ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

A GUIDE FOR DISCOM READINESS

LIGHTHOUSE DISCOM PROGRAMME
A NITI AAYOG, RMI INDIA + ROCKY MOUNTAIN INSTITUTE COLLABORATIVE

MAY 2020

RMI India is an independent organization. RMI India takes inspiration from and collaborates with Rocky Mountain Institute, a 40-year-old non-governmental organization. RMI India's mission is to accelerate India's transition to a clean, prosperous and inclusive energy future.

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, com-munities, institutions, andentrepreneurs to accelerate the adoption of market-based solutions that costeffectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; the San Francisco Bay Area; Washington, D.C.; and Beijing.

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Energy Efficiency Services Limited (EESL)

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01 INTRODUCTION

INTRODUCTION

Electric vehicles (EVs) represent a growing opportunity for discoms to capture new sources of demand flexibility while increasing revenue from a customer class that will grow significantly over the next decade. Converting India's existing vehicle fleet to electric will add terawatt-hours of new demand to the grid and requires thoughtful and timely planning to minimize costs and maximize benefits to discoms and customers alike. Additionally, the generous FAME II subsidy is availed to a range of vehicle segments and will spur rapid adoption of EVs in targeted vehicle segments. However, in order for FAME II to be successful in jumpstarting the EV market, it will require direct support of charging infrastructure.

If managed correctly and planned for proactively, this new large and flexible load (in time and location) will support revenue growth and improve the efficiency of discom operations. However, if new demand is not met proactively, discoms will be challenged by large numbers of interconnect requests and little control of the new load. This will result in a lost demand side management opportunity and a slowing of demand growth.

Discoms need to start planning today for the expected demand growth in the coming years and decades. The first step in planning for an EV future is to build capacity across the key stakeholders to ensure all parties have the fundamental knowledge required to have productive planning discussions.

This EV charging guide address actions and considerations specifically relevant to Indian discoms preparing for electric mobility in their territory. The following topics are covered.

01 Charging technology and vehicle segments

02 Cosumer charging behavior

03 Best practices in planning for EV charging deployment

04 Key considerations for discom preparedness

> If managed correctly and planned for proactively, EV load will support revenue growth and improve the efficiency of discom operations

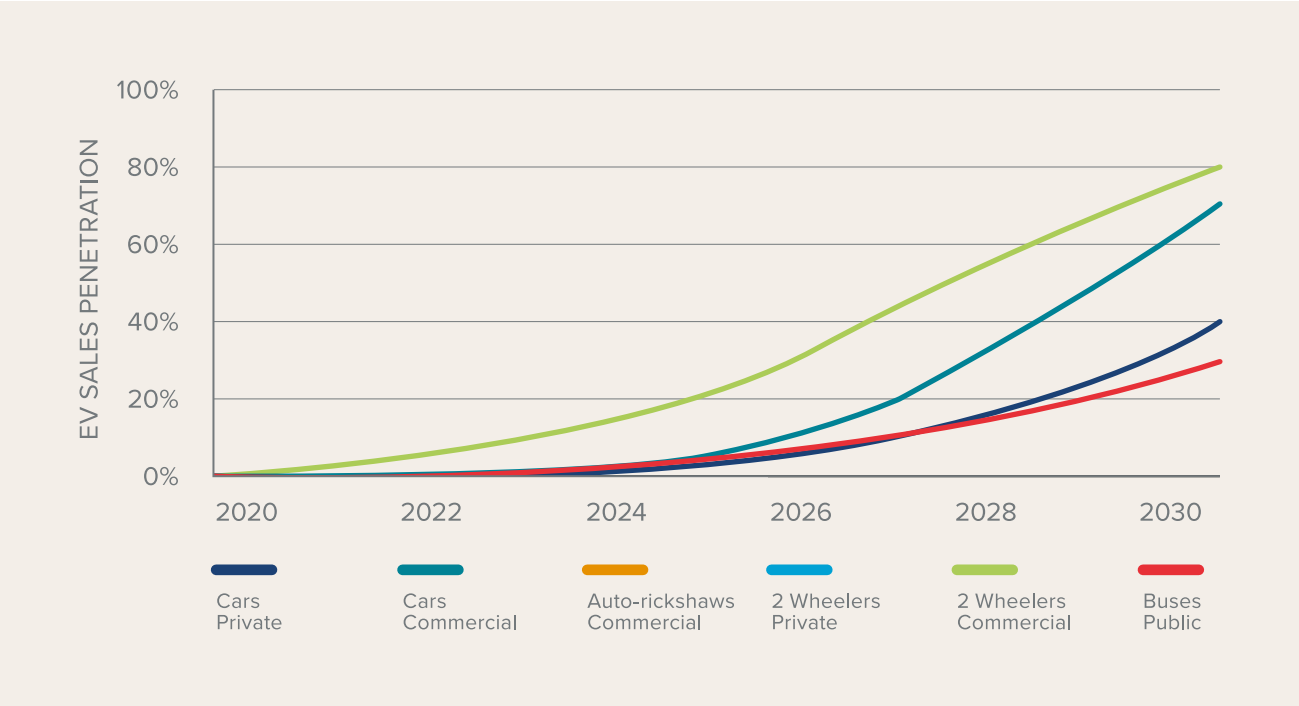
02 ELECTRIC VEHICLE GROWTH SCENARIOS

ELECTRIC VEHICLE GROWTH SCENARIOS

The Indian vehicle market is at the early stages of electrification, propelled largely by central and state government policy support and accelerated by declining costs of lithium batteries and improving vehicle technology. Over the next decade RMI and NITI Aayog expect to see substantial growth in electric two-, three-, and four-wheel vehicles, as well as electric buses. While fully accurate forecasts of EV adoption are not feasible, considering a range of future scenarios is useful to understand implications for long-term system planning that is necessary to integrate high levels of EV charging onto the grid. The scenarios presented below provide a lens into what future EV customer segments could look like over the next decade. The accelerated adoption scenario assumes that FAME II and other policy measures initiated by central and state governments will help trigger rapid adoption of EVs in the country. Segment-wise, the penetration of EVs in new vehicle sales is 30% for private cars, 70% for commercial cars, 40% for buses by 2030, and 80% for two and three-wheelers by 2030.

FIGURE 1

Electric vehicle sales penetration—cccelerated scenario

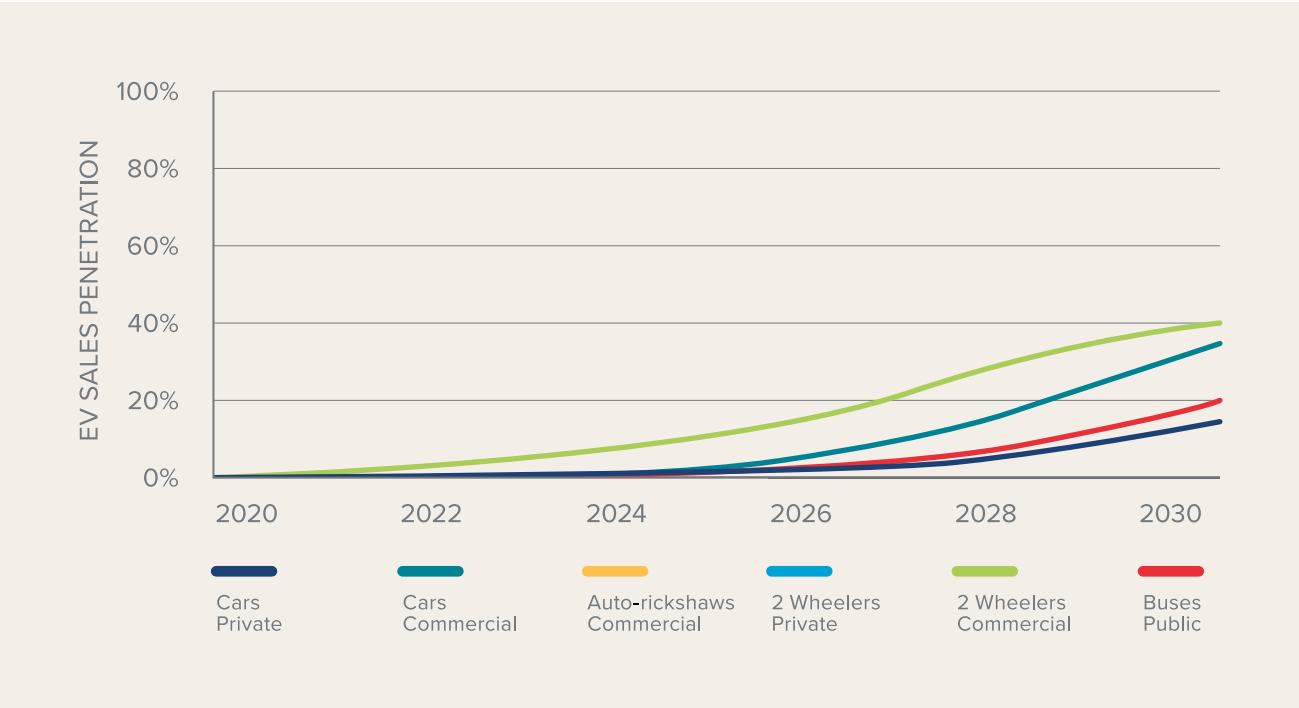


The baseline adoption scenario shown below describes a conservative pathway where the adoption of EVs does not accelerate at the expected rate as hoped under FAME II due to reasons like lags in the formation of EV ecosystems including charging stations, lower than expected introduction of EV vehicle models in the market, delay in policy implementation, lack of consumer awareness, etc. This scenario assumes a weighted average EV sales penetration of 35% in 2030 across all vehicle segments.

Despite slowdown, policy continuity should ensure adequate uptake of EVs

FIGURE 2

Electric vehicle sales penetration—baseline scenario

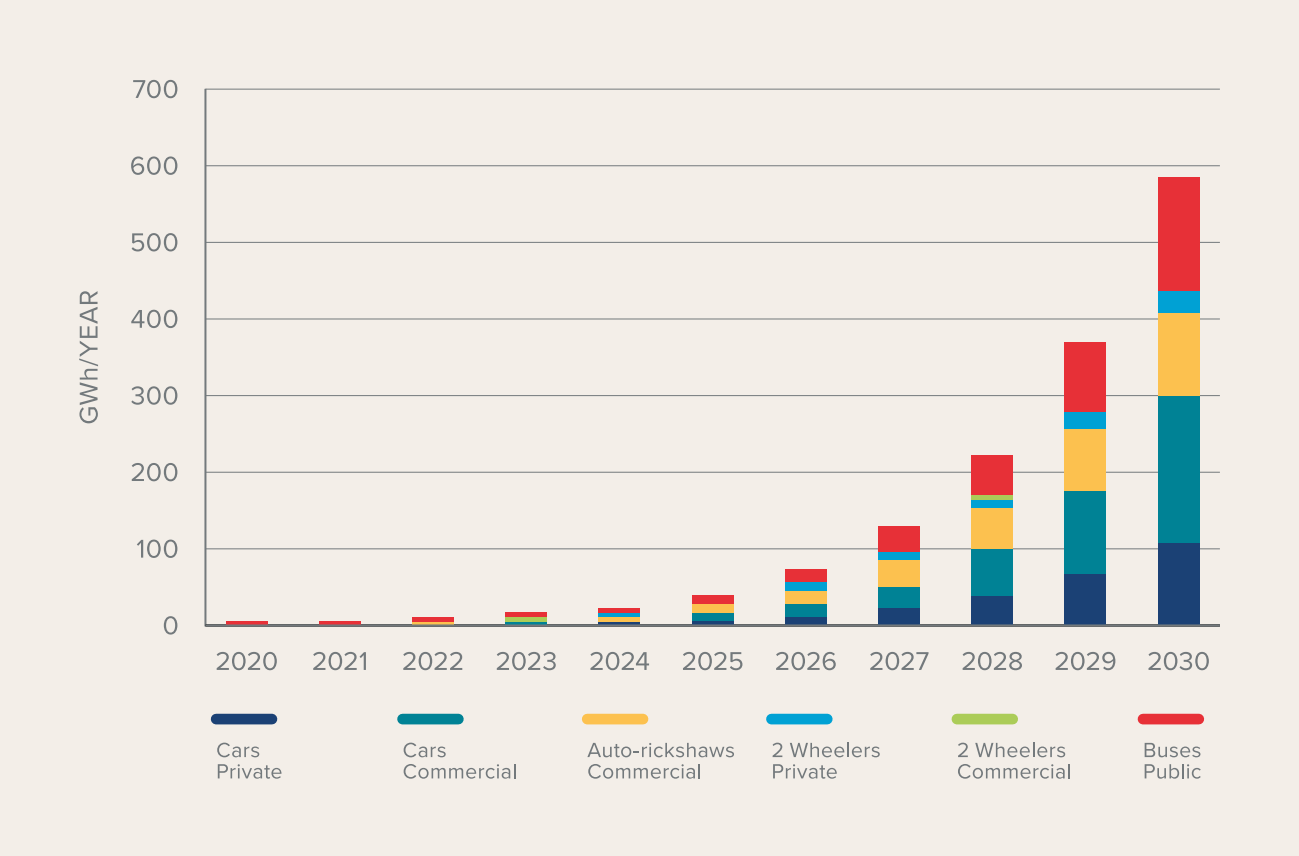


Haryana state-level demand scenario

Recognizing that EV sales trends will vary across India and no scenario will predict EV growth without error, applying RMI's national EV adoption scenario to Haryana's population is a useful planning exercise that allows discoms to begin to better understand implications and opportunities. As can be seen in the charts and tables in the following section, the number of residential and commercial customers needing EV charging services will grow rapidly in Haryana, reaching 56,000 vehicles in 2025 and exceeding 400,000 vehicles in the state by 2030. The annual electricity demand required to charge all vehicles state-wide exceeds 500 GWh/year by 2030. In the following scenario we present the baseline EV adoption rates and the implications for Haryana discoms. This approach gives a good indication of how EVs may enter the market in Haryana and can be used as a guide in preparing for EVs in the system.

FIGURE 3

Haryana's annual electric vehicle electricity consumption—baseline scenario



While most discoms are well prepared to serve new energy demand from a system-level generation standpoint, there is a greater need for readiness at the feeder and circuit level. Discoms will also need to prepare new internal programs to support customer interconnection requests for all types of charging stations.

Discoms should run capacity-building programs for key staff to provide basic education on designing and planning for optimal integration of EVs in the system. Discom management may consider including these subjects in a broader distributed energy resource capacity building program that includes demand side management, energy efficiency, distributed renewable generation, and other consumer facing technologies.

Based on the state level EV adoption scenario prepared for Haryana we estimate the number EVs sold across the state per year and the required energy and power to serve all vehicles in the state. The table below shows the annual electricity consumption and range of peak power required to serve vehicles in the state in 2025 and 2030. Note the large range in peak demand, from 70 to 400 MW in 2030. The low end of the range occurs if the daily electricity demand for vehicles is spread evenly over 24 hours. The upper end of the peak demand range would occur if the daily energy requirement is spread over only 4 hours.

While neither the upper nor lower range are likely to occur in practice, we can confidently assume that peak demand will fall somewhere in this range. Charging behaviour (fast versus slow) and the use of time of day rates will have significant impact on the cost and revenue associated with serving this customer class. It is recommended that discoms act early to develop EV programs and tariffs that encourage behaviour leading to lower peak demands on the system and thus lower costs to discoms and their customers.

TABLE 1

Energy and power requirements to serve electric vehicles in Haryana

	2025				2030			
	EV SALES (Thousands)	ENERGY CONSUMPTION (MWh/year)	RANGE OF PEAK DEMAND (MW)		EV SALES (Thousands)	ENERGY CONSUMPTION (MWh/year)	RANGE OF PEAK DEMAND (MW)	
2 WH	30	4	5	30	120	30	70	400
3 WH	5	12			20	110		
CARS	3	16			40	300		
BUSES	0.1	11			1.4	140		

Discoms should also consider the customer engagement aspect of a growing EV market and what that means for permitting and interconnection processes, metering and billing, and customer service. As EV ownership increases so will the number of new interconnect requests to serve those vehicles. Having processes in place that streamline the permitting and interconnection process while capturing relevant data for discom planning is an important component of EV readiness.

The majority of the interconnection requests in the early phases of EV growth are expected to come from the commercial sector fleet owner/operators, bus transit agencies, and commercial EV charge network operators that serve both commercial and private vehicle segments. These new loads will be large and can range from several hundred kilowatts (kW) to several megawatts (MW), depending on the number and type of vehicles. Dealing with interconnection and permitting requests in a timely and streamlined manner will be essential to supporting EV adoption and securing new and sustained revenue for the discom.

The table below provides a view of expected number and type of new loads in 2025 and 2030. Note, this does not consider home or workplace charging needs that will be required to serve a large fraction of personal vehicles.

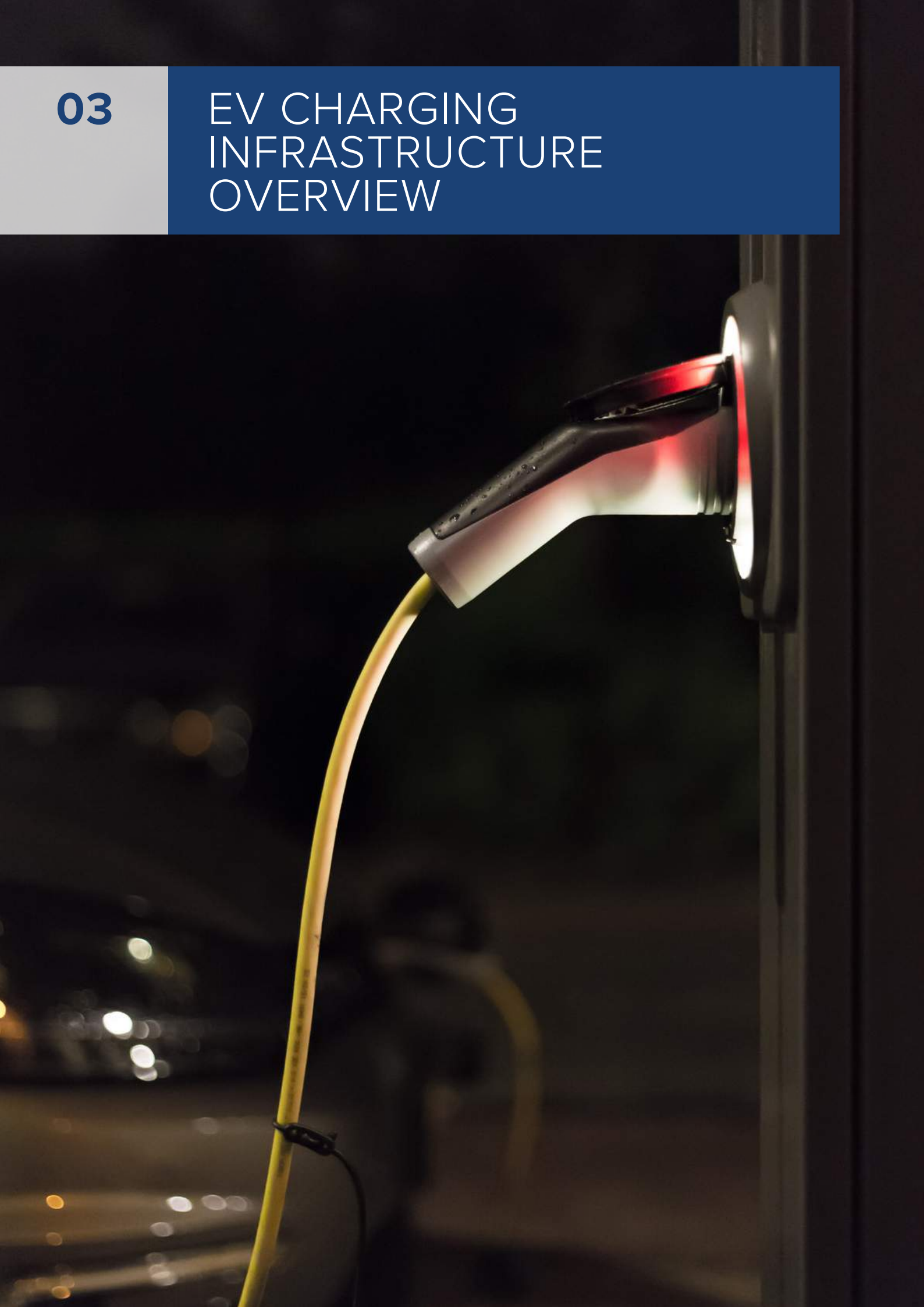
TABLE 2

New load and new interconnection requests for different types of EV charging stations

	2025		2030	
	TOTAL NAMEPLATE CAPACITY* (MW)	NO. OF CHARGING STATIONS	TOTAL NAMEPLATE CAPACITY* (MW)	NO. OF CHARGING STATIONS
Public DCFC with 8 charging connectors, 400 kW	15	40	170	430
Public AC with 8 charging connectors, 80 kW	540	500	350	4400
Commercial DC fast charging depot, 20 charging connectors, 1 MW	1	1	30	30
Bus depot with 40 buses, 20 charging connectors, 1 MW	4	4	50	50
TOTAL	**60**	**540**	**600**	**4910**

*Nameplate capacity represents the total installed charging capacity of all charge stations and is not representative of expected demand to be met by the discom

03 EV CHARGING INFRASTRUCTURE OVERVIEW



EV CHARGING INFRASTRUCTURE OVERVIEW

This section provides an entry-level overview of EV charging infrastructure nomenclature and fundamental hardware and software components. EV charging infrastructure, often referred to as electric vehicle supply equipment (EVSE), is a core component of a healthy EV ecosystem and requires adequate planning and dedicated electrical infrastructure at various levels of the distribution grid. This includes behind-the-meter customer-owned infrastructure.

In their simplest form EV charging stations are a set of power electronics, usually wall or pedestal mounted, that safely supply regulated power from the grid to the vehicle batteries. Different types of chargers supply different current and voltage levels as required to meet vehicle-specific battery requirements. EV chargers range from as low as 500 watts (W) to as high as 500 kW. It is expected that improvements in battery chemistry will enable even higher charging rates in the future.

Most vehicles are equipped with an on-board charging system that converts grid-supplied AC power to the DC power required to charge the battery. Onboard chargers enable a vehicle to be charged directly from a standard home plug (slow AC) or from a specialized AC charger (moderate AC) at home, workplace, or public location. Chargers that provide direct current to the vehicle battery and bypass the onboard converter are referred to DC chargers or DC fast chargers due to their ability to provide higher charging rates.

Charging equipment typically has some degree of intelligence that takes care of user authentication, vehicle communication, data collection and monitoring, and payment. In some cases it will also feature bi-directional control that allows a dispatch system to adjust the level of power being injected into the battery in response to price signals or other dispatch reasons. There are chargers that are sometimes referred to as 'dumb' chargers that do not have communication or control capabilities and simply regulate the electricity from the grid to voltage and current required to charge the battery.

A minimal level of intelligence is advised to enable more advanced data collection and managed charging in a way that supports discoms needs and constraints. Discoms should encourage commercial charging infrastructure owners to deploy smart chargers with a minimal level of dispatch and control functions to enable participation in demand response or time of use tariff programs.

Hardware infrastructure

A standard charging system includes several fundamental hardware components as described below:

- The power electronics assembly is the core of a charging station. It supplies the power to the EV's onboard battery charger.
- The charge controller is the intelligence of the charging station and manages basic charging functions, like turning a charger on and off, metering of power usage, and storing key bits of real-time and event data.
- The network controller provides the interconnection of the charging station to the broader network. It allows the station to communicate with its network using an on-board telecommunications device so that system managers can monitor, review, and control the device usage. It also manages user access to charging stations.
- The cable and connector are sometimes referred to as a charging gun. It plugs into the vehicle making a safe physical connection between the charger and vehicle. Charging guns or connectors often conform to a standard form factor specific to the vehicle OEM (e.g., CCS, CHAdeMO, SAE J1772, IEC 60309).

Data management

EVs and EV chargers are continually generating important data on the state of charge of the battery, the rate of charge of the battery, the kilowatt-hours (kWh) used in charging, price signals from a utility, demand response signals from a demand manage system, and other pieces of information that the network operator or user may find useful.

Charging management software is designed to manage and administer charging stations and their networks. Network software promotes the quick deployment and configuration of EV charging stations and facilitates a two-way flow of data between the charging station and its network control center. This functionality allows operators to remotely configure, manage, and update software; set and control driver access to charging; set pricing; manage billing; and run usage reports.

Software applications also allow drivers to locate and reserve available charging stations. Software tools can be configured to send notifications to operators and drivers.

Maintenance and service

Like any device that is utilized by the public and exposed to the environment, public EV chargers require some level of service and maintenance. Service of public chargers is taken care of by the charger owner/operator and is not generally a relevant consideration for discoms that do not own the charging infrastructure. However, discoms that choose to own public charging stations should also plan on regularly service and maintenance of those assets.

> Network software promotes the quick deployment and configuration of EV charging stations and facilitates a two-way flow of data

04 TECHNICAL DETAILS

TECHNICAL DETAILS

This section provides an overview of the different charging methods currently used in India and globally.

Slow AC charging

Slow AC charging is the most basic form of charging in India today and refers simply to plugging a car or two-wheeler into a standard three-pin 5 amp (type D) or 15 amp (type M) wall outlet without communication function to the on-board charger of the EV. These basic forms of charging are not enabled with managed charging capabilities and deliver about 5–15 km of range per hour, depending on plug and vehicle type. Although this is the most common form of charging today, we expect moderate and fast AC charging to quickly become the default mode of charging in India as the market develops over the next few years.

Moderate AC charging

Moderate AC charging requires the installation of dedicated EV charger to a 15 amp single-phase circuit and is available with (and without) managed charging capabilities. Charging rates start at 2.5 kW and can go up to 20 kW depending the type of EVSE installed and the car model connected. Charging stations above 3kW require branch circuits with higher amperages and in some cases require two-phase or three-phase connections. Indian cars are currently limited to 3 kW and the majority of global OEM vehicles are limited at 7.7kW. Some vehicles charge at 20 kW and draw more than 80 amps. Charging rates between 3 and 7.7 kW deliver between 25 and 65 km of range per hour charging for cars and between 60 and 150 for two-wheelers, respectively.

The below points apply to moderate AC charging in India today:

- Most Indian electric cars and motorcycles can be charged directly using the IEC 60309 connector.
- Most global OEMs use an IEC 62196 Type 2 connector that requires an adaptor to connect with IEC 60309 charging stations.
- Most electric two-wheelers sold in India have a three-pin home charger that is used along with the IEC 60309 to 15 amp adaptor.
- Many electric two-wheelers are designed with a removable battery to enable the charging to take place in the home or workplace and do not always require a curbside charging system.

DC fast charging

DC fast charging is typically used when the vehicle requires a rapid charge and the user/owner is willing to pay a premium for the faster charge. DC fast charging stations are almost always commercial operations owned and/or operated by a charge network operator. DC Fast charging requires dedicated grid infrastructure and some level of discom engagement in the planning and design phase. At a minimum DC fast charging stations require the installation of dedicated three-phase power supply equipment that that draws significantly higher amperage than AC charging options.

Fast charging, sometimes called quick charging in India, is significantly more expensive to install and operate. It is rarely used as the primary mode of private vehicle charging and almost never used as a dedicated charger for an individual car. DC fast charging is common for captive high utilization electric fleets that require rapid charging speeds and can overcome the higher upfront and operational costs. Stations are often deployed in public areas

and are owned and operated by a charging network operator that provides charging services to EV owners at a set cost. Heavy duty and medium duty vehicles and buses typically require some form of DC fast charging to achieve a reasonable recharge time for their larger batteries.

LEVEL 1
DC charger

Specifications

- Public DC chargers with output voltage of 48 V/72 V
- Power outputs of 10 kW–15 kW
- Maximum current of up to 200 amps

As per the Bharat EV specs, these are Level 1 DC chargers.

LEVEL 2
DC charger

Specifications

- Public DC chargers with output voltage up to 1000 V
- Power outputs of 30 kW–150 kW

As per the Bharat EV specs these are Level 2 DC chargers.

DC plug connectors

Four popular DC fast charging connectors currently being used globally:

- **CHAdeMO:** Nissan and other Japanese companies like Mitsubishi
- **SAE Combo Charging System (CCS):** BMW, GM, VW, and other carmakers
- **Supercharger:** Tesla standard connector
- **GB/T:** Mahindra and Tata electric cars use this standard

Per guidelines in the following sections entities setting up public DC fast charging stations are required to meet minimum operational and technical requirements.

Ministry of Power: Public charging infrastructure—minimum requirements

The Ministry of Power (MoP) has issued guidelines and standards applicable to electric vehicle charging equipment. The following section provides an overview of relevant information. The reader is encouraged to review the full notice "Charging Infrastructure for Electric Vehicles—Guidelines and Standards-reg" issued 14 December, 2018.

Operational requirements

- Private charging at residences and offices shall be permitted. Discoms may facilitate the same.
- Setting up of public charging stations shall be a delicensed activity and any individual or entity is free to setup public charging stations, provided that such stations meet the technical as well as performance standards and protocols laid down in the MoP guidelines.
- Any person seeking to set up a public charging station may apply for connectivity and he shall be provided connectivity on priority by the distribution company licensee to supply power in the area.
- Any charging station/chain of charging stations may also obtain electricity from any generation company through open access.
- The tariff for supply of electricity to EV public charging stations shall be determined by the appropriate commission, provided however that the tariff shall not be more than the average cost of supply plus 15%.
- The tariff applicable for domestic consumption shall be applicable for domestic charging.
- The state discom shall generally be the nodal agency for the rollout of charging infrastructure. However, state governments shall be free to select a central or state PSU as its nodal agency. All relevant agencies including CEA shall provide necessary support to the nodal agency.

Technical requirements

Public charging infrastructure must meet the following minimum technical requirements per the MoP guidelines:

- All stations must have an exclusive transformer with all related substation equipment including safety appliance
- All stations must have 33/11 KV lines/cables with associated equipment including as needed for line termination/metering
- Appropriate civil works
- Adequate space for charging and entry/exit of vehicles
- Current international standards that are prevalent and used by most vehicle manufactures internationally are CCS and CHAdeMo. Hence, public charging stations shall have one or more electric kiosks/boards with installation of all the charger models as shown in Table 3.
- The public charging station provider is free to create charging hubs and to install additional chargers in addition to the minimum number of chargers prescribed above.
- The charging provider must tie up with at least one online network service provider (NSP) to enable advance remote/online booking of charging slots by EV owners. Such online information to EV

owners should also include information regarding location, types, and numbers.

» Charging station operators must share charging station data with the appropriate discom and maintain appropriate protocols as prescribed by such discoms for this purpose. CEA and MoP shall have access to this database.

TABLE 3

MoP technical guidance

CHARGER TYPE	CHARGER CONNECTORS*	RATED VOLTAGE	NO. OF CONNECTOR GUNS	VEHICLE TYPE
Fast	CCS (MIN 50 KW)	200–750 or higher	1	4W
	CHADEMO (MIN 50 KW)	200–750 or higher	1	4W
	TYPE-2 AC (MIN 22 KW)	380–415	1	4W, 3W, 2W
Slow/moderate	BHARAT DC-001 (15 KW)	48	1	4W, 3W, 2W
	BHARAT DC-001 (15 KW)	72 or higher	1	4W
	BHARAT AC-001 (10 KW)	230	3; 3.3 kW each	4W, 3W, 2W

*In addition, any other fast/slow/moderate charger as per approved BIS standards whenever notified.

05 CHARGING SCENARIOS

CHARGING SCENARIOS

This section provides an overview of the charging behaviour of different vehicle segments.

International experience with EV charging behaviour can provide insight to how charging may occur in India as the EV market matures. While it is important to consider the unique Indian context, this section provides an overview of the various ways vehicles recharge and is based on both international and Indian experiences.

Unlike petrol or CNG vehicles which must travel to a gas station to refuel, an electric vehicle can charge where petrol vehicles cannot—at people's homes, workplaces, retail destinations, and dedicated recharging stations (similar to a petrol station). EVs can also charge at different power rates, using both AC and DC power. Each vehicle is equipped with an on-board charger to convert AC to DC and depending on its battery size, battery chemistry, and onboard electronics, can accept AC power ranging from 0–25 kW and DC power ranging from 3–150 kW, and up to 500 kW in some heavy-duty vehicle applications. The range of power means charging sessions can be as short as 15 minutes to more than 8 hours depending on battery size and charging power.

When, where, and how a vehicle is charged depends on the options available, the duty cycle required, the cost of each option, and in many cases personal preferences. Typically, private vehicle owners have more flexibility in their charging needs and commercial vehicles are beholden to their vehicles and business constraints (e.g., time driving versus time parked).

Vehicle segments

Each vehicle segment (two-, three-, four-wheelers, buses, etc.) has unique charging needs. The following section provides some key aspects that discoms can consider when designing an EV readiness program.

2 WHEELERS

Two-wheelers have relatively small batteries (2–3 kWh) which often are removable to enable home and office charging from a standard wall socket. Electric two wheelers require a standard three-pin 15 amp connector and are limited in charging rate by the onboard AC charger in the range of 1–3 kW depending on the OEM design specifications. Charging times range between one and six hours. Electric two-wheelers are expected to be a major market for electric vehicles in the coming years and must be included in any EV readiness program.

3 WHEELERS

Three-wheelers have slightly larger batteries (8–12 kWh) and come in variations with fixed and removable batteries. Due to their high utilization compared to private two-wheelers and their tendency to operate in dense urban areas these vehicles are considered good candidates for battery swapping and/or DC fast charging.

4 WHEELERS

Four-wheelers come with various sizes of batteries and utilize different charging standards as determined by the OEM. In India both Mahindra and Tata have launched electric cars with relatively small batteries (11–15 kWh) that are limited by their onboard AC charger at about 3 kW. Global EVs have onboard chargers with higher ratings between 7–20 kW AC and can accept up to 150 kW DC fast charging in some models. Four-wheelers used commercially will charge mostly with DC fast charging options and private vehicles will use a mix of DC fast and moderate AC. Commercial fleet vehicles are expected to be early adopters of electric vehicles due to the favourable total cost of ownership of electric compared to petrol.

+ BUSES

Buses typically have large batteries and high power requirements. Depending on the operational considerations of the bus and size of its battery, the charging requirement can range from 50 kW to 500 kW. Fleets of buses charging in a depot will require dedicated infrastructure and close coordination with discoms. Bus charging depots have the potential to exceed existing network capacity and will likely require grid upgrades. As electric bus and truck technologies rapidly improve, these segments are likely to electrify quickly because they are responsive to the favourable economics of electricity as a very low-cost fuel.

The table below provides a summary of the typical charging characteristics of vehicle segments. It is important to keep in mind that cars and buses will often be operated in a fleet and the aggregate load of the fleet will be much higher than individual vehicle charging load.

TABLE 4

Charging power and energy requirements of different segments

	BATTERY SIZE	SLOW CHARGING	FAST CHARGING
TWO-WHEELER	1–3 kWh	0.5–1 kW	2–3 kW
THREE-WHEELER	3–7 kWh	0.5–1 kW	2–3 kW
CAR	15–80 kWh	3–kW	20–100 kW
BUS	100–400 kWh	7–50 kW	50–500 kW

Public charging locations

Many EV owners will not have access to private/ dedicated parking with charging capacities. These EV owners will need to recharge using publicly available charging options. Several key charging locations are summarized below:

Retail spaces

Locations that attract visitors for relatively longer dwell times and already offer parking options are good candidates for public charging stations. Malls, restaurants, and markets will likely see increased charging station deployment.

Workplace

Many workplaces are already starting to install EV charging equipment for their employees. Large office buildings or technology parks will see a growing demand for EV charging. Workplace charging will also play a key role in enabling EV loads to absorb excess PV generation by providing the option of daytime charging.

Street parking

Curbside and street charging in highly dense urban areas where vehicles are already parking have been part of charging deployment strategies internationally and may become a need in India also.

Corridors/highways

Clusters of DC fast charging stations along highways or other long-distance corridors will become commonplace as EV penetration grows. These stations will be primarily high-speed chargers and will likely offer limited or no demand flexibility to discoms.

Station load profiles

The following section provides examples of hourly load profiles of various charging station types. The charts are based on international experience and real-world anonymous data adjusted to apply to Indian vehicle types and expected behaviors. The load profiles shown in this section are meant for illustrative purposes only and demonstrate what

station profiles could look like under various levels of utilization.

Utilization of a charging station is a useful metric to indicate how well an EV network is serving its vehicle population and when additional chargers are needed. Utilization refers to the amount of time that the station is in use providing electricity to a vehicle as a percent of the total time the station is theoretically available. A charger that is in continuous use over a 24-hour period has a utilization of 100% while a charger that is used only one hour per day has a utilization of 4% (1/24). Based on international experience the utilization of charging stations varies significantly by location and changes over time. As EV penetration in a certain area increases the utilization of stations in that area increases.

Utilization rates have been observed as low as 0% and as high as 50% for public stations. Rates as high as 90% have been achieved in highly opmitized captivate fleet operations where the fleet operator has a great deal of control over fleet charge management. Charging network operators have a business motive to maximize utilization to serve the most customers with minimal infrastructure. Importantly, higher utilization stations have flatter load profiles and are easier for discoms to plan for, but also have limited ability to respond to time of use or demand response signals. In the following examples three scenarios are displayed for AC and DC stations. The charts show example profiles of low-, moderate-, and high-utilization stations that roughly range from 5% to 40% utilization. A highly opmitized captive charger with utilization above 90% would have a nearly flat and continuous load profile and is not included in this report. The charts show the energy delivered per hour from the charging station. The x-axis can be read as kWh energy delivered and also as the average power demand during each hour in kW.

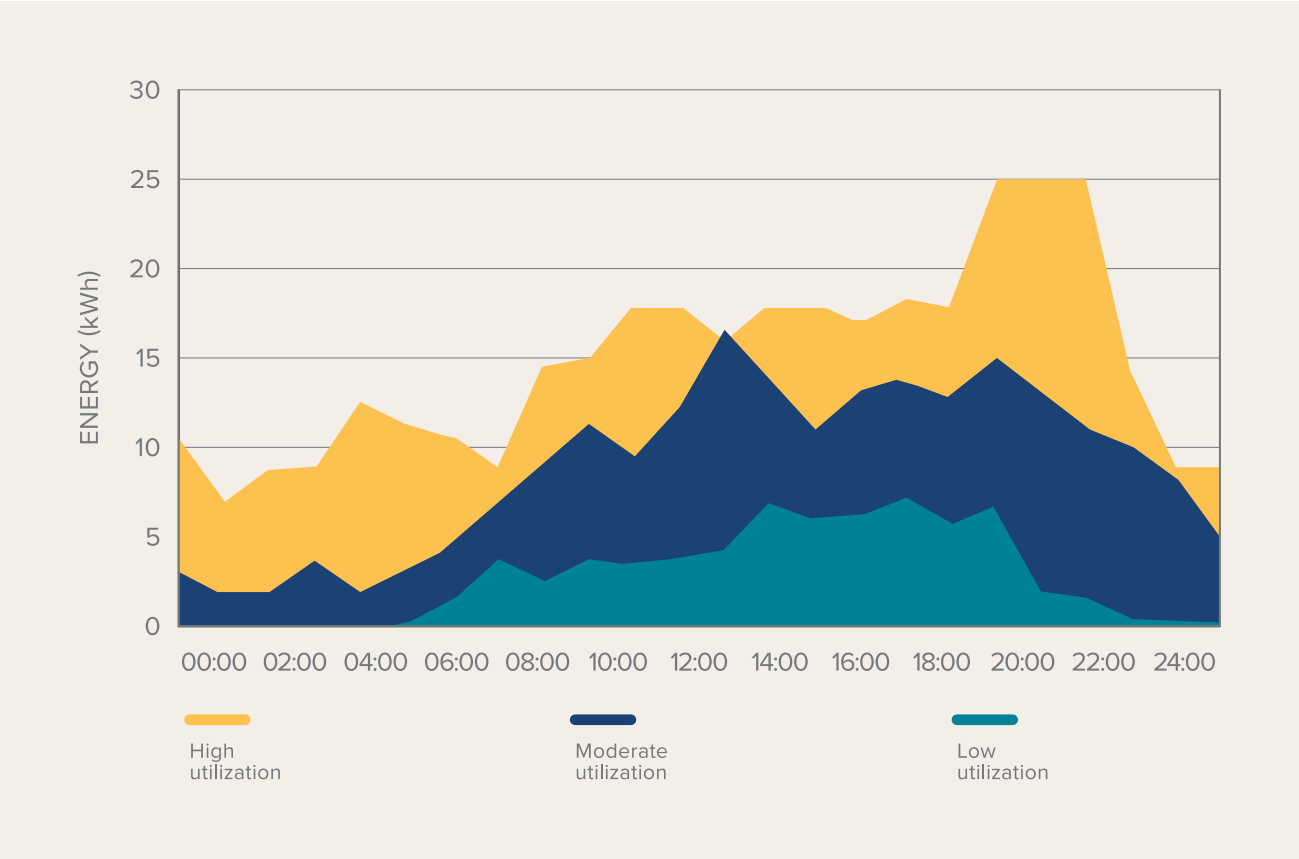
Public AC charging

AC charging stations with power up to 7 kW per charging port are common in retail spaces, restaurants, and workplaces. These typically experience higher daytime and evening use. As utilization increases the daily profile typically flattens as more users are charging in early morning and late evening. Peaks tend to occur in late afternoon and evening when retail activity is higher. The figure below shows what a station profile may look like for a charging station with four 7 kW charging guns. Note that even at higher utilizations the peak station demand is below the theoretical max station demand of 28 kW. However, systems must be designed to deliver the full nameplate capacity of the station.

Utilization rates have been observed as low as 0% and as high as 50% for public stations. Rates as high as 90% have been achieved in highly opmitized captivate fleet operations

FIGURE 4

Example load profile for a typical day of a moderate speed AC charging station with four charging guns



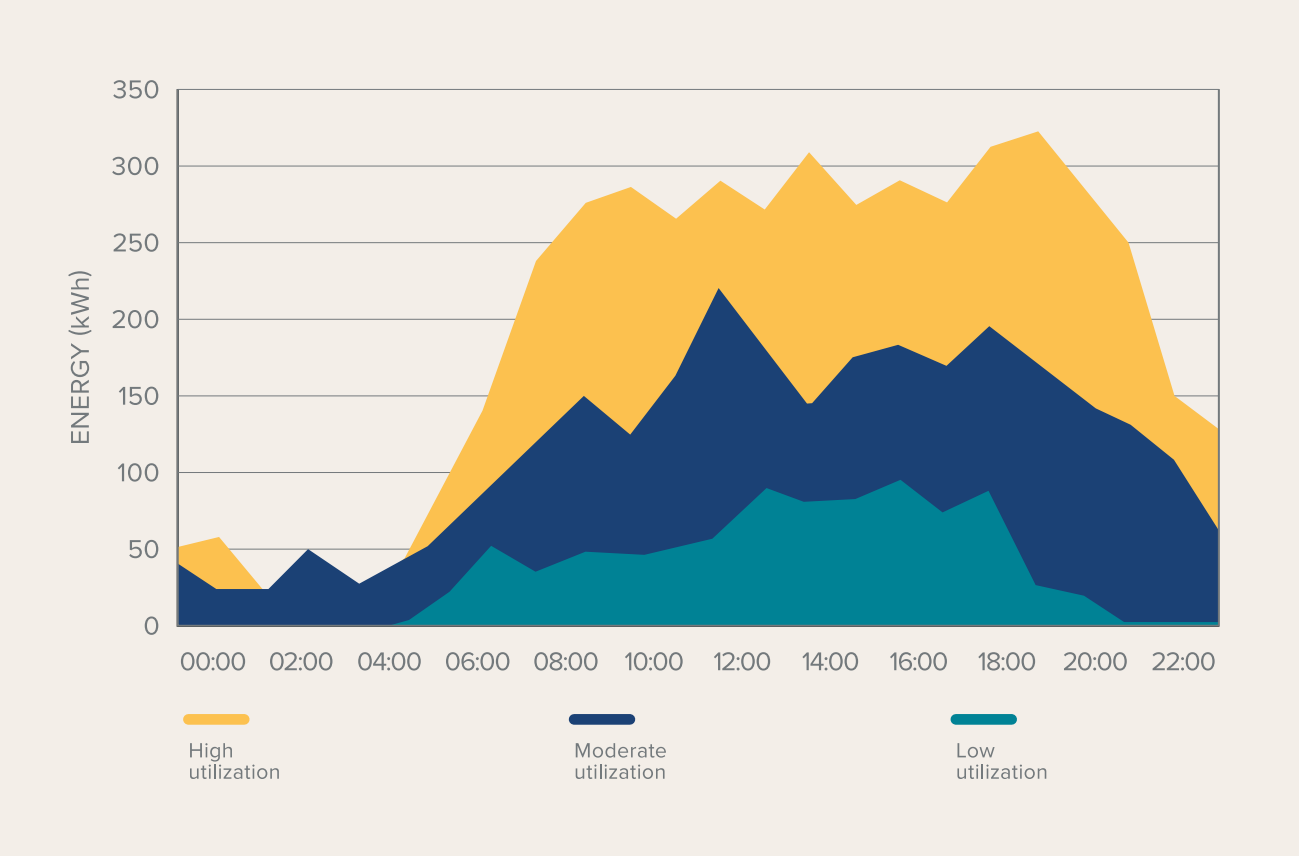
Public DC charging

DC fast charging stations serve significantly higher number of customers per day and have much higher peak power demands. While most Indian-made electric vehicles today cannot accept 50 kW fast charging today, it has been established as the standard fast charging power in the global EV market and it is expected that many vehicles operating in India will charge at 50 kW and higher in the future.

The chart below shows what a daily profile may look like for a station with eight charging guns each delivering up to 50 kW with significantly higher daytime use when people are more active. Note the lower peak demand of lower utilization stations. This happens because lower utilization stations rarely have all eight guns in use at full power at the same time and thus the station peak is much lower than the max nameplate capacity of 400 kW.

FIGURE 5

Example load profile for a typical day of high speed DC charging station with eight charging guns

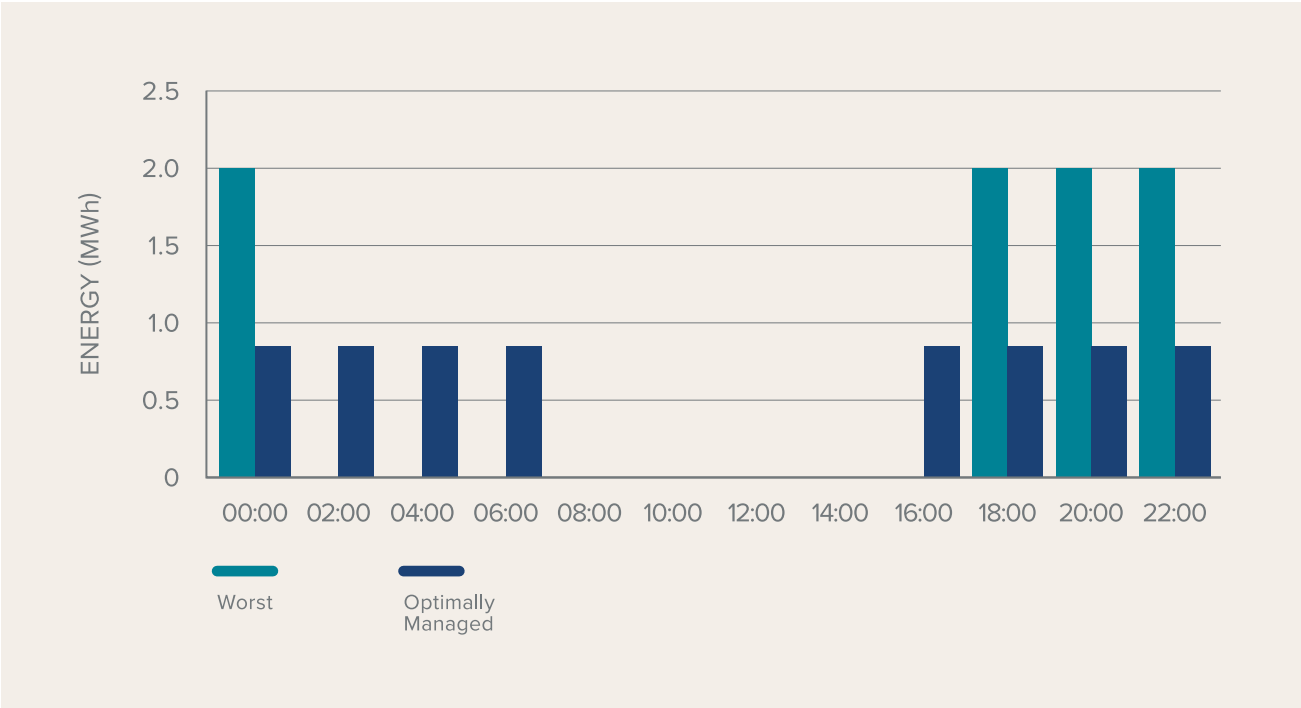


Bus depot charging

Bus charging depots may serve just a few buses or as many as several hundred depending on the size of the fleet. The load profile of a bus depot is dependent on the operational constraints of the transit agency and many transit buses will need to charged overnight during a limited window. Depot loads will range from several hundred kW to several MW. Some routes will require on-route charging that may need charging power as high as 500 kW. The chart below shows what a bus depot load profile might look like for a fleet of 40 buses. The blue bars indicate a 'worst case' and the grey indicate 'optimal managed case' for a fleet of 40 buses. This scenario assumes buses are in use during the day and have an overnight charging window between 8 p.m. to 5 a.m. Note the worst case assumes all 40 buses charge at full power (50 kW each bus) immediately when they get into the depot and the best case is achieved by spreading the charging needs out evenly across the entire time available for charging.

FIGURE 6

Example daily load profile for a bus charging depot serving 40 electric buses with 40 DC fast chargers



Flexibility

Designing a system that treats EV charging as flexible and creating programs and price signals to shape the demand will greatly increase a discom's ability to influence how EVs impact their system and operations. Demand must be managed both in time and space to opmitize overall systems costs. Unless encouraged to charge at a specific time or location, most EV owners will default to a charging behaviour that is easiest and most convenient.

For many that means they start charging as soon as they arrive at their destination and opt for the highest power option. However, in a majority of cases those EV owners do not need to charge using the quickest method. Most personal vehicles are parked more than 90% of the day and thus have 22 hours per day to be recharged, indicating that slow AC charging can meet the needs of many.

Different vehicles and use cases will avail different levels of charging flexibility. Private vehicles with access to home and workplace charging will offer the highest level of flexibility and responsiveness to price signals. On the other hand, high-utilization commercial vehicles that minimize downtime (e.g., charging) and maximize driving will offer the least flexibility. Understanding the level and type of flexibility that different EV customers offer is the first step to designing the right price signals and customer programs. The table below provides a summary of typical flexibility characteristics of various vehicle segments that can help inform tariff design.

TABLE 5

Load flexibility considerations for different vehicle segments

	LEVEL OF FLEXIBILITY	TYPICAL CHARGING BEHAVIOUR	CONSIDERATIONS FOR DISCOMS
PRIVATE TWO-WHEELER	High	Day and night	Individual loads are small, aggregation is necessary
PRIVATE FOUR-WHEELER	High	Day and night	Cars will default to DC fast charging if priced the same as AC
THREE-WHEELER, COMMERCIAL CAR	Low	Slow speed at night High speed during the day	Limited daytime flexibility due to business needs. Fleet operators are a natural aggregation of many vehicles and may be receptive to demand response programs
BUS	Medium/low	Slow speed at night High speed during the day	Buses offer a big opportunity for managed charging and have a great deal of load predictability. Discoms should prioritize working with bus depots to ensure managed charging practices are taken.

06 KEY CONSIDERATIONS FOR VEHICLE SEGMENTS

KEY CONSIDERATIONS FOR VEHICLE SEGMENTS

When considering the impact that time, location, and charging method has on system operations and planning, it is useful to understand the different types of vehicles and their operational needs

This section provides a summary of important questions and issues that discoms should consider when planning for EV readiness.

When considering the impact that time, location, and charging method has on system operations and planning, it is useful to understand the different types of vehicles and their operational needs. Not only do different vehicle segments draw different power levels and require different amounts of energy per charging event, each vehicle segment has multiple options for how, when, and where they can charge. Private vehicle owners will behave differently than commercial vehicle owners and respond differently to price signals. While commercial customers will have different levels of price sensitivity across different business operations and those different levels of flexibility will determine how responsive they can be to price signals given by discoms.

The section below offers some important considerations for private, commercial, and transit vehicle charging behaviour.

Private vehicles

1 **Two-wheelers will likely charge on a standard outlet:** 70% of vehicles sold in India are two-wheelers. Electrification of this vehicle segment is expected to grow quickly and will likely be a leading market segment. The majority of electric two-wheelers on the market today can be fully recharged overnight or during the workday in a matter of hours using standard three-pin household plug. Many models have removable batteries that allow charging anywhere existing plugs exists and may not necessarily require a dedicated charging station for home or workplace charging.

While this is good news for the ease of charging, it could mean that discoms will not have full awareness of when and where new electric vehicle loads are added to their system and the charging method may not include capabilities for automated charge management.

It is recommended that discoms develop EV programs that encourage or require customers to notify discoms when they register a new electric vehicle and offer incentives for charging systems with some automated control capabilities.

2 **Cars from different OEMs will have wide ranges of power ratings:** Currently the electric cars manufactured in India have relatively small batteries and are not designed to accept high power levels. However, imported, higher-end vehicles can charge at rates between 7 and 20 kW at home and as high as 50–150 kW on pubic DC fast chargers. Different customer demographics

may require different system upgrades depending on the vehicle. The implication for network capacity and potential upgrade requirements will not be the same for all vehicle types and the value of demand response from higher power AC home and workplace charging will be greater for vehicles with higher charging capacities (e.g., imported vehicles).

We recommend discoms consider different interconnection requirements for vehicles with lower and higher charging rates (e.g., minimal red tape for low-speed charging two-wheelers as compared to potentially more evaluation and communication for moderate AC home charging or DC fast chargers).

3 **EV adoption happens in clusters:** Often EV adoption will happen in neighborhood clusters with customers having similar levels of affluence. Experience in California has shown that EV penetration in certain neighborhoods can be 10 times higher than the service territory average. This is particularly important for highly affluent neighborhoods where global EVs may have a higher than average penetration level and add significant new load to the network (e.g., if 10 Teslas could add 200 kW of new demand to a feeder where 10 Hero Electric scooters would add only 20 kW). This also applies for workplace and retail charging stations that are likely to grow in capacity as EV penetration increases.

We recommend that discoms assess areas in their service territory where EV adoption may grow more rapidly and carefully consider the size of the transformer upgrade used. For example, consider planning for the next 10–20 EV chargers in the area rather than just the few in the near term.

4 **Private vehicles can charge at home, work, or on public networks:** Private vehicles typically drive shorter distances on a daily basis and may have multiple options for when and where they charge. Owners can choose to slow charge at home overnight, at work during the day, or fast charge during lunch or evening times. This creates a high level of flexibility in their charging behavior that can be captured by discoms if the appropriate price signals are sent. For example, if an owner has the option to charge at home or at work and one of those options is better for the discom (either the time or the location) then we recommend discoms offer the right signal to the

owner so they choose the charging option that is best for the grid. This includes both time of use price signals and in some case, location-based price signals.

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5 **Cars need dedicated parking with charging:** Customers who own electric vehicles do not all have dedicated parking and thus public charging will be the primary means of charging their vehicle. Areas where consumers go for long periods (malls, restaurants, other retail) with dedicated parking will be likely locations for setting up public charging stations. Existing parking garages may require service upgrades as EV penetration increases over time and new parking garages should be properly equipped to handle load growth.

We recommend that discoms consult with new large commercial customers to understand their EV infrastructure plans.

Commercial vehicles

Commercial vehicles include fleets of vehicles owned and operated by a single entity or privately-owned vehicles used for commercial purposes such as taxi services. In the near term we expect that commercial vehicles will be likely candidates for electric replacement and thus extra attention should be placed on commercial customers that currently operate vehicle fleets.

1 **Different fleets will have different levels of flexibility and without price signals loads will be unmanaged and potentially have unnecessarily high peaks.** Some very high-utilization fleets may have no flexibility in how they charge, where they charge, and when they charge as they must meet strict business operational needs. Other fleets that have more down time (time when vehicle is not in use) can have a more flexibility. However, having flexibility does not necessarily mean a fleet will use it to the advantage of the discoms. Inquires on flexibility should be made at the early stages of new interconnection requests so both discoms and fleet operators are aware of saving potential.

We recommend that discoms proactively educate customers on cost saving potential that fleet operators can realize if they are thoughtful about when and how they charge.

2 **Charging hubs can be multi-MW loads.** When fleets of hundreds and eventually thousands of vehicles use a single depot for charging, the unmanaged peak load can quickly overwhelm existing transformer capacity and in some cases will require dedicated substations. Creating maps and guidance on where hosting capacity exists and sharing it with commercial customers makes early siting decisions easier for discoms and fleet managers.

We recommend choosing charging depot locations with both discom and fleet business needs in mind.

3 **Fleets will grow over time, sometimes rapidly moving from pilot to full implementation.** Understanding how a fleet will grow over time can help with initial infrastructure sizing decisions. For example, if a commercial fleet is planning on transitioning to electric in phases, they may choose to operate 10 electric vehicles this year and choose to expand to 50 the following year and then 1000 in year three. It is important to understand the potential need for capacity expansion so the discom can avoid upgrading the customer connection capacity multiple times.

We recommend that discoms consider the likelihood of future expansion and design initial upgrades to have some expansion capacity planned into the upgrade.

Public transit buses

Transit buses are good candidates for electrification due to their predictable routes and the favourable economics of their operations over diesel buses. Globally and in India there is growing policy and subsidy support early adoption of electric buses. Already FAME II has sanctioned subsidy for nearly 6,000 electric buses this year and continued interest in electric buses is likely. Taking care to include transit buses in EV readiness plan is necessary. Below are some key considerations when planning for electric bus deployment in a discom service territory.

1 **Bus depots will have very large loads.** Bus fleets will be charged primarily in existing or new depot buildings where other fleet management tasks already occur. This will require a large number of high-power chargers to be installed and served by a single interconnection point. Transit agencies are currently procuring their first tranche of electric buses in the numbers of 100-500+ and in the future the number of electric buses will be in the thousands. Every bus will need to be fully recharged each night over a several hour period and is likely to draw between 25 and 100 kW and consume 200–400 kWh per day, depending on the operational schedule. Thus, bus depots serving 100 buses could require up to 10 MW of service to meet their charging needs.

We recommend that discoms begin assessing grid capacity at existing transit depots and assess what network upgrades will be required as electric buses begin to be deployed.

2 **Bus depots will be charging primarily overnight.** Most intercity buses serve a majority of their customers during the day and will be charged overnight when not in use. Without guidance and price signals from the discom, the fleet operators will charge the buses at their convenience and may not consider the opportunity to shift their loads in a way that lowers costs and network congestion.

We recommend that discoms work directly with large fleet operators in their planning phase to help them opmitize charging behavior to minimize infrastructure and upgrade costs that could be associated with unmanaged charging.

3 **Loads will start with a small number of buses and then grow rapidly after the pilot phase.** Many transit agencies are currently experimenting with electric buses and have procured a relatively small number of new buses in their pilot phase. After they become comfortable with operating the electric buses and are exposed to the lower fuel and operation cost, they will begin to expand their electric fleet rapidly. This is particularly important for citing of new charging depots and on-route high speed (500 kW) charging.

We recommend that discoms work early with transit agencies to understand the future service needs of these agencies when they move from pilot phase to full fleet electrification.

4 **Some buses will require on-route charging.** Depot charging will likely serve a large fraction of electric bus charging needs. However, some intercity routes and many long-distance routes will require on-route super-fast charging. These on-route super-fast chargers can draw as much as 500 kW per charger. On-route charging is likely to be a very 'peaky' profile where the system is used for short periods at a regular frequency. There is an opportunity to utilize the grid capacity for other charging needs at these locations when the on-route charge is not in use.

We recommend that discoms play a 'match making' role in areas where high capacity is used intermittently so that the locational load can be filled in by other charging needs.

07 KEY CONSIDERATIONS FOR SITING

KEY CONSIDERATIONS FOR SITING

This section provides important considerations to be taken by all stakeholder groups when planning for public EV charging deployment.

Urban public charging

Urban public charging infrastructure will serve a mix of customers including personal vehicle owners who cannot charge at home or work, personal vehicles that need a top-up to make it to their normal charging means, transportation network companies (Ola, Uber), eAutos who need to recharge in the middle of their shift, and others. The diverse customer base adds complexity to forecasting where and when demand will occur. However, there are a number of considerations that will minimize the uncertainty and allow for early preparedness:

- Mapping where vehicles are parked now provides insight to where they will likely need charging in the future. Taking advantage of times when vehicles are parked for long periods gives greater amount of demand flexibility and maximizes the EV user experience.
- Considering the FAME II location requirements for the minimum number of chargers in an urban area (e.g., based on a 3 x 3 km grid minimum) provides some guidance on where public chargers will be sited in the early phases of EV infrastructure buildout.
- Assessing the availability and cost of land (from government or private sector) in the urban areas of discom service territory will be an important constraint in citing public charging infrastructure.
- Knowing the length of customer visit (dwell time) at different parking locations (home, work, retail) can indicate the type of chargers (slow, moderate, fast) that will likely be used.
- Forecasting the likelihood of coincident peaks at large charging banks and assessing the feasibility of storage or onsite solar to mitigate infrequent peaks can lower system upgrade costs.

Highway public charging

Highway charging stations will primarily serve longer distance commuters and commercial applications. Highway charging will take the form of large depots with dozens of charging guns including both fast and slow charging options. Due to the nature of highway charging it is expected that the majority of stations will be high-speed fast chargers aiming at the shortest refueling time and least disruption to the user's journey. The following are some key considerations that should be taken when planning for highway infrastructure:

- FAME II location requirements indicate a maximum of 100 km between highway charging stations.
- Existing service capacity along highway corridors can be mapped and shared with EV network operators to identify good locations for charging stations.
- Coincident peaks at charging banks can result in high but infrequent peak demands. A bank of 10 chargers may not often all be in service at one time. Batteries and on-site PV can be used to help mitigate infrequent peak demand events and avoid costly grid upgrades.
- Increasing battery size and performance over

time will result in increasing power needs and shorter sessions. Station profiles will get peakier with lower load factors in the future.

Captive commercial charging

Unlike public charging networks that serve a diverse set of users, and as a result have unpredictable and highly varied charger load profiles, a captive charging network is used by a single fleet and under the prevue and planning of a single fleet operator. Having a dedicated charging network serving a single fleet allows for much higher charger utilization and better optimization of the network. This higher level of control gives the fleet operator and the discom a better understanding of the load profile now and in the future.

Importantly, early engagement between fleet operators and discoms provides an opportunity for co-optimization of fleet and discom priorities (e.g., lowest cost while still meeting business needs). Leveraging discom network capacity maps makes it possible to identify priority areas for captive charging depots that make use of existing infrastructure. These will need to be mapped alongside land availability, location of charging needs, and real-estate costs—making for a complex optimization problem.

The following should be considered when planning for captive charging infrastructure, including for electric buses:

- Understand early if the fleet operator plans to make use of a depot charging strategy where all vehicles return to a depot to charge or if the fleet operator needs a disperse network of chargers across their operating footprint.
- Work with large fleets early to understand what level of load flexibility they will have and ensure they are subscribed to the right tariff that allows flexibility savings to be captured.
- Many fleets will first electrify a subset of their fleet to test operations and only expand when economic and operational aspects are proven out. Discoms should be aware of the potential growth in charging needs that are likely to occur when the fleet operator chooses to have a 100% electric fleet.
- Knowing the location of existing fueling and maintenance depots for public buses gives a good indication of where they will require significant new load capacity to charge buses when they go electric.

08 REVIEW OF EXISTING EFFORTS IN INDIA

REVIEW OF EXISTING EFFORTS IN INDIA

Role and efforts of government entities

As a part of the larger EV adoption push, different aspects of EVSE deployment—standards, incentives, adoption and execution—have been entrusted to different government entities. The following table lists out the entities and the roles and responsibilities:

EV Charging deployment is being driven by government incentives and initiatives

TABLE 6

Roles and responsibilities of government entities

ORGANIZATION	DETAILS
Department of Heavy Industries (DHI)	» Overseeing the second phase of Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME II) in India. » Circulated an expression of interest (EOI) inviting proposals for availing incentives under FAME II for deployment of EV charging infrastructure.
Ministry of Power (MoP)	» Issued "Charging Infrastructure for Electric Vehicles—Guidelines and Standards". » Charging of EVs to be considered a service and not a sale of electricity.
Department of Science and Technology (DST) & Bureau of Indian Standards (BIS)	» BIS and DST are working together on indigenous charging standards. » DST is supporting industry-academia collaborations to develop indigenous low-cost chargers.
Central Electricity Authority (CEA)	CEA is entrusted for the creation and maintenance of a national database of all public charging stations working with both state and national nodal agencies.
Bureau of Energy Efficiency (BEE)	BEE to is the central nodal agency for rollout of EV public charging infrastructure as MoP's guidelines.
State discoms	State discoms are the default nodal agencies at the state level unless a state government deems in favour of other urban local bodies or public sector units.
GST Council	Tax reduction on charger or charging stations for EVs from 18%t to 5% (with effect from 1 August, 2019).
Energy Efficiency Services Limited (EESL)	A JV under MoP, EESL has been actively installing public charging stations in Delhi.

EV charging infrastructure under FAME II

A key driver of EV adoption in India has been the INR 10,000 crore FAME II scheme. An important and relevant component is the INR 1,000 crore earmarked for charging infrastructure. DHI had issued an expression on interest (EoI) inviting proposals for availing of this incentive for deployment of EV charging infrastructures for cities in August 2019. As of January 2020, 2,636 EV chargers have been allotted the incentive in 24 states and union territories, out of which 1,633 are fast chargers.

1633 fast chargers and 1003 slow chargers have been sanctioned under FAME II

TABLE 7

EV chargers sanctioned under FAME II

NO. OF EV CHARGERS SANCTIONED BY STATE				
317 Maharashtra	205 Rajasthan	131 Kerala	37 Bihar	18 Odisha
266 Andhra Pradesh	172 Karnataka	72 Delhi	29 Sikkim	10 Uttarakhand
256 Tamil Nadu	159 Madhya Pradesh	70 Chandigarh	25 Jammu & Kashmir	10 Puducherry
228 Gujarat	141 West Bengal	50 Haryana	25 Chhattisgarh	10 Himachal Pradesh
207 Uttar Pradesh	138 Telangana	40 Meghalaya	20 Assam	
TOTAL EV CHARGERS SANCTIONED **2636**				

EESL's experience in rolling out public charging stations in Delhi

Energy Efficiency Services Limited (EESL) has been at the forefront of the EV charging roll-out in India. It developed this in partnership with USAID's SPARC Program. In 2019 EESL initiated a large-scale deployment of public charging stations, with its role as the owner and operator, in New Delhi within the New Delhi Municipal Council (NDMC) area. This area was selected on the basis of high traffic and footfall, ease of coordination, and complementarity with the national smart cities mission.

Key to its success have been detailed analysis and thinking around organizational partnerships, business model design, cost economics of the public charging stations, well-designed site selection methodology, identification of non-tariff revenue streams, active use of technology and lastly scalability of their methodology.

Partnership

Perhaps the most important aspect has been the MoU with the New Delhi Municipal Council (NDMC) which has a role as both land owner and power discom. This allowed for a reduced transaction cost in terms of having a single authority to coordinate for both land and power. This may not always be replicable in different geographies, but it nonetheless goes to show the need to get alignment across land and power provider for charging operators to have success. EESL created value for NDMC through additional revenue streams from real estate rental as well as an EV tariff, through increased EV adoption in its area which will lead to improved local air quality, and through potential for load management for its role as discom. For EESL, beyond ease of coordination, this partnership allows for suitable guidance on siting to maximize asset utilization over time. An energy-based rental in the form of revenue sharing was designed in a manner which benefitted both EESL and NDMC.

Business model—costs and revenue

The type of charger was decided based on an assessment of EV availability in the market. Given that most public charging will be opportunity charging, EESL decided to install chargers which would support fast charging for the available models. The business cost for EESL is listed below. Land cost remains the largest cost component.

EESL's experience with demand aggregation and synergies in this existing program is helping bring down the per unit cost of EVSE by 15–20%. EESL is also exploring low cost financing from multilateral banks such as the Asian Development Bank (ADB) and the World Bank. While there are multiple pricing strategies that could be deployed for public charging stations, EESL has deliberated and decided to implement an energy-based pricing model due to its simplicity, with the eventual goal to transition towards a time of use or membership model once the market matures. Additionally, EESL is also exploring options to generate non-tariff revenue through advertising and marketing rights at the public charging stations.

TABLE 8

Business cost for EESL

POWER	CAPITAL EXPENDITURE	OPERATING EXPENDITURE
» Tariff (fixed and energy charges) » Additional surcharges and duties » Cost of power loss in AC to DC transformation » Taxes/duties as levied by state and central governments	» EVSE unit » Civil works » Earthing » Auxiliary equipment such as meter, meter box, barricades and canopy, cameras, etc. » Power connection and transformer costs depending on who is providing it » CAPEX for Customer Management System (CMS) and mobile app	» Annual O&M for EVSE, CMS and data » Insurance for EVSE » Gateway charges » Land rental and O&M for car parking space » Facility management services » Marketing and awareness

Siting

Ultimately the challenge of making the business viable rests on increasing the utilization rate of each public charging station, and clever siting is the crux of this. EESL went about a location assessment under the following framework:

The location was prioritized based on ease of parking, power availability, distance from nearest power source, civil works required, visibility and footfall.

Customer interface and data analytics

EESL developed a digital platform to book and pay for charging. Data is being collected around state of charge (SOC), total energy consumed, etc. A charging and monitoring dashboard was developed to draw out key insights.

Scaling

EESL has standardized this methodology including all templates and frameworks as check-lists for future scale up efforts in New Delhi and beyond. Additionally, regular capacity building is being deployed to train officials from regional offices.

Source: *www.eeslindia.org/content/dam/doitassets/eesl/pdf/programmes/eVehicles/EVCI.pdf*

09 RECOMMENDATIONS AND BEST PRACTICES

RECOMMENDATIONS AND BEST PRACTICES

The following section provides a summary of international best practices and recommendations for discom's EV readiness. The section covers tariff design, operational best practices, and key steps to developing an EV readiness program.

Tariff design

Thoughtful and fair tariff design is an important component of a functional EV ecosystem. Tariff design must consider many factors including cost recovery, level of cross subsidy, price signals, and other socio-economic components beyond the scope of this primer. The following is a list of important EV-related considerations for good tariff design:

tariff desig

TIME OF USE

Tariffs that utilize a time varying rate for both energy and power consumption can significantly reduce the cost to serve a customer by lowering system upgrade costs and maximizing use of lower cost electricity. Discoms should provide price signals to customers to charge when power is least expensive or to manage aggregate load to keep loads below system thresholds.

CRITICAL PEAK PRICING

For the few hours per year when the system is overly constrained, at distribution, transmission, or generation levels, the use of critical peak pricing can help alleviate demand for those few hours. Significantly increased cost per kWh can be applied to strongly encourage users with flexibility to shift their load a few hours from time to time.

LOCATION-BASED INCENTIVES

Making use of distribution network capacity data, specifically areas of excess capacity, to provide discounts or interconnection priority to customers willing to setup their charging services there can allow for more optimal use of existing infrastructure and delay the need for new infrastructure.

FLEET/AGGREGATED DEMAND RESPONSE

Developing a program that allows third parties to aggregate and manage large numbers of individual loads to provide a flexible demand reduction capacity to the discom can provide a low-cost capacity management option.

Operational practices

The following provides key learnings from international experience in setting up EV readiness programs:

key learnings

HAVE ADEQUATE STAFF AND PROCESSES IN PLACE EARLY

Discoms need to be properly staffed and have processes in place to plan for and serve new EV customers. Public charging companies can make the process better by using standard specifications that meet utility requirements.

MAKE INFORMATION + DATA NEEDS CLEAR

Good interconnection practices require the discom to make clear what information it needs from the customer to prepare the site and to develop a quote. This information should be in a standard format and clearly posted in the public domain. Paperwork and requirements should be minimal for small interconnection requests.

CREATE TRANSPARENCY AROUND DISCOM NEEDS + PRIORITIES

Achieving good private sector engagement in deploying and funding charging infrastructure in a way that is beneficial to the discom requires a high level of transparency about the process steps, the timelines, and what is needed from the charger company to build out their network. Discoms should work closely with charging companies in the early stages to make sure communication is good and processes are understood to ensure that discom benefits are maximized and customer costs minimized. Discoms must have clear channels of communication throughout the entire process.

ENSURE EASY ACCESS TO NETWORK INFORMATION

Providing easy and early access to network maps that show discom network system capacity can streamline interconnection processes by avoiding requests at locations where significant upgrades will be necessary and thus face delayed interconnect timelines. This is especially helpful for large captive charging stations that may have some early flexibility in where they setup their operations.

MAKE USE OF PRICE SIGNALS, DEMAND RESPONSE, STORAGE + PV

Regularly evaluating system needs and identifying areas where demand side measures and distributed energy resources can provide costs saving opportunities can lower cost and maximize flexibility value.

Building EV readiness programs

The following provides a set of near-term actions that can be taken to begin building a discom EV readiness program:

quick actions

#1 Circulate details on state and central policies relating to EV and EV chargers to appropriate staff so they are aware of government intentions to support electric mobility.

#2 Educate relevant staff and build internal capacity around EV and EV charging implications for discoms (e.g., this report). Include technical, customer facing, and business unit employees.

#3 Conduct a needs assessment for your service territory that explores current and future EV penetration, as well as identifying likely commercial customers that may be requiring EV charging in the next years (e.g., bus transit, taxi fleets, office buildings, malls).

#4 Designate a nodal officer for EV infrastructure customers and inform relevant staff of the nodal officer and their role and responsibilities.

#5 Establish a separate interconnection queue for large EV infrastructure customers.

#6 Produce customer guidelines for interconnection requests.

#7 Develop a hosting capacity map of network capacity that identifies areas of limited and available interconnection capacity.

#8 Design time of use rates for EV customers that send price signals, work with SERCs to avail the tariff.

#9 Assess growth and outlook of different customer types and flag areas where additional planning is required.

#10 Identify pilot opportunities to work with commercial and industrial customers on managed EV charging, depot siting, etc.

#11 Develop a customer awareness program to share information on EVs and EV charging infrastructure.

10 CONCLUSION

CONCLUSION

The first step in planning for an EV future is to build capacity across the key stakeholders to ensure all parties have the fundamental knowledge required to have productive planning discussions and understand the trade-offs and constraints each group faces. In order to capture demand flexibility and opmitize network build out discoms, regulators, OEMS, and charge network operators need to understand the forces driving adoption and work together to influence how those vehicles interact with the grid.

Early pilot projects that demonstrate how EV load profiles can be shaped in a way that minimize gird infrastructure costs, maximize consumption of renewables, and meet customer needs though time-of-day pricing and aggregated demand response programs must be prioritized and highlighted across Indian discoms.

Network operators will deploy an assortment of charging technology options to meet their customers' various charging needs. Discoms need to provide the appropriate information and price signals to indicate to users when, where, and how they can charge at least cost to disocms, ratepayers, and EV owners. When designed properly this price-based choice gives discoms greater influence over how EVs interact with their grid.

The time for discoms and other stakeholders to prepare for EV readiness is now. Discoms across India are in various stages of rolling out smart meters, testing time-of-day rates, building out demand side management (DSM) programs. It is important that discoms develop EV readiness plans that are in alignment and support ongoing and future smart meter implementation. Discoms that embrace the growing EV market and are proactive and not reactive to the opportunity will benefit greatly from the electric mobility market.

Improving and developing internal processes and leveraging national and international best practices around EV charging infrastructure will support discoms in maximizing benefit and minimizing challenges associated with the global transition to electric mobility. This EV infrastructure primer gives discoms the practical guidance to begin preparing for EVs in their territory and sets discoms up for success through proactive and integrated planning.

Key takeaways include:

- Prepare for the electric mobility transition early and educate staff on the benefits and challenges associated with this new customer class.
- Create an EV readiness team or nodal officer that works cross-functionally across all relevant internal departments.
- Be aware of central and state government incentives, targets, and schemes that will influence the rate of EV adoption in your territory.
- Develop an EV readiness plan that addresses near, mid, and long-term planning horizons in an integrated way that considers growing penetration of renewable generation, smart meters, demand response, energy efficiency, time-of-day tariffs, and increased wholesale market participation.
- Ensure good communication with customer segments that are likely to adopt electric vehicles rapidly and at a large scale (e.g., transit, taxi fleets, Ola/Uber, etc.)
- Learn from peers in India and globally that have early experience with EV infrastructure planning and share your own learnings and challenges with other discoms.

11 APPENDIX A

APPENDIX A

EV charging incentives under state EV policies

Beyond the national level incentives, state EV policies have shown intent and ambition to deploy EVSEs. Incentives include capital subsidies on plants and equipment, discounted electricity, reimbursement of state goods and services tax (SGST), interest subsidy and earmarking of land, etc.

state policies

ANDHRA PRADESH

- Capital subsidy of 25% of equipment and machinery for DC chargers for first 100 and 300 chargers—for chargers 100 V and up and below 100 V, respectively
- Capital subsidy of 25% of FCI for the first 50 swapping stations
- 100% net SGST reimbursement
- DISCOMs will invest in chargers at government buildings and public places through a PPP model

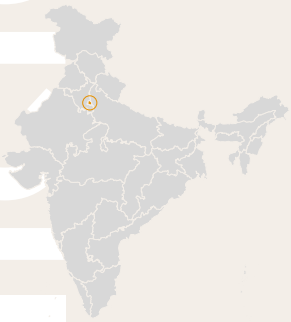
BIHAR*

- Commercial public EV charging stations to be eligible for 25% capital subsidy on equipment/machinery (limited to INR 5 lakhs per station) for first 500 stations
- Industrial electricity rates to be applicable to EV chargers
- Government will identify and allot suitable land across the state on lease basis for charging and swapping stations
- Transport Department to create charging stations at all “Rain Baseras” for rickshaw pullers who will be charged at concessional rate
- Fast chargers to be installed at government offices
- Common charging points in residential areas, societies, bus depots, public parking areas, railway stations, fuel pumps, etc. to be allowed.

state policies

CHANDIGARH*

- Public parking lots will have a 30% space dedicated for EVs
- Fixed charge of INR 4 per unit and a monthly charge of INR 100 on electricity bill for EV charging stations
- Subsidy of 30% on the installation of home chargers and 15% for charging infrastructure companies



DELHI

- All new home and workplace parking to allocate 20% of all vehicle holding capacity/parking required to be EV ready
- 100% subsidy for the purchase of charging equipment up to INR 6,000 per charging point will be provided for the first 30,000 charging points at residential and non-residential buildings
- For public charging stations, 'energy operators' (EOs) will be invited to set up charging and battery swapping stations across Delhi in multiple phases by pooling and providing concessional locations at bare minimum lease rentals
- Provision for providing capital subsidy for the cost of charger installation
- Favourable electricity tariff for EOs and BSOs

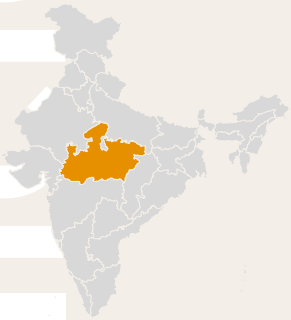
KARNATAKA

- Investment subsidy for first 100 chargers
- EV charging manufacturing to avail of similar incentives as EV manufacturing

state policies

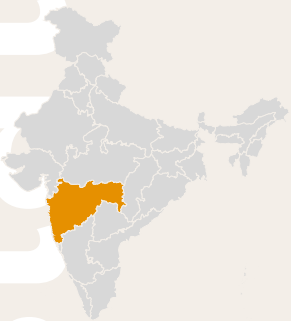
KERALA

- Kerala State Electricity Board (KSEBL) to setup initial charging and swapping stations



MADHYA PRADESH*

- Capital Subsidy of 25% of the value of the charging station equipment/machinery for the first 300 small charging stations, first 100 medium charging stations and first 100 large charging stations
- City codes to be modified for both public places and private buildings
- DISCOM to invest in charging networks in government buildings and public places
- All new permits for private development with a built-up area 5,000 square meters and above will mandatorily have charging stations
- Existing private buildings will be incentivized to setup charging/battery swapping stations
- Electricity tariff to be not more than 15% above ACS



MAHARASHTRA

- A subsidy of 25% or INR 10 lakhs, whichever is less, on the first 250 charging stations that will be set up near bus depots, petrol pumps, and public parking spots

state policies

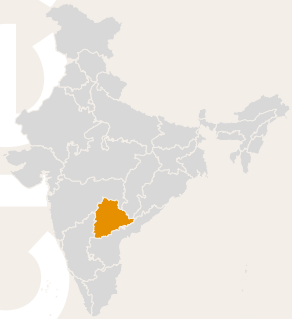
PUNJAB*

- Public charging stations through PPP with PSPCL as the nodal body
- 25% capital subsidy for first 1000 charging points (50% for equipment manufactured in Punjab). Limit of INR 50,000 per charging point (INR 1 lakh for equipment manufactured in Punjab).
- State to identify concessional lands
- Private charging: one charging point for every three parking slots For non-residential buildings, one charging point for every five parking slots for residential plots
- 100% electricity duty exemption

TAMIL NADU

- Public charging infra will be setup by TANGEDCO or through PPP model
- Charging points will be provided in the government office parking lots, TANGEDCO will invest
- One charging station to be set up at 25 km intervals on both sides of NHAI and state highways
- Electricity tariff to be not more than 15% above ACS
- Amendment to building and construction to be made
- 10% of parking space to be earmarked for EVs in commercial buildings

state policies



TELANGANA*

- Government to set up first 100 fast charging stations in GHMC and other cities
- Discoms will amend their policies
- Government land will be offered on long term lease at subsidized rates and 2-year moratorium period on rental
- Apartment associations will be provided capital subsidy of up to 25%, capped at 5 lakhs, for charging points in parking lots
- Residential townships will be encouraged to develop charging stations with capital subsidy of up to 25%, capped at 10 lakhs for each station with 4 fast chargers
- 75% of SGST paid on plant and equipment will be reimbursed
- Supply of renewable energy will be ensured on preferential basis

UTTAR PRADESH

- The state will facilitate land to PSUs at concessional rates in designated areas
- Electricity supply at commercially viable rates—policy will be introduced by Dept. of Power within three months of policy notification
- Capital subsidy to service units setting up charging stations and exemption of electricity duty for such service units

**Draft policy; yet to be notified*

12 APPENDIX B

APPENDIX B

Indian charging standards and codes

India Charging Standards 2017

The central government has proposed two sets of standards as of 2017: Bharat EV Charger AC-001 and Bharat EV Charger DC-001. These standards have been adopted by the leading Indian auto OEMs, including Hero Electric, Mahindra, Tata, and various electric rickshaw manufacturers. Global OEMs have adopted a different set of standards that are described later in this section.

Bharat AC-001 charging standards: IEC 60309 connector with a capacity of 2.5–3 kW has been adopted by the market. Most two-, three-, and four-wheelers in the market do not have on-board chargers that support fast AC charging, thus the Committee on EV Charging Specifications has yet to define faster AC charging standards and will wait until those features are introduced to the market to do so. RMI expects this to occur in the next 1–3 years.

Bharat DC charging standards: GB/T 20234.3 connector with up to a capacity of 10-25 kW with a current less than 200 A has been adopted by the market. Like the AC standards the committee has deferred to further define faster AC standards, however they have suggested that the Combined Charging System (CCS) is in consideration for faster DC chargers.

TABLE 9

Charging standards for India

	SERVICE REQUIRED (V, PHASE)	SERVICE REQUIRED (AMPS/PORT)	COMMUNICATION STANDARD	CONNECTOR COMPATIBILITY
LEVEL 1—STANDARD OUTLET	230 V, single phase	15	None	Standard three-pin
LEVEL 2 BHARAT AC-001	415 V, three-phase, five-wire AC system	15	OCCP 1.5 protocol	IEC 60309
LEVEL 3 BHARAT DC-001	415 V, three-phase, five-wire AC System	Up to 200	OCCP 1.5 protocol	IEC 62196 Type 2

India National Building Code 2016

Article 10.7.1: Electrical vehicle charging: Adequate electrical provisioning should be made for electric vehicle charging in designated spaces for electric car parks in enclosed/covered car parking. These electrical outlets should be fed from a separate distribution board located near such outlets for electric car parks. Distribution board and outlets should be protected and metered.

NOTE: Reference may be made to IEC 60364-7-722:2015 'Low-voltage electrical installations Part 7-722: Requirements for special installations or locations Supplies for electric vehicles.'

Article 10.7.2:
Car park management system: Wherever car park management system is provided in multi-level parking or other parking lots with features of boom barriers, pay and display machines (manned or unmanned type) and parking guidance system (for displaying number of car spaces vacant on various floors, direction of entry and exit, etc.), the electrical provisions for the same shall be adequately backed with UPS for protection of vehicle and for efficient car park management.

TABLE 10
International charging standards

SPEED	CURRENT	POWER (KW)	INTERNATIONAL STANDARDS				MINUTES TO SUPPLY 80 KM
			CHINA	EUROPE	JAPAN	NORTH AMERICA	
SLOW LEVEL 1	AC	Below 3.7	Standard wall socket			SAE J1772	400–540
MODERATE LEVEL 2	AC	3.7–22	GB/T 20234 AC	IEC 62196 Type 2	SAE J1772 Type 1		40–220
	AC	Up to 22	Tesla connector				
FAST LEVEL 3 DCFC	AC, three-phase	22–43.5	SAE J3068	IEC 62196 Type 2	SAE J3068		20–40
	DC	Up to 400	GB/T 20234 DC	CCS combo 2 connector (IEC 62196 type 2 + DC)	CHAdeMO	CCS combo 1 connector (SAE J1772 type 1 + DC)	3–40
	DC	Up to 150	Tesla and CHAdeMO connectors				10–40

12 APPENDIX C

APPENDIX C

International charging infrastructure statistics

Charging approach by country

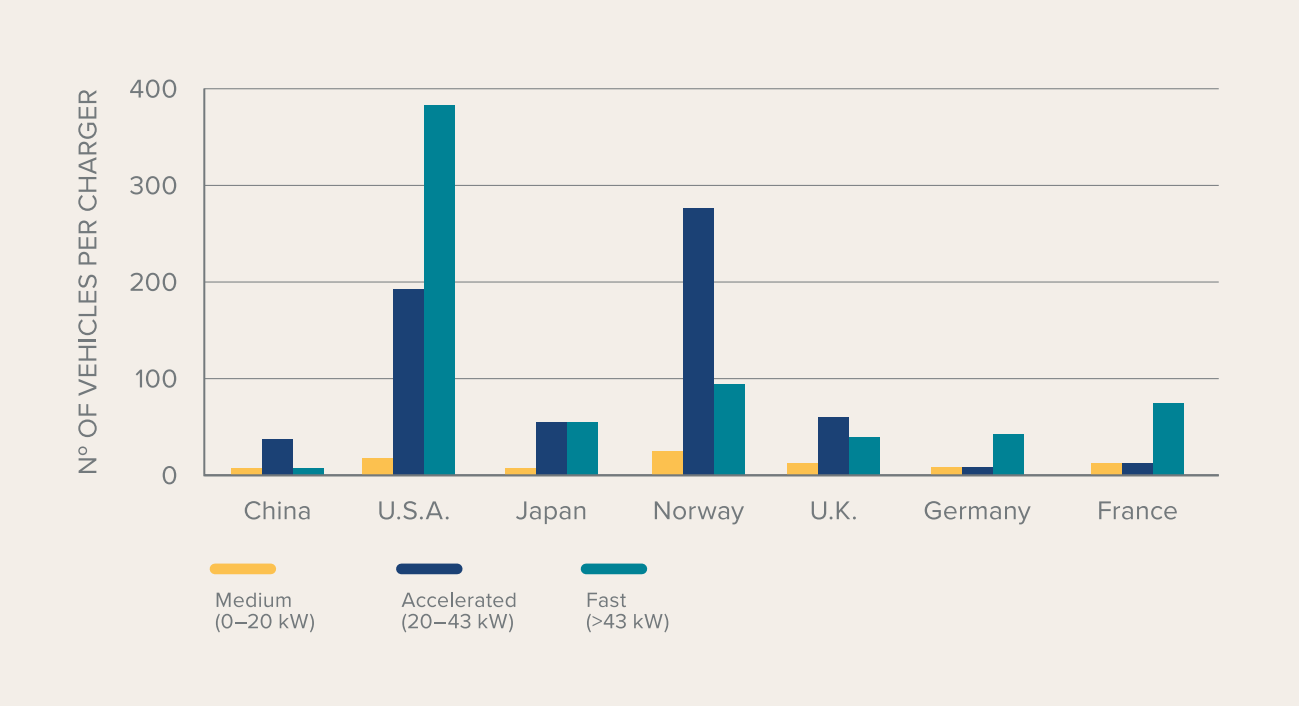
While most charging today happens at home or the workplace there is an underserved demand for public charging stations to support a robust and healthy EV city ecosystem, particularly in India. Public charging stations are especially important for EV owners that don't have access to private dedicated charging and parking facilities at their home or workplace.

In the nascent stages of the EV and EV charger ecosystem there is no globally accepted guideline or best practice used to determine the right number of chargers to support a particular size EV fleet. However, by observing the current state of charging infrastructure deployment in the top EV regions across the globe we can notice a range of tactics that are being tested across various EV populations, with each country taking a slightly different approach to charging infrastructure buildout.

The chart below shows the wide range of EV charging deployment for the top seven EV regions. As an example, we can compare China to the United States. China has taken a more aggressive and capital intensive approach across all charger types with a strong focus on DC Fast chargers, deploying roughly one DC Fast Charger for every 10 vehicles registered, while the United States has invested significantly less in charging infrastructure and has focused more on medium-speed charging with nearly 400 vehicles for every DC fast charger. China has relied heavily on government funding while the United States has relied primarily on the private sector.

FIGURE 7

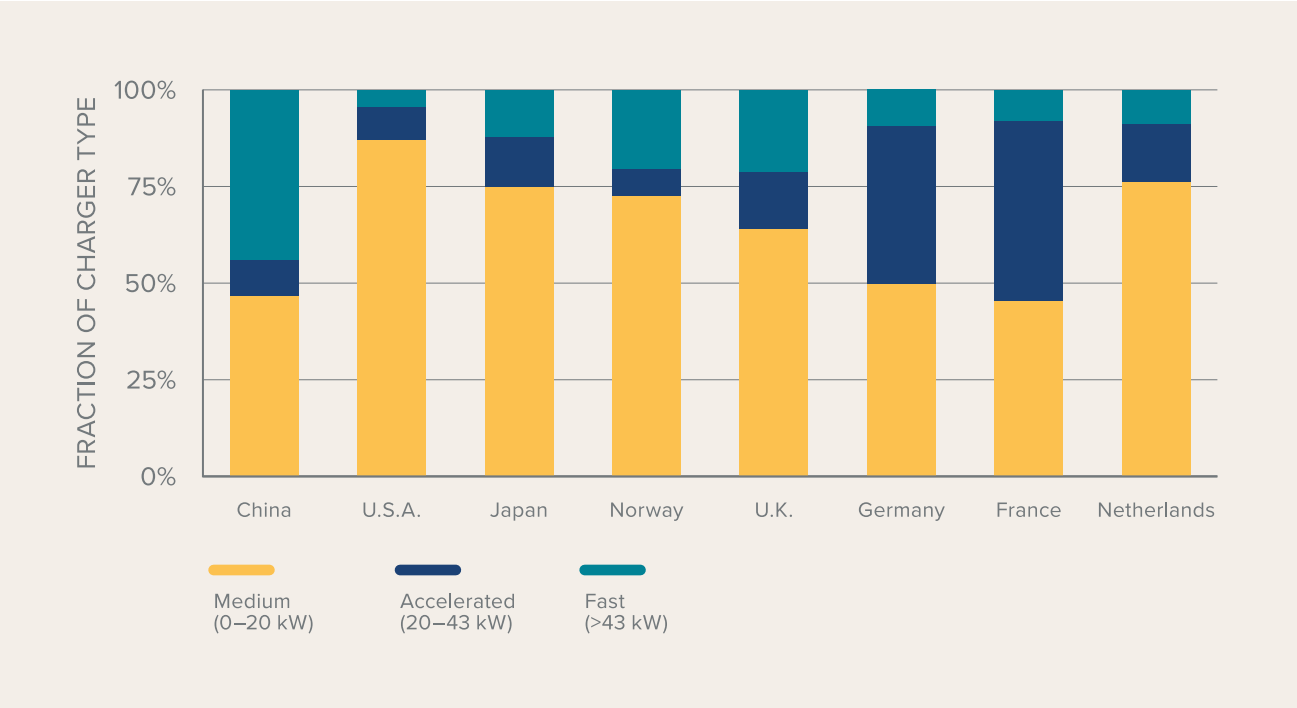
Vehicle to charger ratio for leading EV regions



While the strategy for DC fast charging varies widely from country to country, the variation for medium-speed chargers (0–20kW) falls in a much narrower band, varying from between 5 and 25 cars per EV charger. Looking across the top seven EV regions it is apparent that medium-speed charging is by far the most common form of charging and will likely continue to be for the foreseeable future. The chart below shows the distribution of chargers (medium, accelerated, fast) for the top seven EV countries globally. Here we see that medium AC charging represents between 50 to 90% of deployed chargers while DC fast chargers are below 20% of deployment in all countries but China.

FIGURE 8

Distribution of charger types for leading EV regions



ELECTRIC VEHICLE CHARGING INFRASTRUCTURE
A guide for discom readiness
—
LIGHTHOUSE DISCOM PROGRAMME
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