging load could have significant impacts on local distribution networks. Thus, EV charging load could be shifted to a different time of the day to reduce total system costs. Several studies have recommended and studied the use of ToU or ToD rates to incentivise consumers to shift their charging time to off-peak hours.

The EPRI study evaluated EV customers' reactions to price signals through ToU rates (EPRI, 2018). They found that DISCOM ToU rates manage to shift peak loads of customers to night and early morning hours. The results were most effective for a rate plan which recommends to avoid charging between 1-8 PM and target between 11 PM- 5 AM and load increases from 0.2 kW at 10 PM to 1.2 kW at 12 AM. Most of the charging occurred at Level 2[4] (74.0%), followed by Level 1[5] (23.4%) and direct current (DC) fast charging (2.5%). McKinsey also recommended the use of ToU rates, along with deployment of more local solutions, such as co-locating an energy storage unit with a transformer that charges the unit during times of low demand or use of a small combined-heat-and-power plant to manage the EV demand (Engel, Hensley, Knupfer, & Sahdev, 2018).

Another study by Schey, Scoffield, and Smart (2012) found that "charging availability for residential charging units is similar in each EV Project region. It is low during the day, steadily increases in the evening, and remains high at night". However, charging demand varied from region to region. They examined two EV Project regions with and without ToU rates to identify regional differences. In Nashville, without ToU electricity rates for EVs, demand increased in the evening as charging availability increased, starting at about 16:00. Demand peaked at 8 PM on weekdays. In San Francisco, where the majority of EV Project participants had the option of choosing a ToU rate plan from their DISCOM, demand spiked at 00:00. This coincided with the beginning of the off-peak electricity rate period. They witnessed a strong preference among EV Project participants for night-time residential charging. In San Francisco, ToU rates were deemed successful in shifting charging demand to off-peak hours, but the study identified a different set of problems for the DISCOM in this case. If a large number of users in this region schedule charging to begin immediately at midnight, it could result in an unintended demand spike at the beginning of the off-peak period (Schey, Scoffield, & Smart, 2012). The above challenge was also highlighted in study by American Council for an Energy-Efficient Economy (ACEEE) (Khan & Vaidyanathan, 2018). They concluded that consumers in California are willing to shift their EV charging time to off-peak hours based on the ToD incentives.

There were other concerns raised by ACEEE regarding tariff rates. They highlighted the fact that dynamic rates could be beneficial for the fast charging of EVs but may prove challenging for most EV owners, who typically cannot adjust charging times to respond to variable and unpredictable pricing (Khan & Vaidyanathan, 2018). Demand charges, in which customers are charged based on maximum power draw, are a potential concern for DC fast charging (Level 3 charging) and could adversely affect EV adoption. For example, businesses may discourage workplace EV charging to avoid demand charges from simultaneous charging, which in turn could discourage EV ownership among people without convenient residential or public charging options. Utilities are aware of the consequences of demand charges on EV charging and are taking remedial measures. For example, Portland General Electric Company, which charges USD $0.50 for each kW of demand above 40% of the maximum demand, adjusts these charges downward in many cases, including when the excess is associated with EV charging.

4 Classification standards for EVSEs in USA is based on the charging power levels, or simply "Levels". Level 2 charger has a voltage rating of 240 V and output power in the range of 4.8 to 24 kW.

5 Level 1 charger has a voltage rating of 120 V and output power in the range of 1.4 to 2.4 kW.

3.5 Key Observations from the Literature Review

Several observations drawn from the reviewed studies are highlighted below:

- International studies considered the impact of actual EV penetration in the area of study. However, in the case of India, analysis is done based on scenarios built around the government EV targets. None of the studies carried out EV sales/usage estimation for India.
- Existing studies estimated that the impact of EV charging on peak power demand might vary from 3% to 6% of the total electricity peak demand in India by 2030 [(Abhyankar, Gopal, Sheppard, Park, & Phadke, 2017); (Ali & Tongia, 2018)].
- As the batteries in e-buses are larger than those in light-duty vehicles, e-bus charging could potentially cause a sudden spike in peak power demand. In analysing the impact of EVs on the peak power demand and energy requirement, the bus segment has not been considered in most of the studies, except the research done by Ali and Tongia (2018).
- In the case of private vehicles, most of the charging happens at home, especially during evening hours (EPRI, 2018).
- The network augmentation cost and its impact on tariffs have only been considered in the FoR (2018) study. However, the assumptions used in the study are not representative of conventional power grid conditions.
- The positive impact of ToU rates on charging patterns has been shown in international studies. The use of EV-specific ToU rates to flatten the load curve has also been recommended by studies focusing on India [(Abhyankar, Gopal, Sheppard, Park, & Phadke, 2017); (Ali & Tongia, 2018); (Forum of Regulators, 2017)]. However, EV-specific ToU rates have not been implemented so far in India.
- Some states have announced EV-specific ToD rates, which will be discussed in detail in the following section. With ToU/ ToD rates, EV owners save money by charging at lower tariffs during off-peak hours, while the utilities can manage the peak load efficiently and cost-effectively and also ensure grid stability.
- Different studies have assessed different issues, such as EV impact on the overall energy requirement, contribution to peak power demand in India, charging patterns of the commercial 4W fleet, etc., related to the impact of EV charging on DISCOMs, but no study has examined all these issues holistically—charging patterns, category-wise contribution to the peak power demand and energy requirement, and the impact of network upgradation costs on tariffs.

4. Impact of EV Charging on DISCOM's Cost of Supply

The impact of EVs on the peak power demand and energy requirement may not be significant at the national level, as evident from the studies discussed in the previous section. However, EVs may represent a significant addition to the load and energy requirements at the distribution level (Coignard, MacDougall, Stadtmueller, & Vrettos, 2019). Furthermore, the energy requirement for charging an EV is not uniform, as battery size varies with vehicle category. For example, 2-Ws have a battery capacity of 2 kWh, compared to 250 kWh in e-buses. Therefore, it is necessary to evaluate the additional energy requirement due to EV adoption, considering all the possible EV segments, their contributions to the base and peak loads based on their possible charging patterns, and their impact on the CoS of a DISCOM.

To cater to the additional demand, the DISCOM may have to procure additional power. In some cases, it may have to invest in infrastructure augmentation to avoid the overloading of existing transformers and feeders. Thus, meeting the EV charging load may entail additional costs for the DISCOM, which would result in a change in CoS. A DISCOM's CoS, in turn, is the fundamental basis for the setting of electricity consumption tariffs by a regulator. Therefore, assessing the degree of impact on the CoS is critical to understanding the corresponding tariff implications. This chapter thus examines the key components of CoS, discusses the impact of EV charging on these components, and presents a detailed case study on the impact of EV charging at the DISCOM level.

Assessing the degree of impact on the CoS is critical to understanding the corresponding tariff implications.

4.1 Cost of Supply

The CoS is computed by dividing the aggregate revenue requirement (ARR) estimated by the regulator by the total energy sales for the year. ARR comprises power purchase cost, operation and maintenance (O&M) expenses, administrative expenses, return on capital employed (RoCE), depreciation, and income tax [(Das, Consumer Power Subsidies: Brewing Crisis in India's Economy, 2016); (DERC, 2018a); (DERC, 2018b); (DERC, 2018c); (DERC, 2018d)]. However, only the costs associated with the licenced business of the DISCOM can be recovered through consumer tariffs. Therefore, to estimate the amount for recovery through consumer tariffs, non-tariff income is deducted from ARR. Power purchase cost constitutes the largest component of CoS, accounting for 70-80% of the total cost.

Ideally, the average tariff for a consumer category should be at par with the CoS of electricity. However, the National Tariff Policy 2016 allows cross-subsidising within ±20% of the average CoS, i.e. one can charge higher prices to a set of consumers in order to subsidise another consumer category (Ministry of Power, 2016). Traditionally, commercial and industrial consumers pay more than the CoS to compensate for the subsidies provided to domestic and agricultural consumers.

The key components of CoS are:

- **Power Purchase Cost:** The estimation of the power purchase cost is based on the volume of energy to be procured. It primarily includes transmission charges and represents 70-80% of the total revenue requirement. Power purchase cost is the rate at which a DISCOM purchases power from the various power stations and is calculated based on the fixed and variable costs of each power plant and the total amount of electricity sourced from each plant. Each DISCOM also has mandatory renewable purchase obligation (RPO) targets. To meet the targets, the DISCOM may have to purchase renewable energy certificates (REC), which also adds to the total power purchase cost.

- **Operation and Maintenance Expenses:** This broadly includes employee-related costs, administrative and general expenses, and repair and maintenance costs. The latter covers the cost associated primarily with repair and maintenance of transmission lines, substations, and distribution transformers.
- **Return on Capital Employed (RoCE):** It is based on the capitalisation of assets of the utility and calculates as the product of the regulated rate base and the weighted average cost of capital. Weighted average cost of capital is calculated as sum of proportionate share of debt and equity multiplied with cost of debt and return on equity respectively.
- **Depreciation and Income Tax:** Depreciation rates—typically around 5.26%—are prescribed in Multi-Year Tariff (MYT) regulations of states and UTs. Income tax applies to the licenced business of the distribution licencee and is limited to the return on equity component of the weighted average cost of capital. Any additional tax other than this is not allowed to be passed on to the consumer, and the amount is payable by the distribution licencee itself.
- **Energy Sales:** This is the sum of the estimated electricity sales to all types of consumers. The consumer base can be divided into seven broad categories: domestic (also known as household/ residential), commercial, agricultural (also termed irrigation), industrial, railway traction, and outside state (denotes the electricity sales outside the state of power generation).

4.2 Impact of EVs on Cost of Supply

With EVs getting added to the consumer basket of a DISCOM, requiring additional electricity to be supplied, the DISCOM needs to procure more electricity. This may lead to an increase in the power purchase cost of the DISCOM. The magnitude of the increase in cost will primarily depend on the time of day at which there is substantial demand for EV charging. This will also have implications on the distribution and transmission losses. Other components of ARR that will be impacted are O&M expenses, depreciation, RoCE, and income tax. The increase in O&M expenses will be directly proportional to the network augmentation and upgradation required to cater to the additional demand from the EV charging facilities. However, it is not possible to generalise the percentage of increase based on an average network augmentation cost, as it depends on the loading pattern of the existing network and the spare capacity available at the distribution transformer or feeder level. Thus, in evaluating EV impact on the CoS, the O&M expenses are assumed to be constant. If there is an addition of distribution infrastructure, depreciation costs will also increase. As it is difficult to project the need for infrastructural expansion due to EV charging, a change in depreciation cost for the DISCOM has not been considered in this assessment. Furthermore, there will be no impact on RoCE unless the share of equity increases due to additional capital expenditure. There will be no change in income tax if RoCE remains constant.

The actual impact on CoS per unit of electricity sales will depend on whether the magnitude of the increase in ARR is higher or lower than the increase in revenue from higher energy sales.

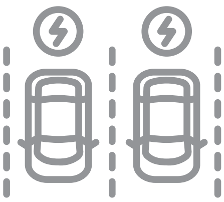
Apart from the possible increase in the cost, EV charging creates an opportunity for a DISCOM to increase its energy sales. Thus, the actual impact on CoS per unit of electricity sales will depend on whether the magnitude of the increase in ARR is higher or lower than the increase in revenue from higher energy sales.

4.3 Delhi Case Study

To evaluate the contribution of EVs and their vehicle mix to the peak power demand and energy requirement, a case study has been performed at the DISCOM level. Considering the potential concentration of EVs in metro cities like Delhi and the availability of recent data in the public domain, the four DISCOMs in Delhi – Tata Power Delhi Distribution Limited (TPDDL), BSES Rajdhani Private Limited (BRPL), BSES Yamuna Private Limited (BYPL), and New Delhi Municipal Council (NDMC) – have been selected for the case study. As the objective of the study is to show DISCOM level impact, irrespective of the state or region and considering the regulatory sensitivity of such analyses, the names of the DISCOMs have been kept anonymous in the analysis. Henceforth, they are referred to as DISCOM-I, DISCOM-II, DISCOM-III, and DISCOM-IV (not in the same order).

4.3.1 Data and Methodology

Considering the availability of the latest data in the public domain, the impact analysis has been carried out using the DISCOM data from 2018-19. Load data for the DISCOMs have been retrieved from the State Load Dispatch Centre (SLDC) in Delhi and the data on the components of CoS (such as power purchase cost, energy sales, transmission and distribution losses, etc.) have been obtained from the DISCOMs' 2018-19 tariff orders. In terms of tools used, an Excel-based model is applied to study the EV charging patterns and evaluate the impact on energy requirement, peak power demand, and contribution to CoS.



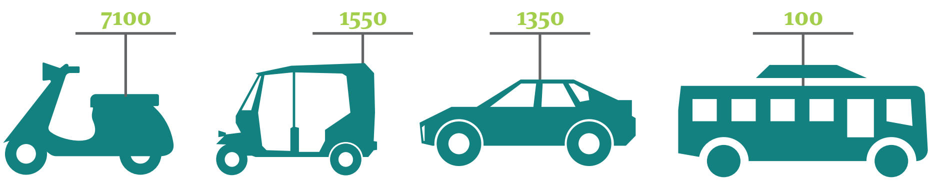
To carry out the impact analysis, the study has assumed a case where 10,100 EVs would be charged in each DISCOM's service area, out of which 100 would be e-buses. The remaining 10,000 EVs are assumed to consist of 2-Ws, three-wheelers (3-Ws), and 4-Ws in the same proportion as projected in the report on "India's Electric Mobility Transformation" (NITI Aayog and Rocky Mountain Institute, 2019). This cumulatively accounts for 40,400 EVs in the entire Delhi area, including 400 e-buses. This initial period of increase in EV adoption is a challenging time from the point of view of planning for power purchase and network upgradation by DISCOMs, since the time for preparedness may not be sufficient for DISCOMs and regulators, causing them to resort to knee-jerk reactions.

Apart from the number of vehicles, another critical factor in peak power demand assessment is the simultaneous charging of EVs. To account for this, various scenarios have been considered and are discussed in detail in the next section.

Apart from the number of vehicles, another critical factor in peak power demand assessment is the simultaneous charging of EVs.

The EV mix considered in the case study is shown below. In the 4-W category, only commercial passenger vehicles have been considered, since EV adoption in this segment in the near term is expected for predominantly commercial passenger transport[6].

ASSUMED NUMBER OF EVs UNDER DIFFERENT VEHICLE CATEGORIES IN CASE STUDY



Source: NITI Aayog and RMI (2019); AEEE Analysis

6 Use of electric 4-Ws for goods transport is yet to be seen in Indian cities.

Table 1 provides details of charging specifications for different EV categories considered in the case study. When and where different EV segments are charged could potentially impact the CoS. Urban e-bus charging is expected to happen primarily at the bus depots/ terminals, according to the research on “Charging India’s Bus Transport” (Das, Sasidharan, & Ray, Charging India’s Bus Transport, 2019). Thus, the study has considered depot charging for e-buses. For other EV categories, both home/captive charging and charging at public facilities have been considered. For 4-Ws, as the study has considered only commercial fleets, captive charging and public charging are applicable. However, for 2-Ws and 3-Ws, charging is possible at home and captive and public charging stations.

When and where different EV segments are charged could potentially impact the CoS.

As EV charging can be done during both the day and night, the study has considered the frequency of charging for each vehicle category. Different amounts of time have been allocated for public charging during the day and home charging at night, maintaining the overall assumption that the bulk of charging will happen at home or by captive charging. Charging frequency is defined as the number of times each vehicle is charged per day. For example, 1.5 implies one full charge at night and 0.5 opportunity charging during the day.

For any battery, the rated capacity does not correspond to the total energy available for usage. Rather, to maintain the health of the battery, there is a limit up to which battery can discharge, i.e. the maximum depth of discharge (DoD). The present study has considered the DoD of the battery as 70% (Das, Sasidharan, & Ray, Charging India’s Bus Transport, 2019). Another important consideration related to charging is the efficiency of the charger. There are certain losses during energy conversion and transfer. To account for the losses, based on stakeholder interaction, the efficiency of the charger is considered to be 95 percent.

TABLE 1: KEY DETAILS OF CASE STUDY CHARGING SPECIFICATIONS FOR DIFFERENT EV CATEGORIES

Parameters			Unit	2-W	3-W	4-W	Bus
Rated charger Power	Home/ Captive		kW	0.55[a]	1.5[a]	3.0[b]	
	Bus Charging	Slow Charger[c]	kW				80.0[d]
		Fast Charger[c]	kW				100.0[e]
	Public		kW	2.0[f]	2.0[g]	15.0[i, 7]	
Rated Battery Capacity[h]			kWh	2.0	5.0	20.0	200.0
Charging Frequency[h]			Ratio	1.1	1.5	2	1.5

Sources:
a: Charger power calculated at 0.3C C-rate[8] for charging
b: Maximum output power available from domestic electric sockets (230 volts (V), 16 amperes (A))
c: Fast or slow charging depends on the vehicle battery’s C-rate
d: Maximum output power of charger for BYD manufactured buses
e: Ministry of Power guidelines (Ministry of Power, 2019)
f: Maximum output power of DC charger in Ather Grid
g: Maximum output power of DC portable charger from Exicom
h: Based on stakeholder consultation and internal analysis
i: Maximum output power of Bharat DC001 charger

7 In the 4-W segment, most on-road electric four wheelers in India are low-voltage cars with battery capacities of around 20 kWh. The Bharat DC001 charger is mostly used in PCS for charging these low-voltage cars (as a 50 kW combined charging system (CCS) or CHArge de MOve (CHAdeMO) is not suitable). Therefore, the rated charger power of Bharat DC001 (15 kW) has been considered against the EV battery capacity of 20 kWh.

8 The C-rate is the rate at which a battery is discharged relative to its maximum capacity.

4.3.2 EV Charging Scenarios

As mentioned above, the charging pattern of EVs is an important factor that can significantly impact the ability of a DISCOM to serve its consumers. However, predicting EV charging patterns is difficult at this stage (except for e-buses), due to the limited number of EVs on the road. The charging patterns would depend on the convenience and availability of charging infrastructure. Thus, the study has assumed that night-time charging starts at 10 PM for e-buses and 9 PM for other EV categories. This is based on the assumption that most people charge their EVs once they reach home, and for e-buses, the depot timetable is considered. During the daytime, charging starts somewhere around noon. However, there will be a variation in the number of vehicles charging at the same time. To factor that into the impact analysis, two scenarios for EV charging patterns have been considered:

Scenario I- All EVs start charging at the same time

Scenario II- 50% of EVs start charging at the same time

Figure 2 and **Figure 3** show the projected EV charging load curve of 10,000 EVs (excluding e-buses) with different charging options (public, home, and captive) in Scenario I and II, respectively. As 4-Ws have larger batteries, it results in a high energy requirement, which is evident in **Figure 2** and **Figure 3**. In the case of PCS, 4Ws contribute the most to power demand in both scenarios, compared to 2-Ws in the case of home/captive charging. The increase in the charging power and energy requirement is greatest at night in both scenarios. However, peak power demand is highest at noon in Scenario I.

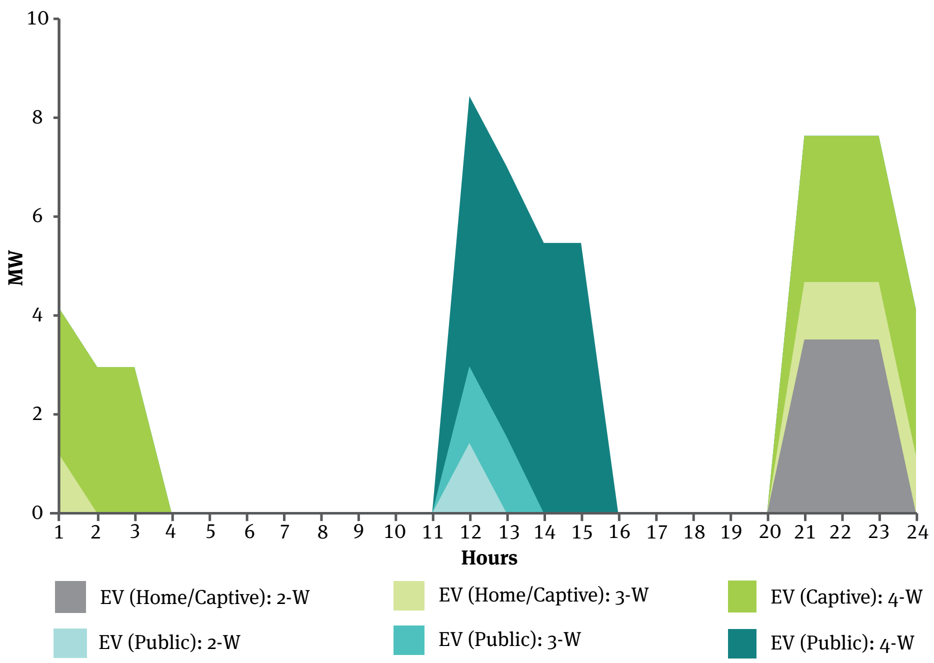


FIGURE 2: PROJECTED EV CHARGING LOAD CURVE FOR 10,000 EVs IN SCENARIO I

Source: AEEE analysis

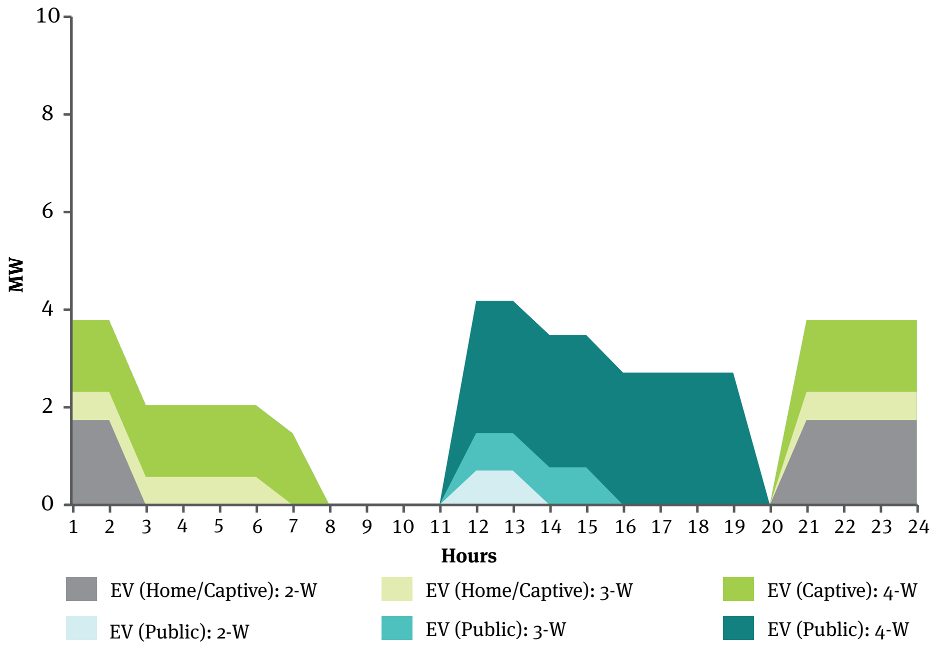


FIGURE 3: PROJECTED EV CHARGING LOAD CURVE FOR 10,000 EVs IN SCENARIO II

Source: AEEE analysis

Unlike other vehicle categories, e-buses have much higher battery capacities, and, hence, their charging is accounted for separately. As per current MoP guidelines, a fast charger (100 kW or higher) is applicable for heavy-duty vehicles (such as trucks and buses) (Ministry of Power, 2019). However, the charger power of the BYD manufactured bus charger is 80 kW (Das, Sasidharan, & Ray, Charging India's Bus Transport, 2019). Therefore, two cases have been developed to study the impact of e-buses. The first case considers bus charging with an 80-kW charger, as shown in **Figure 4**.

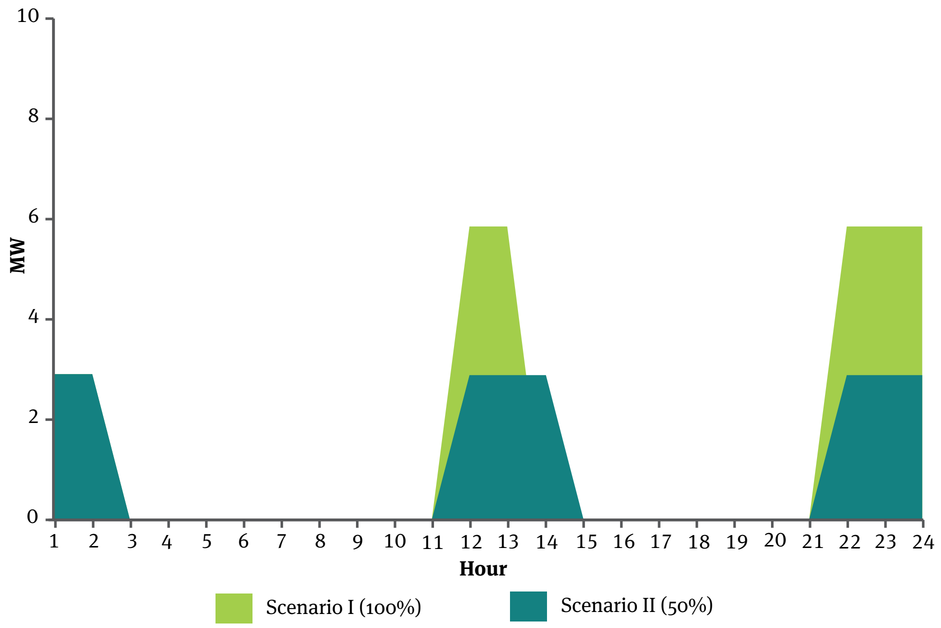


FIGURE 4: PROJECTED EV CHARGING LOAD CURVE FOR 100 E-BUSES USING SLOW CHARGERS

Source: AEEE analysis

In the second case, bus charging with a 100-kW charger has been modelled (**Figure 5**). The bus charging causes a sudden increase in the energy requirement and power demand at night in both cases, with maximum impact if all buses charge at the same time. However, peak power demand is highest at noon in Scenario I. Results show that the bus charging contribution to peak power demand is greatest with the fast charger, in both scenarios.

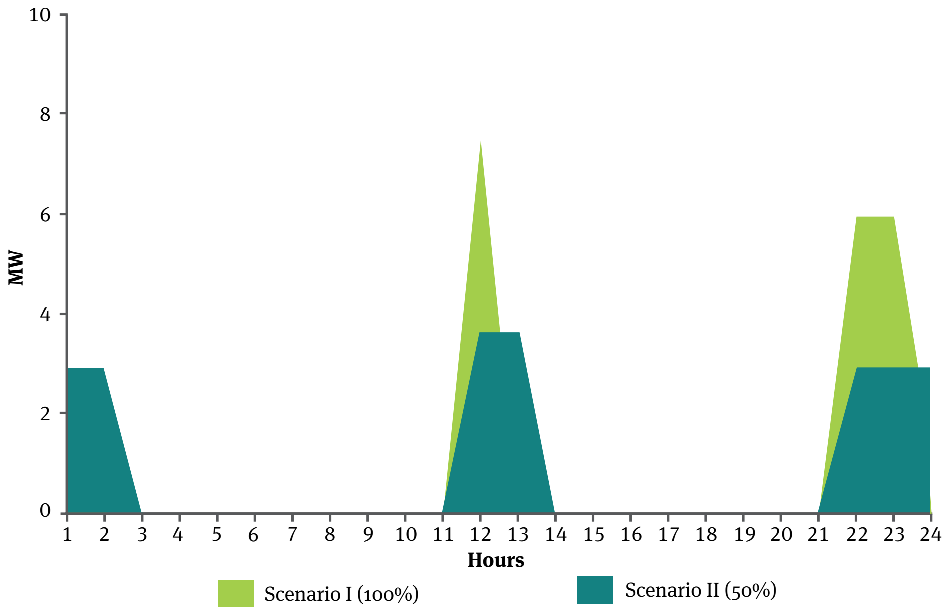


FIGURE 5: PROJECTED EV CHARGING LOAD CURVE FOR 100 E-BUSES USING FAST CHARGERS

Source: AEEE analysis

4.3.3 Impact on Delhi's Energy Requirement

The next step is to evaluate the impact of EV charging on the energy requirement for Delhi. To estimate the impact, an arbitrary day (other than the weekend or a holiday) in each season has been considered. This will help in assessing the seasonal impact of EV charging on the energy requirement. The impact on energy requirement is considered for an extreme situation where all EVs start charging at the same time, and every EV is charged at least once a day. The entire 24-hour energy requirement is divided into 4 slots of 6 hours each.

Figure 6, **Figure 7**, and **Figure 8** show the average and estimated daily energy requirement both pre and post EV adoption for the summer, monsoon, and winter, respectively. The results are based on the same EV mix as mentioned in **Subsection 4.3.1**. The graphs indicate that the increase in energy requirement in Delhi due to EV charging is marginal. The graphs also do not show any significant seasonal variation in energy requirement from EV charging. However, with an increase in EV penetration in Tier I cities, particularly metro cities, the impact on energy requirement could be significant.

A marginal increase is identified mainly in two slots: 12-6 PM and 6 PM-12 AM. This is primarily contributed by 4-Ws and e-buses, as most of the EV charging between 6 PM and 12 AM is happening at the captive and depot charging stations. The marginal increase in energy requirement from 12 to 6 PM is due to charging at PCS.

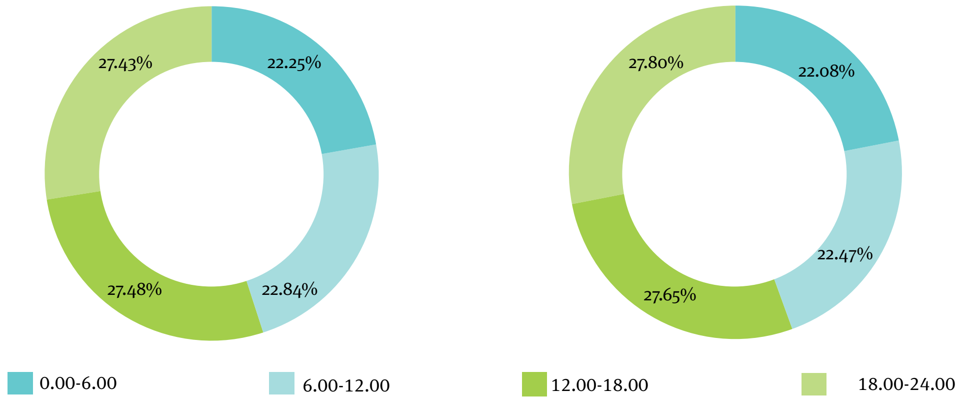


FIGURE 6: PRE AND POST EV ADOPTION: ESTIMATED AVERAGE DAILY ENERGY REQUIREMENT (MEGAWATT-HOUR (MWh)) IN SUMMER

Source: SLDC Delhi and AEEE analysis

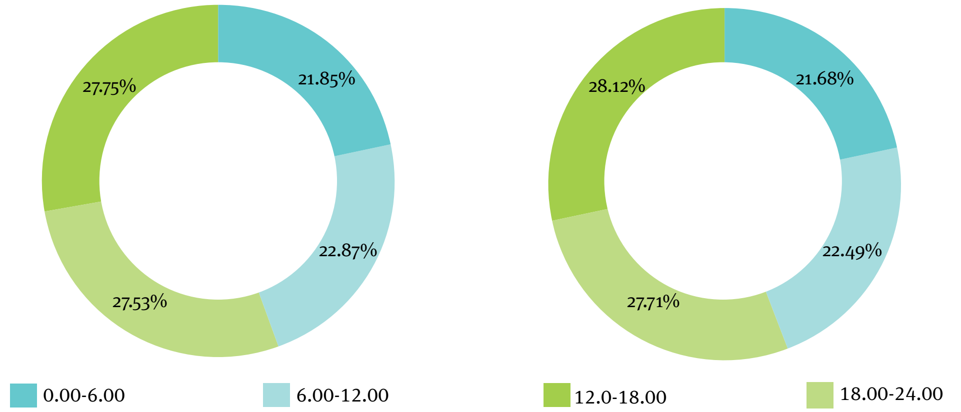


FIGURE 7: PRE AND POST EV ADOPTION: ESTIMATED AVERAGE DAILY ENERGY REQUIREMENT (MWh) IN MONSOON

Source: SLDC Delhi and AEEE analysis

FIGURE 8: PRE AND POST EV ADOPTION: ESTIMATED AVERAGE DAILY ENERGY REQUIREMENT (MWh) IN WINTER

Source: SLDC Delhi and AEEE analysis

4.3.4 Impact on Peak Power Demand and Energy Requirement in Delhi DISCOMs' Service Areas

In the case of Delhi, the impact on energy demand from EV charging is marginal, as discussed in **Subsection 4.3.3**. However, EVs may represent a significant addition to the load and energy requirement at the distribution level (Coignard, MacDougall, Stadtmueller, & Vrettos, 2019). Therefore, the next step is to evaluate the impact of EV charging on the peak power demand and energy requirement for each DISCOM. The full-day load profile of each DISCOM on an arbitrary day (other than the weekend or a holiday) has been considered for three seasons (summer, monsoon, and winter). The load curves reveal that all DISCOMs except DISCOM-I experience evening and night peak power demand in the summer, as well as during the monsoon. In the case of DISCOM-I, the peak power demand occurs mid-day in all seasons. In the winter, all DISCOMs except DISCOM-I experience morning and evening peaks. The impact of EV charging on the peak power demand and energy requirement due to the adoption of 10,000 EVs (which include 2-Ws, 3-Ws, and 4-Ws) and 100 e-buses is presented in **Figure 9**, **Figure 10**, **Figure 11**, and **Figure 12**.

In the case of energy requirement, the contribution from 4-W charging, both at PCS and captive charging stations, is the greatest. However, in the case of power demand, the contribution from e-bus charging is the greatest among the EV categories, followed by 4-Ws. This is primarily because of the significantly high battery capacities in e-buses. This also explains the sudden increase in the peak power demand around noon and at night, when e-bus charging starts. The impact of EV adoption is more significant in DISCOM-I than in other DISCOMs. This is primarily due to two reasons. First, DISCOM-I witnesses a mid-day peak, unlike the other DISCOMs; therefore, EV charging at PCS accentuates the peak during the day. Second, the amount of energy requirement in DISCOM-I is significantly lower than that in other DISCOMs. As a result, EV charging, even at a low adoption rate, could have a more significant impact on DISCOM-I. In the case of the other DISCOMs, the EV charging contribution at this EV adoption level constitutes only a marginal fraction of the total demand, and, thus, it is not visible in their load curves. The impact is marginal in all three seasons. However, it is important to note that as the EV adoption rate increases, EV charging could potentially add to the evening and night peaks experienced by all the DISCOMs (except DISCOM-I).

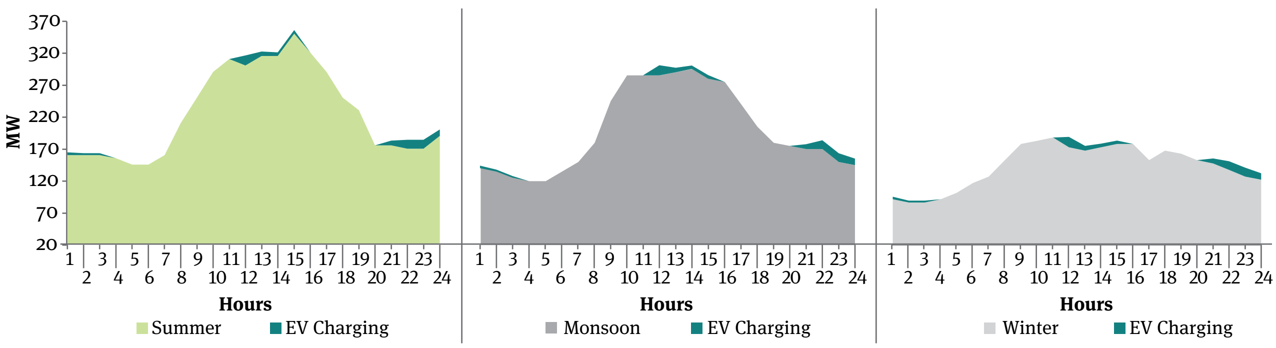


FIGURE 9: IMPACT OF EV CHARGING ON AVERAGE DAILY LOAD CURVE OF DISCOM-I

Source: SLDC Delhi and AEEE analysis

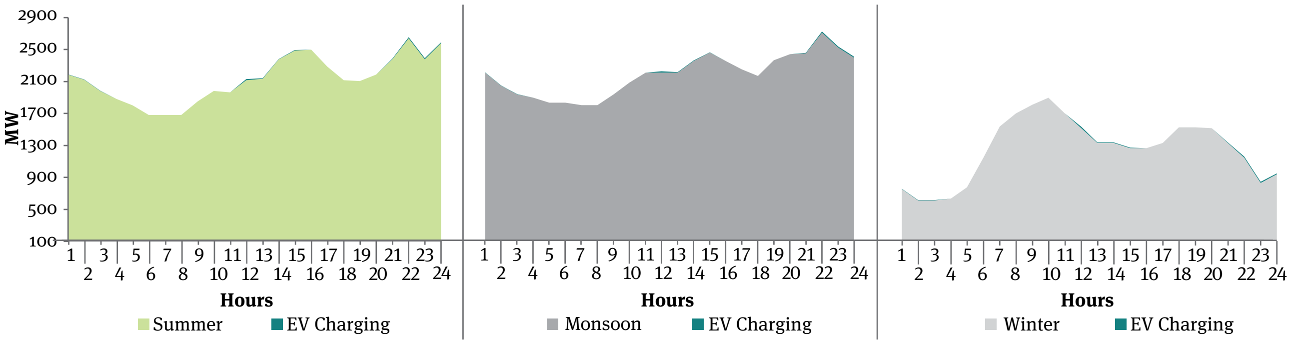


FIGURE 10: IMPACT OF EV CHARGING ON AVERAGE DAILY LOAD CURVE OF DISCOM-II

Source: SLDC Delhi and AEEE analysis

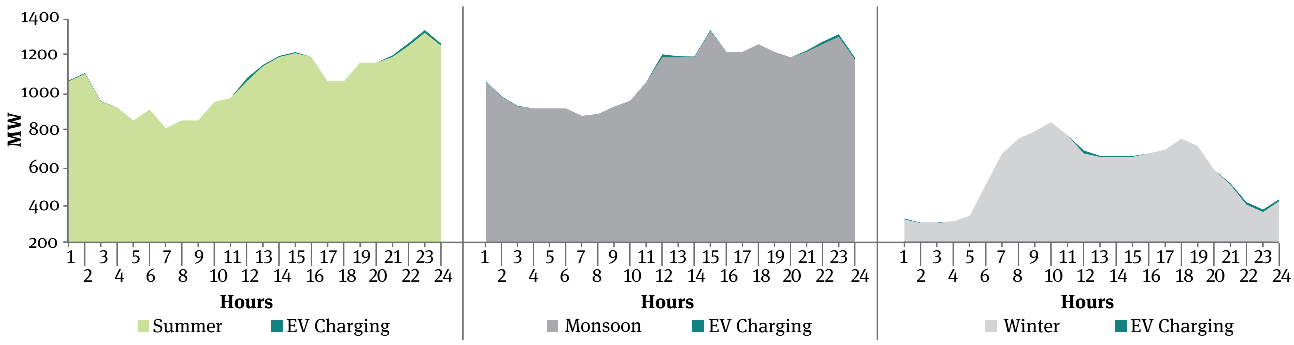


FIGURE 11: IMPACT OF EV CHARGING ON AVERAGE DAILY LOAD CURVE OF DISCOM-III

Source: SLDC Delhi and AEEE analysis

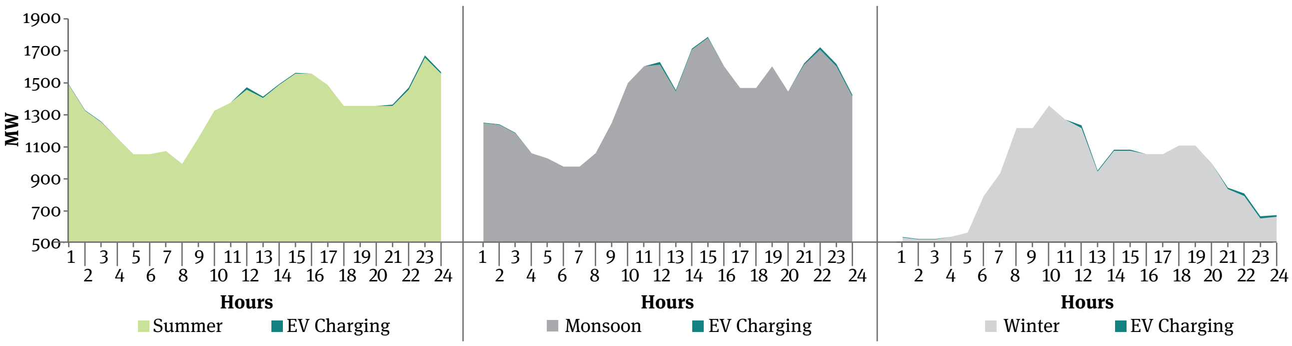


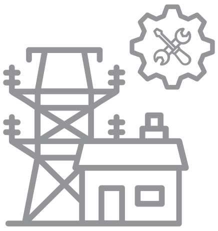
FIGURE 12: IMPACT OF EV CHARGING ON AVERAGE DAILY LOAD CURVE OF DISCOM-IV

Source: SLDC Delhi and AEEE analysis

4.3.5 Impact on DISCOM Cost of Supply in Delhi

After studying the impact of EV charging on the peak power demand and energy requirement of different DISCOMs in Delhi, the next step is to evaluate the impact on their CoS. As highlighted in the previous section, the impact of EV charging on the CoS of a DISCOM depends on the increase in the cost of power procurement vis-à-vis the increase in revenue from higher energy sales. The impact on the cost of power procurement will be contingent on the price at which additional energy is procured, i.e. the peak, off-peak, or average price. Due to data limitations, the spot market price for electricity on the Indian Energy Exchange (IEX) platform has been used to estimate the cost of additional power procurement[9]. As mentioned in the previous subsections, the impact of EV charging on DISCOMs is studied for a case of 10,100 EVs in each DISCOM area, where 100 are e-buses.

9 Due to lack of public data on available power for purchase from power plants and the scheduling in those power plants, it is difficult to estimate the marginal cost of power procurement on an hourly basis for a DISCOM.



The requirement for network upgradation would depend on the loading pattern of the existing network and the spare capacity available at the distribution transformer or feeder level.

Due to limited data availability, a few components of the ARR, such as REC, normative power banking, non-tariff income, transmission, and commercial losses, have been assumed to be constant (i.e. without any year-on-year change) while carrying out the analysis. As mentioned previously in **Section 4.2**, the study has not considered any increase in capital expenditure or O&M due to network augmentation and upgradation to cater to the additional demand from EV charging. The requirement for network upgradation would depend on the loading pattern of the existing network and the spare capacity available at the distribution transformer or feeder level. Investigating this aspect is beyond the scope of this study.

The analysis applies the compound annual growth rate (CAGR) to account for any escalation in power purchase cost, distribution losses, and pre-EV energy sales. In the case of distribution losses, the analysis maintains the threshold of 7% as the minimum level of line losses. Transmission charges are kept constant, as the CAGR is negative. Sensitivity is applied to the increase in energy sales from EV adoption over the years at the rate of 10%, 15%, and 20%, respectively.

Table 2 presents the impact on the CoS over 5 years due to EV adoption. The study evaluates the year-on-year (y-o-y) percentage change in CoS in comparison with post-EV adoption values of the preceding year. The results presented in the table are based on the assumption of a 15% y-o-y increase in EV energy sales. The investigation finds that for all the DISCOMs (except DISCOM-III), the CoS decreases marginally in Year 1 of the analysis period. In this initial year, the percentage increase in ARR is found to be less than the increase in energy sales, which results in a decrease in CoS. This is primarily due to the availability of surplus contracted power in Delhi DISCOMs, aided by an increase in revenue due to additional energy sales. Furthermore, EV charging is found to help fill valleys in the load curves of the DISCOMs in certain scenarios, thus improving the economics of electricity provision. It is interesting to note that among the DISCOMs, the decrease in CoS is the highest for DISCOM-I. This is primarily because the proportion of additional energy requirement from EVs is higher for DISCOM-I than for other DISCOMs, as mentioned in the previous subsection.

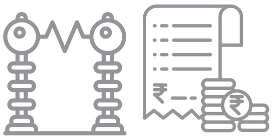
The analysis indicates that from Year 2 onwards, CoS starts increasing in the case of DISCOM-II and DISCOM-IV while, for DISCOM-III, the CoS starts increasing from the first year onwards. For DISCOM-I, the percentage change in CoS remains negative, but the margin decreases over the years. The percentage increase in ARR is found to be higher than the increase in energy sales, primarily because the CAGR of O&M is significantly higher in the case of DISCOM-II, DISCOM-III, and DISCOM-IV, compared to DISCOM-I. Furthermore, the proportionate contribution of EV charging to energy sales is greater in the case of DISCOM-I compared to other DISCOMs. It is notable that even if energy sales increase by 10% or 20%, there is no significant impact on the DISCOMs' CoS.

TABLE 2: IMPACT OF EV ADOPTION ON COST OF SUPPLY OVER 5 YEARS

DISCOM	Year 1	Year 2	Year 3	Year 4	Year 5
DISCOM-I	-1.84%	-1.57%	-1.26%	-0.89%	-0.47%
DISCOM-II	-0.52%	0.31%	1.26%	2.32%	3.48%
DISCOM-III	0.19%	1.87%	3.74%	5.75%	7.84%
DISCOM-IV	-0.18%	0.19%	0.60%	1.04%	1.51%

Source: AEEE analysis

It should be noted that the results from analysis of Delhi DISCOMs cannot be generalised for all DISCOMs across India. Hence, one should not conclude that CoS will always decrease in the case of other states or DISCOMs. EV impact on CoS is contingent on a number of varying DISCOM- and context-specific factors, including the availability of surplus power, rate of EV adoption, EV mix, and price at which additional power is procured by a DISCOM.



EV impact on CoS is contingent on a number of varying DISCOM- and context-specific factors, including the availability of surplus power, rate of EV adoption, EV mix, and price at which additional power is procured by a DISCOM.

Although the study finds that there could be a decrease or minor increase in the CoS of Delhi DISCOMs in a moderate EV penetration scenario, this does not imply that the impact would remain at this level if EV adoption accelerated in the city. Hence, it is important to examine a high EV penetration scenario and determine the level of penetration at which there would be a significant increase in CoS for DISCOMs in Delhi. In this regard, the study has estimated the number of EVs that would lead to a 10% increase in the CoS of individual DISCOMs in Delhi. **Table 3** shows the results in terms of total number of EVs and the vehicle mix for each DISCOM. The number of EVs corresponding to 10% increase in CoS would range from 0.10 million (in the case of DISCOM I) to 1.13 million (in case of DISCOM II). In terms of vehicle mix, the analysis indicates that 2-Ws would constitute the largest share in such a scenario. For example, the 2-W population could be as high as 0.79 million in case of DISCOM II. This resonates with the overall trend of 2-Ws and 3-Ws dominating in the EV sector in India (International Energy Agency, 2019).

TABLE 3: EV NUMBER CAUSING 10% INCREASE IN DELHI DISCOM CoS (IN MILLIONS)

DISCOM	2-W	3-W	4-W	e-bus	Total
DISCOM-I	0.07	0.02	0.01	0.0009	0.10
DISCOM-II	0.79	0.17	0.15	0.01	1.13
DISCOM-III	0.41	0.09	0.08	0.006	0.58
DISCOM-IV	0.37	0.08	0.07	0.005	0.53

Source: AEEE analysis

4.3.6 Discussion

The results of the case study are summarised as follows:

- In the case of PCS, the contribution of 4-Ws to peak power demand is greatest. However, in the case of home/captive charging, 2-Ws are the biggest contributors to an increase in power demand. Increase in the power and energy requirement due to EV charging is highest at night; however, the peak is observed around noon.
- E-bus charging also causes a sudden increase in the energy requirement and peak power demand at night, with maximum impact when all buses charge at the same time. The contribution of bus charging to peak power demand is highest when e-buses are charged with a fast charger, as opposed to a slow charger.
- At a moderate level of EV adoption, any increase in energy requirement in Delhi is expected to be negligible. There is no significant seasonal variation in energy requirement due to EV charging in the case of Delhi.
- A marginal increase in energy requirement is predicted mainly in two time slots: 12-6 PM and 6 PM-12 AM. This is primarily contributed by 4-Ws and e-buses.
- At the DISCOM level, the impact of EV adoption on the peak power demand and energy requirement is higher in the case of DISCOM-I, compared to the other DISCOMs. This is primarily due to two reasons. First, DISCOM-I witnesses a mid-day peak, unlike the other DISCOMs. Therefore, EV charging at PCS could accentuate the peak during the day. Second, the total amount of energy requirement in DISCOM-I is significantly lower than that in other DISCOMs.
- In the case of the other DISCOMs, the charging contribution is a marginal fraction of the total energy requirement, and, thus, the shares of EV charging are not visible in their load curves.
- For all the Delhi DISCOMs except DISCOM-III, CoS decreases with the adoption of EVs in the Year 1, due to the availability of surplus contracted power with the DISCOMs, aided by an increase in revenue due to additional energy sales. However, the decrease in CoS is marginal.
- The decrease in CoS is greatest for DISCOM-I.
- CoS is predicted to decrease initially for all the Delhi DISCOMs except DISCOM-III, due to EV charging, and is then expected to start increasing. The increase in CoS may be more delayed in the case of DISCOM-I, because its O&M CAGR is significantly lower. Moreover, the proportionate contribution of EV charging to energy sales is greater in the case of DISCOM-I, compared to the other DISCOMs.
- Overall, it is difficult to generalise the results and assume that the CoS will decrease in the case of DISCOMs in other states as well. This will be contingent on the availability of surplus power, level of EV adoption, EV mix and charging patterns, and price at which additional power is procured by the respective DISCOMs.
- To cause a 10% increase in CoS, 0.10 million EVs would be needed in the case of DISCOM I, compared to 1.13 million in the case of DISCOM II. Among EV categories, the share of 2-Ws would remain the highest in this scenario, followed by 3-Ws.

5. Current EV Tariff Scenario in India

This section discusses the EV-specific tariff rates in different states and UTs, draws key learnings from the existing tariff structures, and highlights the crucial considerations for formulating EV tariff frameworks in India. The key questions examined in this section are:

- Which states have introduced electricity tariffs for EVs?
- How are EV tariffs categorised in the tariff orders by different states and UTs?
- Do EV tariffs vary between high-tension (HT) and low-tension (LT) connections?
- Have the states and UTs introduced demand charges for EV charging?
- How do the energy charges vary across different states and UTs?
- Are there ToD or ToU tariffs for EV charging in different states and UTs?

5.1 State-specific EV tariffs

Following the clarification issued on 13th April 2018 by the MoP regarding the delicencing of the EV charging activity, a handful of states, such as Delhi, Haryana, Karnataka, and Maharashtra, announced EV-specific tariff rates (Ministry of Power, 2018). However, at that time, there was no specific direction or guidelines concerning tariff determination for EV charging. The set of guidelines entitled "Charging Infrastructure for Electric Vehicles – Guidelines and Standards -reg." first issued on 14th December 2018 by MoP and last amended on 8th June 2020 specify that the tariffs should not exceed the ACoS by 15%, and allow for domestic charging at the tariffs applicable for domestic consumption [(Ministry of Power, 2018); (Ministry of Power, 2019); (Ministry of Power, 2020)]. Several states, such as Andhra Pradesh, Uttar Pradesh, and Telangana, announced EV-specific tariffs, keeping the 14th December MoP guidelines as a basis for the tariffs.

Tariff-setting for DISCOMs in India is a state subject i.e. the SERC in each state is responsible for determining tariffs for different consumer categories. However, the National Tariff Policy remains the overarching guidance for the SERCs on fixing tariffs. This policy, in contrast to the MoP guidelines on EV charging, specifies that consumer tariffs should be brought within ± 20% of the ACoS. In the context of India's cross-subsidy tariff regime, this essentially means that the subsidised consumers should not be charged less than 80% of ACoS, and the tariffs for the cross-subsidising consumers should not exceed 120% of ACoS. Traditionally, domestic and agricultural consumers are the beneficiaries of subsidies, whereas commercial and industrial consumers cross-subsidise the beneficiaries by paying more than ACoS. However, the state governments have the discretion to also offer a subsidy to a class of consumers, and in such cases, the governments have to make the subsidy amounts available to the distribution licencees upfront. With the addition of EVs as a new set of consumers, it is interesting to see whether the different regulators and the state governments offer preferential tariffs for EV charging to promote EV adoption, consider EV charging on an equal footing with commercial consumers, or take a neutral stance. This warrants a closer look at the EV charging tariffs currently applicable in different states. **Table 4** gives a snapshot of the state-wise tariffs (energy charges, demand charges, ToD rates, etc.) for EV charging at PCS, as on 11th November 2019.

Tariff-setting for DISCOMs in India is a state subject i.e. the SERC in each state is responsible for determining tariffs for different consumer categories.

TABLE 4: DETAILS OF EV-SPECIFIC TARIFFS INTRODUCED BY DIFFERENT STATES AND UTs

Issuing Agency	State/ UT	Tariff			Year	Remarks (if any)
		Energy Charge	Fixed/Demand Charge	ToD Surcharge or Rebate		
AERC	Assam	**LT EV Charging Stations** • ₹ 5.4/kWh **HT EV Charging Stations** • ₹ 6.9/kWh	**LT EV Charging Stations** • ₹ 120/kVA/ month **HT EV Charging Stations** • ₹ 160/kVA/ month	Not specified	Fiscal Year (FY)20	• Created separate category for PCS • Consumers can charge their EVs at their respective premises and pay the charge applicable as per the consumer category.
APERC	Andhra Pradesh	**FY19** **LT: II (C) Non-Domestic** • ₹ 6.95/kWh **HT Category-II(E): EVs / Charging Stations** • ₹ 5.95/ kVAh **FY20** LT: ₹ 5/kWh HT: ₹ 5/kVAh	Not specified	**FY19** **LT & HT** • Peak: Tariff for usage from 6 AM to 10 AM and 6 PM to 10 PM: ₹ 8/kWh • Off-peak: Tariff for usage from 10 PM to 6 AM: ₹ 5.95/kWh **FY20** • NO ToD charges	FY19 & FY20	• Created new sub-category under LT non-domestic and HT category • DISCOMs have also set up charging stations for EVs, to be expanded gradually • To encourage EV adoption, APERC reduced the tariff from the proposed ₹ 5.95 with ToD charges to ₹ 5.00 per unit and removed the ToD charges for EVs / charging stations.
BERC	Bihar	• Same tariff for EVs as the respective category rate	Not specified	Not specified	FY20	• No new category created • Consumers getting electricity supply under regulated tariff categories may use the electricity supply for EV charging and pay the charge applicable for the respective category
CSERC	Chhattisgarh	**LV[10]-2 (Non-Domestic)** • ₹ 5/kWh **HV[11]-3 (Other Industrial and General Purpose Non-Industrial)** • ₹5/kWh	Not specified	• ToD applies to HV-2, HV-3, and HV-4 tariff categories • Peak (6 PM to 11 PM): Surcharge of 20% • Off-peak (11 PM to 5 AM): Rebate of 25%	FY20	

10 Low-Voltage

11 High-Voltage

Issuing Agency	State/ UT	Tariff			Year	Remarks (if any)
		Energy Charge	**Fixed/Demand Charge**	**ToD Surcharge or Rebate**		
DERC	Delhi	**Charging Stations for E-rickshaw/E-vehicle on single-point delivery** • LT: ₹ 4.5/kWh • HT: ₹ 4.0/kVAh • If charging at premises other than designated stations, tariff applicable as per relevant consumer category	Not specified	• Applicable to consumers with load above 10kW/ kVA • Surcharge or rebate of 20% in case of peak and off-peak hours • May-September: Peak hours: 2-5 PM & 10 PM-1 AM • Off-peak hours: 4-10 AM	FY20	• Created separate category for PCS • Other surcharges applicable
GERC	Gujarat	**LT EV Charging Stations** • ₹ 4.1/kWh **HT EV Charging Stations** • ₹ 4/kWh	**LT EV Charging Stations** • ₹ 25 per month per installation **HT EV Charging Stations** • For billing demand up to contract demand: ₹ 25/ kVA/ month • Above contract demand: ₹ 50/ kVA/month	Not specified	FY20	• Created separate category for PCS • Consumers also required to pay Fuel and Power Purchase Price Adjustment (FPPPA) charges as applicable from time to time
HERC	Haryana	**Bulk Supply** • LT Supply: ₹ 6.2/ kWh • HT Supply: ₹ 5.58/ kVAh	**Bulk Supply** • ₹ 100/kW/ month	Not specified	FY20	• No new category created
HPERC	Himachal Pradesh	**Non-Domestic Non-Commercial Supply** • Up to 20 kVA: ₹ 5/ kWh • Prepaid meter: ₹ 4.9/kWh • Above 20 kVA: ₹ 4.7/kWh	**Non-Domestic Non-Commercial Supply** • Up to 20 kVA: fixed charge ₹ 130/ connection/ month • Above 20 kVA: demand charge ₹ 140/ kVA/ month	Not specified	FY20	• Added EVs under existing Non-domestic non-commercial category • HPERC approved the applicability of Non-Domestic Non-Commercial Supply (NDNC) Tariff category for Electric Charging Stations for e-buses.

Issuing Agency	State/ UT	Tariff			Year	Remarks (if any)
		Energy Charge	Fixed/Demand Charge	ToD Surcharge or Rebate		
JERC	Goa	**Public Charging Stations** • ₹ 4.2/kWh Other Categories • Tariff for domestic consumption applicable for domestic charging (LT/HT)	**Public Charging Stations** • ₹ 100/kW/ month	Not specified	FY20	• Created separate category for PCS
JERC	Chandigarh	**Public Charging Stations** • ₹ 4/kWh **Other Categories** • Tariff for domestic consumption applicable for domestic charging (LT/HT)	**Public Charging Stations** • ₹ 100/kW/ month	Not specified	FY20	• Created separate category for PCS
JERC	Andaman and Nicobar Islands	**Public Charging Stations** • ₹ 6.89/kWh **Other Categories** • Tariff for domestic consumption applicable for domestic charging (LT/HT)	**Public Charging Stations** • ₹ 100/kW/ month	Not specified	FY20	• Created separate category for PCS
JERC	Daman and Diu	**Public Charging Stations** • ₹ 4/kWh **Other Categories** • Tariff for domestic consumption applicable for domestic charging (LT/HT)	**Public Charging Stations** • ₹ 100/kW/ month	Not specified	FY20	• Created separate category for PCS
JERC	Lakshadweep	**Public Charging Stations** • ₹ 4.76/kWh **Other Categories** • Tariff for domestic consumption applicable for domestic charging (LT/HT)	**Public Charging Stations** • ₹ 100/kW/ month	Not specified	FY20	• Created separate category for PCS

Issuing Agency	State/ UT	Tariff			Year	Remarks (if any)
		Energy Charge	Fixed/Demand Charge	ToD Surcharge or Rebate		
JERC	Puducherry	**Public Charging Stations** • ₹ 5.2/kWh **Other Categories** • Tariff for domestic consumption applicable for domestic charging (LT/HT)	**Public Charging Stations** • ₹ 200/kW/ month	Not specified	FY20	• Created separate category for PCS
JSERC	Jharkhand	**Commercial Category** • Rural: ₹ 6/kWh • Urban: ₹ 6.25/ kWh	**Commercial Category** • Rural: ₹ 40/ connection/ month • Urban: ₹ 150/ connection / month	Not specified	FY20	• No new category created. Classified under the commercial category
KERC	Karnataka	**LT6: Water Supply and Street Light Installation** • EV Charging Stations • LT & HT: ₹ 5.00/ kWh	**LT6: Water Supply and Street Light Installation** • EV Charging Stations • LT: ₹ 60/kW/ month • HT: ₹ 190/kVA/ month	Not specified	FY20	• Created new sub-category of PCS for both HT and LT under Water Supply and Street Light Installation category • Mandatory ToD Tariff for HT2 (a), HT-2(b), & HT2(c) consumers with contract demand of 500 KVA and above
KSERC	Kerala	**LT EV Charging Stations** • ₹ 5.00/kWh **HT EV Charging Stations** • ₹ 5.00/kWh	**LT EV Charging Stations** • ₹ 75/kW/month **HT EV Charging Stations** • ₹ 250/kVA/ month	**HT EV Charging Stations** • 50% surcharge during peak hours from 6 PM to 10 PM- and 25% rebate during off-peak hours from 10 PM to 6 AM	FY20	• Created separate category for PCS

Issuing Agency	State/ UT	Tariff			Year	Remarks (if any)
		Energy Charge	Fixed/Demand Charge	ToD Surcharge or Rebate		
MERC	Maharashtra	**LT EV Charging Stations:** • LT: ₹ 5.06/ kWh **HT EV Charging Stations** • HT: ₹ 5.06/ kWh	**LT EV Charging Stations:** • ₹ 70/kVA/ month **HT EV Charging Stations** • ₹ 70/kVA/ month	**LT & HT EV Charging Stations** • Additional charge of ₹ 0.80 / kWh levied for usage from 9 AM to 10 AM and ₹ 1.1/ kWh from 6 PM to 10 PM. • Rebate of ₹ 1.50 / kWh for usage between 10 PM and 6 AM	FY20	• Created new sub-category under HT and LT • Wheeling Charges • LT: ₹ 0.94/kWh • HT: ₹ 0.94/kWh
MPERC	Madhya Pradesh	**LV (EV/ E-rickshaw) Charging Stations** • ₹ 6/kWh **HV (EV/ E-rickshaw) Charging Stations** • ₹ 5.9/kWh	**LV (EV/ E-rickshaw) Charging Stations** • ₹ 100/kVA or 125/kW of Billing Demand **HV (EV/ E-rickshaw) Charging Stations** • ₹ 120/kVA of Billing Demand	Not specified	FY20	• New tariff category introduced under LV and HV
OERC	Odisha	**LT Category:** GP >=110 kVA (General Purpose) • ₹ 5.7/kWh **HT Category:** GP >=110 kVA • <= 60%: ₹ 5.35/ kWh • > 60%: ₹ 4.25/ kWh **EHT Category** • <= 60%: ₹ 5.3/ kWh • > 60%: ₹ 4.2/kWh	**LT Category:** GP >=110 kVA • ₹ 200/kW or kVA/ month **HT Category:** GP >=110 kVA • ₹ 250/kW or kVA/ month **EHT Category** • ₹ 250/kW or kVA/ month	Not specified	FY20	• EV charging treated as GP category if vehicle charged is owned by the concerned consumer

Issuing Agency	State/ UT	Tariff			Year	Remarks (if any)
		Energy Charge	**Fixed/Demand Charge**	**ToD Surcharge or Rebate**		
PSERC	Punjab	**Non-Residential Supply** • Electric Vehicle Charging Stations: ₹ 6/ kVAh	Not specified	Not specified	FY20	• Created new sub-category under LT non-residential supply
TSERC	Telangana	**LT EV Charging Stations** • ₹ 6.00/kWh **HT EV Charging Stations** • ₹ 6.00/kWh	Not specified	ToD applicable for HT • Peak hours: 6 AM to 10 AM and 6 PM to 10 PM: ₹ 7/ kWh • Off-peak hours: 10 PM to 6 AM: ₹ 5/ kWh	FY19	• Created new sub-category under HT and LT
UPERC	Uttar Pradesh	**Domestic** • Tariff as per rate schedule provided EV load does not exceed sanctioned load **Multi-Storey Buildings** • LMV-1b: ₹ 6.20/ kWh • HV-1b: ₹ 5.90/ kWh **Public Charging Stations** • LT Supply: ₹ 7.7/ kWh • HT Supply: ₹ 7.3/ kWh **Other Consumers** • Tariff as per rate schedule provided EV load does not exceed sanctioned load	Not specified	Public Charging Stations • 15% surcharge or rebate during peak and off-peak hours • Peak hours for summer and winter months from 5 PM to 11 PM • Off-peak hours for summer and winter months from 5 AM to 11 AM and 11 PM to 5 AM, respectively	FY19	• Created separate category for PCS • For multi-storey buildings, need to take separate connection for EV charging • UPERC initiated the process Suo moto for EV tariffs • Consumer required to pay one-time charge wherever applicable • Penalty in case of breach of sanctioned load

Source: Tariff orders of respective states and UTs for 2018-19 and 2019-20

*Note: * The information in the table is as on November 11, 2019.*

*** There is no distinction between demand and fixed charges in tariff orders in India.*

5.2 Salient Features of the Tariff Framework across India

Electricity regulators in eighteen states and five UTs have already stipulated specific rates for EV charging in their respective tariff orders through November 11, 2019 (**Figure 13**). However, the recognition of EVs as a consumer category in tariff orders varies from state to state. Some states, e.g. Goa, and UTs have introduced a separate category called Public EV Charging Stations, which is distinct from existing consumer categories. Other states (e.g. Andhra Pradesh, Chhattisgarh, and Punjab) have specified EV tariffs under existing categories, such as the non-domestic or non-commercial categories. Jharkhand is the only state that has introduced EV tariffs under the commercial category. A few states (Andhra Pradesh, Delhi, Gujarat, Maharashtra, Uttar Pradesh, etc.) have also specified tariffs for EV charging stations by type of connection (HT/LT). Such categorisation of EV-specific tariff rates affects the viability of EV charging businesses.

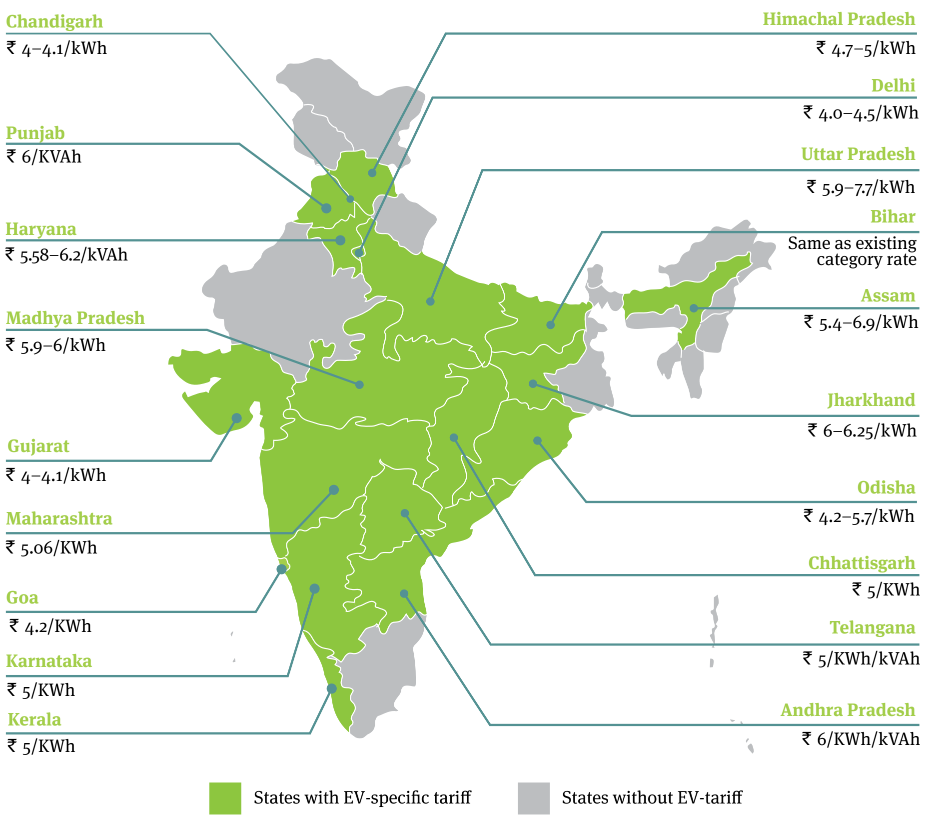


FIGURE 13: MAP OF STATES WITH AND WITHOUT EV-SPECIFIC ENERGY CHARGE [12]

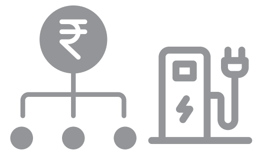
Source: AEEE analysis, based on state and UT tariff orders from FY19 & FY20

Electricity tariffs generally have two parts – Fixed/ Demand Charge and Variable/ Energy Charge. A few states have introduced demand charges: Gujarat (₹ 25 per month/installation for LT and ₹ 25-50/kVA/month for HT), Haryana (₹ 160/kW or 160/kVA), Karnataka (₹ 60/kW/month for LT and ₹ 190/kVA/month for HT), among others. The Joint Electricity Regulatory Commission (JERC) has announced a demand charge of ₹ 100/kW/month for Goa and UTs, including Andaman & Nicobar Islands, Chandigarh, Daman & Diu, and Lakshadweep. Regulatory commissions in some states, such as Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Punjab, Uttar Pradesh, and

12 Information as on November 11, 2019

Telangana, have introduced a single part tariff with no demand charge to incentivise EV adoption.

On the other hand, state regulatory commissions have introduced flat rates for energy charges, which vary depending on the type of electricity connection. Presently, LT energy charges vary from ₹ 4.1/kWh in Gujarat to ₹ 7.7/kWh in Uttar Pradesh. HT energy charges vary from ₹ 4/kVAh in Gujarat to ₹ 7.3/kVAh in Uttar Pradesh. The Bihar Electricity Regulatory Commission (BERC) is the only commission that has the same energy charge for both LT and HT connections for EV charging. Jharkhand announced separate tariffs for rural and urban consumers under the commercial category – ₹ 6/kWh and 6.25/kWh, respectively, which are applicable for EV charging. In the case of Andhra Pradesh, Andhra Pradesh Electricity Regulatory Commission (APERC) made a significant change to its EV tariff structure from FY19 to FY20. Initially, APERC introduced different HT and LT tariff rates - ₹ 5.95/kWh and ₹ 6.95/kWh, respectively, for FY19. They also specified ToD rates for FY19. However, in FY20, APERC introduced a single part flat tariff for both HT and LT connections and removed ToD charges to encourage EV adoption. In addition to energy and demand charges, other surcharges, such as Late Payment Surcharge (LPSC), Power Purchase Adjustment Cost (PPAC), etc., are also applicable to EV charging in most states. Maharashtra also specified wheeling charges of ₹ 0.94/kWh for both LT and HT EV charging stations.



In India, there are only three regulatory commissions UPERC, KSERC, MERC that have introduced ToD rates specifically for EV charging.

As discussed in Section 3.4, ToD and ToU rates have been successfully used in other countries to incentivise consumers to shift their charging time to off-peak hours. In India, there are only three regulatory commissions (Uttar Pradesh Electricity Regulatory Commission (UPERC), Kerala State Electricity Regulatory Commission (KSERC), and Maharashtra Electricity Regulatory Commission (MERC)) that have introduced ToD rates specifically for EV charging. In the case of Delhi, ToD rates are applicable to consumers with a load above 10kW/kVA, including EV consumers. DERC has specified a ToD 20% surcharge and rebate for peak and off-peak hours, respectively. Similarly, ToD rates are applicable by default to EV consumers with HT connections in the case of Chhattisgarh and Telangana. In Chhattisgarh, a 20% surcharge and 25% rebate apply to the HV consumer category; in Uttar Pradesh, the surcharge and rebate rate is 15 percent. ToD rates are applicable in Kerala for HT PCS at a surcharge of 50% for peak hours and a rebate of 25% for off-peak hours. In contrast to Chhattisgarh, Delhi, and Uttar Pradesh, Maharashtra has stipulated absolute amounts of surcharge and rebate per kWh, instead of a percentage. They levy an additional charge of ₹ 0.80 / kWh for usage from 9 AM to 10 AM and ₹ 1.1/kWh from 6 PM to 10 PM. They also offer a rebate of ₹ 1.50/kWh for usage between 10 PM and 6 AM. Similarly, Telangana levies a surcharge of ₹ 1/kWh for usage between 6 AM and 10 AM and 6 PM and 10 PM and offers a rebate of ₹ 1/kWh for usage between 10 PM and 6 AM.

The salient features of the tariff structures observed across Indian states and UTs are summarised below:

Energy Charge

- Flat tariff rates have been introduced by state and UT regulatory commissions.
- Energy charges vary between LT and HT connections:
    - LT energy charges vary from ₹ 4.1/kWh in **Gujarat** to ₹ 7.7/kWh in **Uttar Pradesh**

    - HT charges vary from ₹ 4/kVAh in **Gujarat** to ₹ 7.3/kVAh in **Uttar Pradesh**
- In the case of **Bihar**, unlike other states, the respective category's tariff would be applicable for the electricity consumed for EV charging.
- **Jharkhand** has introduced separate tariffs for rural and urban consumers under the commercial category.
- **Maharashtra** is the only state that has specified wheeling charges for EV charging (₹ 0.94/kWh for both LT and HT)

Demand Charge

- A few states and UTs have announced demand charges for EV charging stations:
    - **Maharashtra** (₹ 70/kVA/month)
    - **Karnataka** (₹ 60/kW/month for LT and ₹ 190/kVA/month for HT)
    - **Haryana** (₹ 160/kW/month or 160/kVA/month)
    - **Gujarat** (₹ 25 per installation for LT and ₹ 25-50/kVA/month for HT)
    - **Madhya Pradesh** (₹ 100/kVA/month for LV and ₹ 120/kVA/month for HV)
    - **Goa** (₹ 100/kW/month)
    - **Chandigarh, Andaman and Nicobar Islands, Lakshadweep, and Daman and Diu** (₹ 100/kW/month)
    - **Puducherry** (₹ 200/kW/month)
- On the other hand, states such as Delhi, Andhra Pradesh, Uttar Pradesh, Bihar, Punjab, Chhattisgarh, and Telangana announced no demand charge, to boost EV adoption.

EV-specific ToD/ ToU rates

- Three regulatory commissions (UPERC, MERC, and KSERC) introduced ToD rates specifically for EV consumers (see **Table 5**):
    - **Uttar Pradesh**: 15% surcharge and rebate
    - **Maharashtra**:
        - Surcharge (₹ 0.80/ kWh for usage from 9 AM to 10 AM and ₹ 1.1/ kWh from 6 PM to 10 PM)
        - Rebate (₹ 1.50/kWh for usage between 10 PM and 6 AM)
    - **Kerala**:
        - Surcharge (50% for usage from 6 PM to 10 PM)
        - Rebate (25% for usage from 10 PM to 6 AM)
    - There are a few SERCs where ToD rates are applicable by default for EV consumers.
    - **Delhi** – ToD rates applicable to consumers with load >= 10kW/kVA, with 20% surcharge and rebate
    - Telangana- ToD applicable to HT consumers, with surcharge and rebate at ₹ 1/kWh
    - Chhattisgarh- ToD applicable to HV consumers, with 20% surcharge and 25% rebate
- After introducing ToD rates in FY19, APERC removed them in FY20 to encourage EV adoption. In the FY20 tariff order, the state introduced a single part flat tariff for both HT and LT consumers in FY20.

TABLE 5: STATES WITH ToD RATES APPLICABLE FOR EV CHARGING

Issuing Agency	State	ToD Hours		ToD Rate (₹/kWh or % of usage)	
		Peak Hours	Off-peak Hours	Surcharge	Rebate
MERC	Maharashtra	9 to 10 AM and 6 to 10 PM	10 PM to 6 AM	₹ 0.80/kWh	₹ 1.50/kWh
TSERC	Telangana	6 to 10 AM and 6 to 10 PM	10 PM to 6 AM	₹ 1/kWh	₹ 1/kWh
UPERC	Uttar Pradesh	5 to 11 PM	5 to 11 AM and 11 PM to 5 AM	15%	15%
KSERC	Kerala	6 to 10 PM	10 PM to 6 AM	50%	25%
DERC	Delhi	2 to 5 PM and 10 PM to 1 AM	4 to 10 AM	20%	20%
CERC	Chhattisgarh	6 to 11 PM	11 PM to 5 AM	20%	25%

Source: Tariff orders of respective states for 2018-19 and 2019-20

It is evident from the analysis that every state follows a different approach for setting tariffs for EV charging. Based on the analysis of the existing scenario, the key considerations relevant to EV tariff framework development are discussed in the next sub-section.

5.3 Key Considerations for EV Tariff Framework

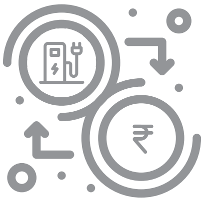
The tariff landscape in India is very complex and diverse. As shown in the previous section, almost all states have unique tariff structures for EV charging. Furthermore, within just one year of introducing separate tariffs for EV charging, some states made changes to the EV tariff structures, which could be due to their evolving understanding of this new consumer category. DISCOMs and regulators are trying to figure out the characteristics of this new consumer category, which is not a straightforward exercise. EV charging is distinct from other types of consumer categories, because of the following three key aspects:

1. **Mobile source of electricity requirement:** Unlike the other consumer categories, such as residential, commercial, and industrial, EVs are mobile sources of electricity requirement. Although the charging points of EVs are stationary, the electricity and power demand at the charging places could be very dynamic and, at least in the initial days, very unpredictable. This will have a dynamic impact on network/connection points, due to spatial variability. As a result, network planning/augmentation will have to factor in this diversity of loading on the network at different points, as well as variation at different times.

2. **Uneven load:** Utilities and load dispatch centres are more accustomed to managing smooth load curves with minimal peaks and valleys. Electricity grid stability is vulnerable to sudden load changes, which may cause power failures at local (division), zonal, state, and sometimes regional or national levels. As EV charging loads at charging points are anticipated to be very dynamic, with spikes in the demand curve, there is serious concern regarding the impact on the distribution network, especially in distribution areas with low available hosting capacity. Fast charging of heavy-duty EVs with large batteries is envisaged to have the maximum impact on the load curve and distribution network.

3. **Bi-directional energy flow:** EVs are more than a consumer; they are a potential distributed energy resource, too. Batteries, as the core of EVs, can be effectively leveraged to feed electricity back into grid using V2G functionality when the DISCOM faces a supply constraint. An analogy can be made with a prosumer such as a building with a rooftop solar plant and net metering facility, where the connection can draw from the grid, as well as feed electricity into it. Hence, appropriate metering and tariff-setting would be required to enable the application of EVs as Virtual Power Plants (VPPs). However, for the purposes of this study, in examining the EV charging tariff framework, EVs are solely considered as consumers.

Regulators have to take these factors into account when framing the tariff schedule.



From the review of the EV charging tariff schedules across various states and UTs and the latest literature, this study has identified five key areas that warrant special consideration.

From the review of the EV charging tariff schedules across various states and UTs and the latest literature, this study has identified five key areas that warrant special consideration and appeals to regulators and policymakers to provide more clarity regarding these aspects, which would help potential investors in the EV charging space in decision-making.

1. **Categorisation of EV charging in the tariff schedule:** Presently, the SERCs have differing views on recognising EV charging as a consumer category. It is currently categorised as non-residential, commercial, non-industrial, or bulk supply. In some states or UTs, a separate category has been created for PCS. Against this backdrop, key questions arise: Will the differing nomenclatures create confusion for EV owners and charging service providers? Should there be a uniform categorisation of EV charging as a consumer category? Such categorisation of EV charging has an implication on its tariff schedule and, in turn, impacts the commercial viability of EV charging businesses, since rates under the commercial category are generally significantly higher than in the residential or domestic category. It is therefore important to provide potential EV customers clear electricity price signals.

2. **Applicability of EV charging tariffs[13]:** As on 11th November 2019, eighteen states and five UTs have introduced separate tariffs for EV charging. However, the applicability of these tariffs is not clear. Tariff orders in different states have used different nomenclatures to refer to EV charging, which are not well defined. It is unclear, for example, whether the special EV charging tariffs would be applicable for charging public e-buses or charging EVs in public parking areas managed by different types of entities. The guidelines and standards issued by MoP, both on 14th December 2018 and 1st October 2019, are also quite vague about this [(Ministry of Power, 2018); (Ministry of Power, 2019)].

3. **Application of demand charge:** The primary impact of EV charging on a DISCOM's CoS and its distribution network comes from the power demand at a public EV charging station. Although the overall load curve of a DISCOM may remain unaltered even when there is a sizeable number of EVs on the road, spikes in power demand due to EV charging can be expected, which may have the following ramifications:

13 Another critical factor is the long-term certainty of tariff design for EV charging, i.e. whether SERCs are determining year-to-year tariffs or tariffs for the entire control period (3 years or 5 years). This knowledge could offer great stability/regulatory certainty to investors and EV charging service providers and aid them in their decision-making. However, the report has not explored this issue, as most states recently introduced tariffs for EV charging, but this could be investigated in future studies.

- **Creation of momentary gaps between actual power demand and the contracted power of the DISCOM**: To meet this power demand, the DISCOM may have to purchase power on the spot market, which could be expensive. This would drive up the power purchase cost of the DISCOM. The other apprehension is that the DISCOM may resort to load shedding, which is not a rare occurrence in India.
- **Surge in EV power demand exceeding the system capacity of a feeder**: This would have a serious negative effect on the stability of the distribution grid and could cause power cuts at the local level, requiring the DISCOM to make a significant investment in grid augmentation beyond periodic capacity improvement.

The primary instrument at the DISCOM's disposal to tackle surges in EV power demand is the demand charge. However, the demand charge needs to be appropriately designed to make charging service provision a viable business opportunity for investors and avoid making EV adoption unattractive for potential EV users.

4. **Introduction of ToD tariffs:** ToD tariffs, i.e. a surcharge during peak hours and rebate during off-peak hours throughout the day, are an effective tool for a DISCOM to flatten the load curve. Depending on the time-pattern of EV charging, the charging load can potentially accentuate the peak power demand within a DISCOM's service area. As seen in the existing tariff framework, ToD tariffs are applicable for industrial and commercial consumers during certain months in most states, in order to shift the load to off-peak hours. As EV charging demand is anticipated to rise, it is important to consider the need to introduce, as well as how to design, ToD tariffs for EV charging. Understanding the EV charging patterns is critical for this, but it is challenging at present, in the absence of discernible charging demand in a DISCOM's licence area.
5. **Applicability of taxes and PPAC[14]:** In many states, taxes (sometimes cess), non-tariff surcharges, and PPAC are included on top of the tariff amount in the final billable amount to an electricity consumer. Following similar bill structure, taxes and other charges are expected to be applicable for EV charging connections; however, there is currently a lack of clarity regarding their applicability to EV charging tariffs.

14 Apart from tariff design, the setting of "Service Connection Charges" is another important topic to explore. This aspect is governed by the Supply Code provisions of respective states and has not been studied in this report.

6. Framework for Determining Appropriate EV Tariffs

This section sheds further light on the five key considerations highlighted in **Section 5.3** and provides recommendations on the key elements of the EV tariff framework considering the feedback from stakeholders in the e-mobility ecosystem.

6.1 Stakeholder Perspectives

EV tariffs have different implications for different stakeholders in the e-mobility ecosystem.

EV tariffs have different implications for different stakeholders in the e-mobility ecosystem. While appropriately designed EV tariffs can enhance the revenue of DISCOMs and help them flatten the load curve in their distribution areas, this also can potentially impact the commercial viability of the charging service business and the total cost of EV ownership. Hence, depending on the stakeholders' interests, their viewpoints will differ and sometimes be in opposition. Thus, the question of how to design a tariff framework that supports the different players' interests and enables India's EV ecosystem to mature and thrive arises. To understand the wide range of perspectives on different aspects of the EV tariff framework, a closed-door roundtable was organised in which senior representatives from key stakeholders such as EV fleet operators, charging service providers, DISCOMs, and electricity regulatory experts from India and abroad, international think tanks, and consulting firms shared their candid views on the subject. The critical aspects identified in the review of EV charging tariff schedules, as mentioned in **Section 5.3,** have been put forth as discussion points at the roundtable. A questionnaire-based survey was also carried out at the roundtable to capture the viewpoints of all stakeholders on these critical aspects. The views, insights, and recommendations received from different stakeholders are discussed in detail below.

1. Categorisation of EV charging in the tariff schedule

There is a consensus among all stakeholders that there should be a separate categorisation of EV charging in the tariff schedule. This is important for two main reasons. First, as per section 62(3) of the Electricity Act 2003, there should not be undue preference for any consumer. Therefore, a separate category would help the state governments to decide whether they want to subsidise EV tariffs to encourage EV adoption. Second, state governments have the discretion to impose duty/tax on consumed energy units, and, hence, a state has the option to waive it in the case of EV tariffs.

Globally, most EV charging happens at home. However, such a scenario may not be applicable in the Indian context. It has been observed that in Indian cities, most charging happens in the middle of the day and primarily at public places. Therefore, an EV-specific tariff would be an effective tool to promote EV adoption and manage the charging demand. A separate metered connection would help the DISCOM identify and manage the additional load from EV charging. This is especially important for 4-Ws, but may not be as critical for 2-Ws. There is also the idea that it is "*better to catch them young*", i.e. DISCOMs can learn from early experiences, before EV charging becomes a significant load for them.

However, some stakeholders were of the view that separate categorisation for EV charging is needed for all categories of EV users, including domestic charging. They proposed that the EV chargers be hard-wired to the electric meters (preferably prepaid), which could auto disconnect in the case of any tampering. This is primarily to avoid the misuse of domestic connections, as the applicable tariff is subsidised, and it will be difficult to keep track of the usage of these connections. **Table 6** summarises the viewpoints of different stakeholders on EV charging categorisation.

TABLE 6: VIEWPOINTS OF DIFFERENT STAKEHOLDERS ON EV CHARGING CATEGORISATION IN TARIFF SCHEDULE

	EV charging categorisation in tariff schedule
Fleet Operators	• Separate category for EV charging needed in tariff schedule • Most charging happens during the day • EV-specific tariffs would be effective in promoting EV adoption and managing the charging demand
DISCOMs	• Separate category for EV charging for all categories of EV users, including home charging, is preferable. The EV chargers should be hard-wired to electric meters (preferably prepaid), which can auto disconnect in case of any tampering.
Think-Tanks	• Separate category for EV charging needed, for two reasons: • Allows state government to subsidise EV tariffs to encourage EV adoption, preventing undue preference to particular consumer category • State government has the option to waive electricity duty/tax in the case of EV tariffs as per relevant provisions of Electricity Duty Act or Tax on Sale of Electricity Act • Separate metered connection important for 4-Ws - may not be as critical for 2-Ws
Charging Service Providers	• No need for separate tariff category for 2-Ws, but it is essential for 4-Ws

Source: Stakeholder Consultation

2. Application of demand charge

Stakeholders think that, initially, there is no need to introduce a demand charge, but it could be introduced as EV adoption picks up. The demand charge should be implemented based on the growth in the network. As EV adoption increases, network upgradation may be required to adjust for the additional load. Presently, the network upgradation plan is developed based on the peak load met during the year. However, there are typically very few peak hours throughout the year. Many distribution transformers (DTs) have a load of 25-30% of their capacity the majority of the time during the year. Overloading of DTs (as much as 120%) only happens a few hours per year. In such a scenario, EV charging may add up to the peak load resulting in further addition of DT and adding more to the underutilised capacity. Thus, in that case, not having a demand charge gives the DISCOM flexibility to adjust the daily load curve of the asset without needing to upgrade the network. This is also beneficial for the PCS, as they do not have to bear the cost of network upgradation. However, over time, as EV power demand becomes more significant, the network capacity will need to be augmented.

3. Introduction of ToD tariffs

In India, EV uptake has been slow so far. Therefore, the question arises of whether it is the right time to introduce ToD/ToU tariff rates for EVs or

Stakeholders suggested that the combination of ToD tariffs, along with no demand charge, and smart chargers together could increase asset utilisation without increasing the load.

not. Stakeholders suggested that the combination of ToD tariffs, along with no demand charge, and smart chargers together could increase asset utilisation without increasing the load and could potentially reduce technical losses. This is primarily because not having a demand charge offers the option of limited connectivity, and ToD tariffs give the flexibility of time-based connectivity. However, some stakeholders thought that ToD rates may not be sufficient; there may be a need to introduce dynamic rates, to account for different scenarios. An alternative viewpoint was that ToD rates are not required initially in the domestic category and could be introduced first for EV charging stations. It was also suggested that, in the domestic category, EV tariffs could be fixed just above the lowest slab, and then the ToD rebate could be offered. However, the introduction of ToD rates for domestic consumers would require replacement of the existing meters with smart meters, which would increase DISCOMs' capital expenditure.

4. Applicability of taxes and PPAC

There are contrasting viewpoints regarding the applicability of taxes and PPAC. Some stakeholders felt that the impact of regulatory surcharge and tax would not be significant. They also emphasised that electricity duty is not within the regulator's domain, as it is imposed by the state government. Furthermore, PPAC adjustment is a generational gap and will always be there, irrespective of EV charging. Thus, EV charging should be treated like any other consumer category, and similar rules should apply.

An alternative viewpoint was that in some states, these additional surcharges and taxes are too high, which could have a significant impact on EV tariffs. For example, Maharashtra imposes green cess, which is significantly higher compared to similar charges in other states. An exemption should be given to the EV consumer category, given it contributes to clean mobility. Moreover, some stakeholders said that since EV adoption is in a nascent stage, all such charges could be avoided initially and levied later on, as the sector progresses.

5. Socialising the cost of grid upgradation due to EV charging

The energy requirement of a certain EV charging station is assessed based on the heat map. However, it may be possible that the capacity of the existing DT in that area is not sufficient to cater to the additional EV charging load. Thus, there is a need for network upgradation to meet the additional demand.

However, stakeholders made an interesting point, that land outside the distribution asset does not necessarily belong to the DISCOM. Thus, network upgradation is contingent upon the availability of space in that area. Stakeholders suggested that socialisation of the network upgradation cost could be avoided through the use of EV-specific ToD/ToU rates. The cost of infrastructure could be socialised in the future, when there is a sufficient number of chargers and EVs on the road.

Figure 14 depicts the results of a questionnaire-based survey conducted at the roundtable. Stakeholders strongly supported separate categorisation of EV tariffs, the introduction of EV-specific ToD/ToU rates, and addition of other surcharges on top of the EV tariffs.

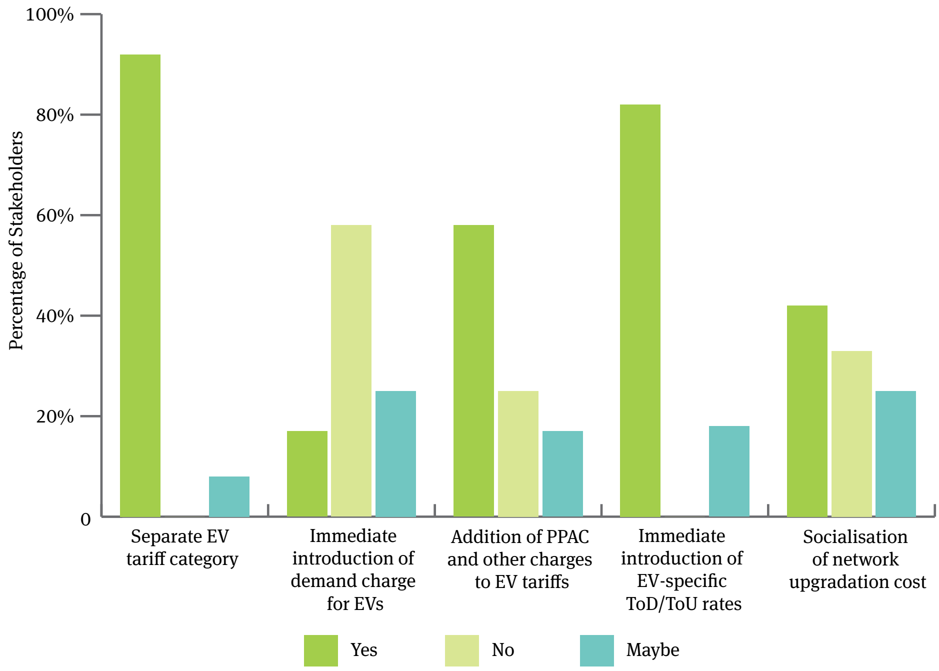


FIGURE 14: SURVEY RESULTS ON CRITICAL ASPECTS OF EV CHARGING TARIFF FRAMEWORK

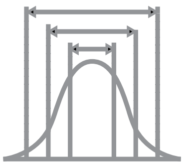
Source: AEEE analysis

The key outcomes from the stakeholder consultation and survey results are summarised as follows:

- There should be a separate tariff category for EV charging. Initially, it may not be required for 2-W charging.
- Application of demand charges can be avoided in the current scenario. However, in the future, when EVs are a sizeable fraction of the vehicle population, demand charges will be needed to manage the EV charging load and recover the cost of network upgradation.
- Electricity duty/ tax is not in the purview of the regulatory commissions, but, rather, the state governments. Approximately 60% of participants agreed that other charges and taxes, which are usually included in the electricity bill for most consumers, should also be applicable to EV charging.
- More than 80% of participants agreed that ToD tariffs for EVs should be introduced now. They also recommended starting ToD metering for EV connections. ToD rates (with no demand charge) are important to avoid increases in the peak load and the need for network upgradation, as well as to enable better utilisation of underutilised capacity.
- There are mixed views concerning the socialisation of network upgradation costs. Some stakeholders felt that the need for network upgradation costs could be avoided with ToD/ ToU rates for EV charging.
- Stakeholders emphasised that the transaction cost of getting a new connection needs to be reduced and the process to be simplified.

6.2 Recommendations on Key Elements of the EV Tariff Framework

6.2.1 Energy Charge



The deviation from ACoS varies from -44% in the case of Delhi to 16% in Odisha.

Initially, there was no specific direction or set of guidelines concerning tariff determination for EV charging. After a set of guidelines was issued by MoP in 2018, the guidelines went back and forth on the issue of ACoS, finally re-establishing the ceiling of ACoS plus 15% for EV charging tariffs, unless otherwise specified in tariff policy, in an amendment in 2020. According to the National Tariff Policy 2016, electricity tariffs need to progressively reflect the CoS of electricity and should be within ±20% of the ACoS (Ministry of Power, 2016). The current study has attempted to examine whether the existing EV tariffs announced by different states remain in the ±20% bracket, as per the National Tariff Policy 2016. The results of the analysis are presented in **Table 7**, which specifies the minimum and maximum deviations of EV tariffs from the corresponding ACoS. The states' ACoS is calculated based on the ARR and energy sales values provided in the respective tariff orders. The deviation from ACoS varies from -44% in the case of Delhi to 16% in Odisha. One can observe from the table that the majority of SERCs have announced promotional tariffs for EVs, as these are lower than the ACoS. This resonates with the objectives of the central and state governments to promote EV adoption. However, there are a few SERCs, e.g. in Assam, Odisha, and Uttar Pradesh, that have introduced EV tariffs above the corresponding ACoS, thereby recognising EV charging as a commercial activity.

TABLE 7: STATE-WISE EV CHARGING ENERGY CHARGES, AND THEIR VARIATION FROM ACoS

S.No.	State	Year	ACoS (₹ / kWh)	EV Charging Energy Charge (₹ /kWh)		Deviation from ACoS	
				Minimum	Maximum	Minimum	Maximum
1	Maharashtra	2019-20	6.07		5.06		-17%
2	Uttar Pradesh	2018-19	6.73	5.90	7.70	-12%	14%
3	Delhi	2019-20	7.16	4.00	4.50	-44%	-37%
4	Himachal Pradesh	2019-20	5.62	4.70	5.00	-16%	-11%
5	Gujarat	2019-20	5.14	4.00	4.10	-22%	-20%
6	Madhya Pradesh	2019-20	6.59	5.90	6.00	-10%	-9%
7	Karnataka	2019-20	7.20		5.00		-31%
8	Andhra Pradesh	2019-20	6.06		5.00		-18%
9	Telangana	2018-19	6.30		6.00		-5%
10	Odisha	2019-20	4.90	5.35	5.70	9%	16%
11	Punjab	2019-20	6.53		6.00		-8%
12	Assam	2019-20	6.46	5.40	6.90	-16%	7%
13	Goa	2019-20	5.56		4.20		-24%
14	Jharkhand	2019-20	6.51	6.00	6.25	-8%	-4%
15	Chattisgarh	2019-20	5.03		5.00		-1%

Source: Tariff orders of respective states and UTs for 2018-19 and 2019-20; AEEE Analysis

The SERCs have the discretion to set tariffs as per the Electricity Act 2003, with tariff policy as the governing principle. Based on the review of existing state-specific EV tariffs and policies and guidelines, along with stakeholder interactions, the study recommends that they can offer a promotional tariff to encourage EV adoption.

6.2.2 Demand Charge

The demand charge is a charge that a DISCOM levies on its customers to cover the cost of operating and maintaining its distribution network assets of adequate capacity. It is levied per kW or kVA of the sanctioned load or contract demand. A fixed demand charge, therefore, binds the DISCOM to maintain network capacity at a level necessary to cater to the contract demand. If a consumer is paying a demand charge, then s/he has the right to demand electricity, subject to the performance standards specified in the respective state's supply code. If there is no demand charge, then the DISCOM can exercise its discretion in providing electricity according to the loading in the network. As discussed in **Section 5.2**, some states have introduced demand charges, while others have not, in order to encourage EV adoption.

Demand charges are levied based on the sanctioned load in some states, irrespective of actual power demand. This could negatively impact the profitability of EV charging stations, particularly when the capacity utilisation of a charging station is low. During the initial period, due to low EV adoption, demand for charging could be similarly low, but the charging service provider would have to pay for the entire contracted demand, regardless of the recorded power demand. There are multiple ways to effectively reduce the burden of demand charges on charging service providers while allowing the DISCOM to recover its costs, as summarised below:

- The demand charge could be waived during the initial years, and once EV adoption increases, the regulator could introduce it. This would allow the DISCOM to provide electricity to a charging station on a discretionary basis and manage the daily load curve in its service area, without needing to augment its network to cater to the new load. This was recommended by various stakeholders during the consultation.
- The demand charge could be imposed on a charging station based on the maximum power demand recorded in a billing period. This would allow the DISCOM to cover the cost of maintaining the network capacity to meet the power demand and, at the same time, reduce the burden on the charging service provider.
- The charging service provider could be offered a subscription-based model for demand charges, whereby it could subscribe for a specified power demand over a certain billing period, based on its estimation of charging station capacity utilisation, instead of paying a demand charge based on the sanctioned load. This gives more flexibility to the charging service provider to optimise its demand charge, factoring in the actual capacity utilisation of the charging station. There is a precedent for the subscription-based model in the telecom industry in India.

CASE STUDY:
TEMPORARY WAIVING OF DEMAND CHARGES

Southern California Edison (or SCE Corp) is a utility in Southern California in the U.S. To promote EVs, SCE has installed more than 1000 charging stations at over 60 locations (Pyper, 2018). Additionally, SCE has announced ToU rates designed specifically for EVs. To boost EV adoption, SCE has temporarily waived demand charges for the period of 2019-2023 (SCE, 2018).

Utilities in the U.S. estimate demand charges based on the highest recorded demand during each monthly billing period, regardless of season, day of the week, or time of day. In India, demand charges for the HT and LT categories (mostly over 50 kW) are applicable on recorded demand/billing demand, while in the case of other LT consumers, they are applied based on the sanctioned load, irrespective of the actual recorded demand. However, this also varies from state to state. For example, in the case of JERC, billing is based on the maximum demand recorded during a month or 85% of the contracted demand, whichever is higher (JERC, 2019). In Assam Electricity Regulatory Commission (AERC), billing demand is based on 100% of contracted demand or recorded demand, whichever is higher (AERC, 2019). In addition, SERCs impose a hefty penalty if the recorded demand exceeds the contracted demand.

For EV charging stations, basing demand charges on the actual demand makes sense, as this will help reduce the financial burden in the case of low station utilisation, an issue charging station operator are currently facing in India.

CASE STUDY:
SUBSCRIPTION-BASED DEMAND CHARGES

Pacific Gas and Electric Company (PG&E) is a DISCOM headquartered in San Francisco, California. To support California's target of achieving 5 million zero-emission vehicles by 2030, PG&E proposed commercial EV rate plans. The proposed EV rates eliminated demand charges and instead adopted a monthly subscription-based pricing model, to enable more affordable charging, simpler pricing structures, and improved certainty and budgeting (Pimentel & Silcox, 2018). The DISCOM introduced separate subscription charges for large (over 100 kW) and small (<100 kW) commercial EV charging service categories. The subscription charges are USD 184 per 50 kW for large commercial consumers and USD 25 per 10 kW for small ones.

6.2.3 ToD/ ToU Tariffs

Several studies have recommended the application of ToU or ToD rates to incentivise consumers to shift their charging time to off-peak hours, as mentioned in **Section 3.4**. The use of ToD/ ToU tariffs would enable DISCOMs to make use of time flexibility to avoid network upgradation and also reduce technical losses. The application of the ToD/ ToU rates can be facilitated by the use of smart meters. These meters would help to send necessary price signals to EV users to charge their vehicles during off-peak hours. This would be beneficial to DISCOMs, charging service providers, and EV users, as detailed below:

- **DISCOMs:** As mentioned above, a DISCOM develops its network upgradation plan based on the peak load met in a year, even though the load rarely reaches the peak throughout the year, causing many DTs to operate at just 25-30% of their capacity most of the time. EV charging may add to the peak load in a static tariff regime, which could necessitate an increase in DT capacity and result in more underutilised network capacity overall. Introduction of ToD/ToU rates with no demand charge gives the DISCOM the flexibility to adjust the daily load curve in its service area, thus avoiding the need for immediate network augmentation. The EV charging load can also be utilised to fill the valleys in demand.
- **EV charging service providers:** The cost of network upgradation warranted due to additional load from EV charging stations could be passed on to the concerned charging service providers, in the case where the service line development cost is not socialised with other consumers, as per the applicable state supply code. As ToD/ ToU tariffs may help delay the requirement to increase the distribution network capacity in a service area due to a charging station, the EV charging service provider should not have to bear the additional cost in the immediate future.
- **EV consumers:** EV users can benefit from ToD/ ToU rates by charging their vehicles when the tariff is low and, thus, spending less on EV charging, which would increase the economic attractiveness of EV usage.

CASE STUDY:
XCEL ENERGY, COLORADO

The state of Colorado in the U.S. has announced a goal of having one million EVs on the road by 2030. To support this, Xcel Energy, a DISCOM in Colorado, has proposed a new pricing methodology that encourages companies and transit agencies to electrify their vehicle fleets (Xcel Energy, 2019 a). They have introduced ToU rates for commercial fleets, charging stations, and certain multi-unit dwellings (Xcel Energy, 2019 b). The DISCOM has defined 9 PM to 9 AM as the off-peak charging hours. If charging happens during the off-peak hours, the energy price is halved. During peak hours, the electricity price is double the normal price. The DISCOM has also announced a special tariff for critical peak hours, at the rate of USD 1.5/kWh (Xcel Energy, 2019 b).

Additionally, ToD rates could be leveraged to coincide charging with renewable energy (RE) sources coming onto the grid. This would provide a good opportunity to exploit low price slots in a day (based on the stations being scheduled). For example, overnight slots offer a good mix of non-loaded network assets and high-wind and low-coal slots. This would enable higher uptake of RE for EV charging and help avoid "cross-subsidisation" in EV tariffs and the need for network upgradation.

6.2.4 Other Charges and Taxes

The electricity tariff specified in the tariff schedule is not the final amount that an electricity consumer pays for their electricity consumption. Rather, in many states, taxes/cess/duties and other surcharges are also included on top of the consumer tariff in the final billable amount. Following a similar billing structure, in the EV charging tariff framework, taxes and other charges are expected to be applicable to EV charging connections. In some states, these additional charges and taxes are quite high, which increases the landed

Electricity duty, tax, and cess are subject to the state government's discretion, while other surcharges, PPAC, etc. are within the purview of state regulators.

cost of electricity for a charging service provider. For example, Maharashtra imposes an electricity duty of 16% and 21% on the residential and commercial categories, respectively (Government of Maharashtra , 2016). This is significantly higher than that in other states like Delhi, where the duty is 5% percent. Moreover, green cess at the rate of 8 paise per unit is also imposed in Maharashtra on the sale of electricity (MNRE, 2013). Presently, there is a lack of clarity regarding whether such taxes, additional charges, etc. are applicable to public EV charging stations or not.

Electricity duty, tax, and cess are subject to the state government's discretion, while other surcharges, PPAC, etc. are within the purview of state regulators. Depending on a state government's policy on EV adoption, electricity duty or cess could be levied. If the government wants to promote EV adoption, it could either reduce the duty/ cess or exempt EV charging from it. PPAC represents the variation in power purchase cost from the approved rate and therefore needs to be passed on uniformly to all consumer categories, including EV charging. However, a regulatory surcharge to liquidate past regulatory assets, for example, should not be levied on EV charging, since it is a new consumer category and therefore should not bear the burden of past regulatory assets imposed on it.

6.2.5 Socialising the Cost of Network Upgradation due to EV Charging

There are mixed views on the socialisation of network upgradation costs due to EV charging. In a regime with no socialisation of cost, if the DISCOM has to augment the network in a locality for a particular consumer category, the entailed cost is passed on to that consumer group. This could have a serious impact on the financial viability of charging station businesses.

As previously mentioned, the DISCOM develops its network upgradation plan based on the peak load met in a year even if it is for a few hours. Thus, it makes sense to avoid the grid upgradation requirement when there is a low EV adoption rate. ToD/ ToU rates can be introduced, along with smart chargers and exemption from demand charge, to encourage EV users to charge their vehicles during off-peak hours, enabling DISCOMs to avoid any change in peak load. As EV adoption increases over time, the anticipated EV charging demand should be a consideration when the DISCOM is preparing its network upgradation plan. The regulator can take a call on cost recovery of the investment for network upgradation.

6.2.6 EV Charging Categorisation

There is a strong recommendation from different stakeholders to create a separate consumer category for EV charging. Recognising PCS as a new consumer class has two major benefits. On one hand, this will give a clear price signal to charging station operators and EV users. On the other hand, a separate category will allow the state governments to offer "EV-only" incentives to encourage EV adoption. Furthermore, standardisation of EV charging as a consumer category across the country may help to provide clarity on the EV charging tariff regime and, as a result, improve the ease of doing business in the e-mobility sector.

7. Summary of Recommendations

Table 8 provides a summary of recommendations on key considerations for the EV tariff framework. It should be considered that EV charging is distinct from other consumer categories due to three salient aspects – a mobile source of electricity requirement, unpredictable and uneven load, and the possibility of bi-directional energy flow. It is highly recommended that regulators take these aspects into account when framing the tariff schedule for EV charging and take a 360-degree view of the subject, considering the viewpoints of all concerned stakeholders, including the DISCOMs, EV charging service providers, EV fleet operators, and think-tanks.

TABLE 8: SUMMARY OF RECOMMENDATIONS ON KEY CONSIDERATIONS FOR EV TARIFF FRAMEWORK

Key Elements	Recommendations
Energy Charge	• State regulators can offer promotional EV tariffs (less than ACoS) to encourage EV adoption during the initial phase.
Demand Charge	• Different alternatives could be adopted to reduce the burden of demand charge on charging service providers, while allowing DISCOMs to recover their costs: • Waiving off the demand charge during the initial phase and introducing it later on, as EV adoption rate increases • Levying demand charges based on the maximum power demand recorded in a given billing period • Adopting a subscription-based model for demand charge
ToD/ToU Tariffs	• Use of ToD/ ToU tariffs would enable DISCOMs to make use of time flexibility to avoid network upgradation and reduce technical losses. • Application of ToD/ ToU tariffs would be beneficial to various stakeholders: ▶ **DISCOMs:** Flexibility to adjust daily load curve without the immediate requirement for network upgradation ▶ **EV Charging Service Providers:** Avoiding the cost burden of network upgradation in the immediate future ▶ **EV Consumers:** Affordable charging cost, increasing the economic attractiveness of EV adoption • ToD rates could be used to coincide EV charging with renewable energy generation, thereby enabling higher offtake of RE for EV charging and helping avoid "cross-subsidisation" in EV tariffs and the need for network upgradation. • In future, dynamic rates need to be introduced. In a scenario of high EV penetration, ToD/ ToU rates may not be effective.
Other Charges and Taxes	• The state government determines electricity duty, tax, and cess, while other surcharges, PPAC, etc. are fixed by state regulators. • To promote EV adoption, the government could either reduce the duty/ cess or provide an exemption for EV charging. • PPAC charges can be applicable to all categories, including EV charging, whereas a regulatory surcharge should not be levied on EV charging.
Socialisation of Network Upgradation Cost	• ToD/ ToU rates should be introduced for EV charging, along with smart chargers and exemption from demand charge, to avoid network upgradation requirement while there is a low EV adoption rate. • As EV adoption increases, charging demand needs to be a consideration in the network upgradation plan, and regulators need to take a call on the cost recovery plan.

Key Elements	Recommendations
EV Charging Categorisation	• Recognising PCS as a new consumer class provides clear price signals to charging station operators and EV users and allows the government to offer "EV-only" incentives to boost EV adoption. • Standardisation of EV charging as a consumer category across the country may simplify understanding of the EV charging tariff regime and improve the ease of doing business in the e-mobility sector.

Source: AEEE Analysis

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