Status Report on Public Charging of Electric Vehicles in Tamil Nadu

ITDP INDIA

September 2025

PREPARED BY

ITDP INDIA

ITDP India is a service provider for the Institute for Transportation & Development Policy—a non-for-profit organisation that works with cities worldwide to promote transport solutions that reduce traffic congestion, air pollution, and greenhouse emissions while improving urban liveability and economic opportunity.

ITDP TEAM:

Prepared by:
Sanjay Krishna A (Ex-ITDP)

Internally reviewed by:
Aditya Rane | Sivasubramaniam Jayaraman | Vaishali Singh (Ex-ITDP)

LAYOUT:
Nirosha Tamiloli (Independent Consultant)
Varsha Jeyapandi

ACKNOWLEDGEMENT:
We would like to thank GUIDANCE Tamil Nadu, Tamil Nadu Power Distribution Corporation Ltd(TNPDCL), Sustainable Development Goal Co-ordination Centre(SDGCC), Charge Point Operators(CPOs) such as JioBp, Tata Power, and Zeon Charging. Original Equipment Manufacturers(OEMs) such as Tirex Chargers, Tamil Nadu Energy Development Agency, Citizen Consumer and Civic Action Group (CAG) and Tamil Nadu Petroleum Dealers Association for their valuable inputs. We acknowledge the special efforts taken by JioBp for facilitating a field visit to their charging stations, hub, and battery swapping stations. We thank the rest of the team at ITDP for their constant support and guidance while developing the report.

STATUS REPORT on

Public Charging of Electric Vehicles

CONTENTS

LIST OF FIGURES

LIST OF TABLES

KEY ABBREVIATIONS

CAGR : Compound Annual Growth Rate

CPO : Charge Point Operator

DISCOMs : Distribution Companies

ERS : Electrical Road System

EV : Electric Vehicle

EVSE : Electric Vehicle Supply Equipment

EVCI: Electric Vehicle Charging Infrastructure

HGV : Heavy-duty Goods Vehicle

HT : High Tension

ICE : Internal Combustion Engine

LT : Low Tension

OEM : Original Equipment Manufacturer

PCS : Public Charging Station

PLI : Production Linked Incentives

TNPDCL : Tamil Nadu Power Distribution Corporation Ltd

TANTRANSCO : Tamil Nadu Transmission Corporation

TNEB : Tamil Nadu Electricity Board

TNERC : Tamil Nadu Electricity Regulatory Commission

TECHNICAL TERMS & UNITS

Kilowatt (kW) : A measurement used to convey the electric motor's output power. It is the amount of energy the motor produces in a specific amount of time.

Kilowatt hour (kWh) : A measurement of energy equal to the energy that a kilowatt of power can transport in an hour. EV battery capacity is usually expressed in kWh, which is comparable with the number of liters in the tank for a non-electric vehicle.

Ampere (Amp) : A unit of measurement for electrical current.

Volts (V) : A unit of measurement for the push that causes electrical charges to move in a wire.

Electric Vehicle Supply Equipment (EVSE) : The element in Electric Vehicle Charging Infrastructure (EVCI) that supplies electrical energy for recharging the battery of electric vehicles

1 INTRODUCTION

1.1 BACKGROUND

In recent years, there has been a substantial increase in the number of automobiles on Indian roads. Population expansion, urbanisation, and rising income levels have all contributed to the growth of personal two-wheelers, four-wheelers, and commercial vehicles.

The year 2023 was a remarkable year for the Indian automotive industry, with record sales across segments:

- Passenger vehicle sales crossed 40 lakh units for the first time, with an increase of 8.2 per cent from 2022[1].
- Two-wheeler sales saw a 9 per cent increase, exceeding 170 lakh units in 2023

The challenges linked with this growth include increasing traffic congestion, air pollution, and energy demand. The Indian government has been working on a variety of programs to address these issues, including encouraging electric vehicles (EVs) and enhancing public transport.

To minimise reliance on fossil fuels, reduce emissions, and promote sustainable mobility, India has prioritised the deployment of electric vehicles. Several government incentives and policies to boost EV use have been implemented. But EV growth is still in its early phases with hurdles connected to infrastructure and customer awareness. In the 2021 UN Climate Change Conference, India pledged to become a net zero nation by 2070 and introduced a range of measures to cut carbon emissions. The nation has set ambitious targets for electric vehicle(EV) adoption, with the aim to achieve by 2030:

- 30 percent EV adoption for private cars
- 40 percent for buses
- 70 percent for commercial vehicles
- 80 percent for two and three-wheelers

[1] https://vahan.parivahan.gov.in/vahan4dashboard/

Vehicular growth in Tamil Nadu

The rapid vehicular growth in Tamil Nadu is a major source of pollution through tailgate emissions. According to Vahan Data from 1991 - 2021, the Compound Annual Growth Rate(CAGR) was 10 per cent for two-wheelers, 6 per cent for three-wheelers and 9.9 per cent for four-wheelers.[2] The state ranks third in India in terms of vehicular population, with over 3.26 crore vehicles registered as of 2023. Two-wheelers dominate, constituting around 78 per cent of the total vehicles.[3] Between 2005 and 2019, the transport greenhouse gas (GHG) emissions quadrupled, from 10 to 27 $MtCO_2Eq$. The share of transport sector emissions in the overall energy sector emissions also grew from 12 to 19 per cent in the same period[4].

Externalities of Vehicular growth

An externality is a consequence of an activity that affects other people and things, but not usually reflected in the cost of the activity. Vehicular growth has both positive and negative externalities.

Positive Externalities

- Economic Growth: The automobile industry is critical to Tamil Nadu's economy, providing jobs and revenue through manufacturing and exports.
- Accessibility and Mobility: Personal vehicles give transportation options in places where public transportation is limited, allowing people to access critical services and opportunities.
- Improved Logistics and Trade: Commercial vehicles help efficient delivery of goods inside the state and across borders, promoting economic growth and trade.

Negative Externalities

- Air pollution adversely effects health, and contributes to conditions such as asthma. In major cities such as Chennai, and Coimbatore, the particulate matter in the air routinely exceeds permissible PM2.5 levels[5].
- Increased vehicle traffic in cities like Chennai causes significant congestion, resulting in poor productivity for individuals and businesses.

[2,3] https://vahan.parivahan.gov.in/vahan4dashboard/

[4] https://www.ceew.in/publications/tamil-nadu-greenhouse-gas-inventory-net-zero-transition-and-climate-change

[5] https://www.iqair.com/in-en/world-most-polluted-cities?continent=59af92b13e70001c1bd78e53&country=SPLi4goKT3JDgP4Mm&state=tGwAee8Y7q5xLnuf7&sort=-rank&page=1&perPage=50&cities=

- Tamil Nadu has a high number of road accident fatalities, with two-wheelers being especially vulnerable. In Chennai in 2023, for every 1 lakh of the city's population 560 people met with a road accident. A total of 425 people died in road accidents till October 2023[6]
- The expansion of road infrastructure encroaches on agricultural land and green spaces, negatively impacting local residents and biodiversity.
- Air pollution-related illnesses and road accidents place a huge cost on the healthcare system. In a 2018 study, it was found that air pollution could have been the cause of premature death of 48 people per 1 lakh of population in Chennai.[7]
- Maintaining and expanding transportation infrastructure involves considerable financial resources.

Tamil Nadu's position as an early adopter of EVs

To curtail tailgate emissions, various states introduced and revised their state EV policies which guides a shift from ICE vehicles to greener EVs. Chennai with the moniker 'Detroit of South India' has a concentration of global automobile manufacturing industries in the city, and is in a position to be an important hub for EV adoption.

The state introduced its first EV policy in 2019, fast-tracking Tamil Nadu to position itself as a global EV manufacturing hub. The policy initially aimed to attract INR 50,000 crores in investments, create 1,50,000 new jobs and bring out various supportive measures for EV adoption. But three years since the policy was introduced, the adoption of electric mobility has remained relatively low.

According to data from the Vahan Portal, only about 3.94 per cent of vehicles registered in the state in 2022 were electric, a slight increase from the 2% in 2021. One significant contributing factor to this was that the policy emphasised non-fiscal, demand-side incentives such as tax exemptions and registration fee reductions, while it lacked upfront capital subsidies for vehicle purchases.

Recognising the need to address the low adoption of EVs, the state government revised the policy in 2023 to rectify the gaps in the 2019 policy and developed a more comprehensive approach to encourage EV adoption. The revised EV policy was officially launched in February 2023. Apart from demand-side incentives, the revised policy also promoted public charging and battery-swapping infrastructure, and put forth suggestions for incorporating building mandates to accommodate charging stations. The policy is unique in providing retrofitting incentives for two and three-wheelers.

[6] https://tnsta.gov.in/pdfpage/pdfpage_tn_0gIsjpL_2023_12_12.pdf

[7] https://www.downtoearth.org.in/news/health/air-pollution-kills-study-counts-100-000-premature-deaths-in-8-indian-cities-82312#:~:text=The%20figures%20rose%20to%2054%2C000,23%2C700%20for%20Hyderabad%20in%202018

This report aims to sum up the status of public charging stations for EVs in Tamil Nadu. It aims to identify the barriers and gaps charging infrastructure faces in Tamil Nadu. The report first introduces the background of EVs in India and reviews the government policies and other literature around EVs in India. It then provides an analysis of the market for EVs, exploring the economic and financial factors, technological advancements, and various stakeholders in the sector. It introduces detailed case studies of EV policies in India and abroad, and presents inputs from various stakeholders such as Charge Point Operators(CPOs) and government bodies. It concludes with the learnings, key gaps to be filled and recommendations to improve the public charging infrastructure for EVs in Tamil Nadu.

1.2. CONTEXT OF EVS AND EV CHARGERS IN INDIA

Public EV chargers in India have a relatively short history in India so far. In the early 2010s, the introduction of personal EVs like the Mahindra e2o in India and the Nissan Leaf globally underscored the need for robust public charging infrastructure. However, at that time, the number of EVs on the road was quite limited, and public charging stations were virtually nonexistent.

Private investments followed suit in the late 2010s, with companies like Tata Power, ChargePoint, and Ather Energy setting up charging stations in cities such as Delhi, Mumbai, and Bengaluru. These stations were strategically placed at shopping malls, hotels, and office complexes to cater to early EV adopters.

The landscape began to change around 2015-2016 when the Indian government acknowledged the significance of EVs for mitigating air pollution and reducing greenhouse gas emissions. The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, launched as part of the National Electric Mobility Mission Plan (NEMMP), aimed to incentivise EV adoption and promote the development of charging infrastructure. As part of this change, the government announced plans to install charging stations in major cities. By 2019, there was increased interest in electric mobility.

The FAME-II scheme included the expansion of charging infrastructure. Several states and cities like Delhi introduced ambitious plans for charging stations and developing partnerships between government bodies, electric utilities, and private charging station operators.

EV charging can be through both slow charging and fast charging. While slower chargers are being adopted for residential use, there is a growing emphasis on deploying fast chargers along major highways to facilitate long-distance EV travel. The ongoing development of public charging infrastructure, backed by government commitment and private sector investments, is poised to pave the way for more widespread EV adoption in India. This will also help address the challenge of ‘range anxiety’ among potential EV users, i.e concerns about how long will the battery power last while driving the EV.

Chargers or EVs first: The 'chicken and egg problem

A common challenge that emerges in EV adoption globally is what is often referred to as the 'chicken and egg' problem: what should come first, deploying vehicles or creating charging infrastructure?

When EVs are introduced, the immediate need is to find accessible charging stations. Therefore, it is imperative to swiftly implement the necessary infrastructure to support the growing number of EVs on the road.

One of the pivotal factors driving the electrification of vehicles hinges on the availability of robust charging infrastructure. In contrast to its predecessor, the revised EV policy has taken substantial steps to bridge this gap by introducing an array of support measures and incentives. These incentives translate to a tangible reduction of approximately 20-25 per cent in the initial setup costs for charging stations. The revised EV policy also extends its support to private e-aggregators offering e-mobility solutions, such as offering incentives to the first 50 applicants in the setup of fast chargers.

Types of EVs

1. **Battery Electric Vehicles (BEVs)** : BEVs are entirely electric vehicles that rely solely on a large battery to store electrical energy. This stored energy powers the electric motor, propelling the vehicle. BEVs produce zero tailpipe emissions and are charged by plugging into an electrical source, such as a charging station.

2. **Plug-In Hybrid Electric Vehicles (PHEVs)** : PHEVs offer a combination of electric and gasoline-powered driving options. They are equipped with a smaller battery compared to BEVs and can be charged via an electrical outlet. PHEVs can operate on electric power alone for a limited range before the internal combustion engine (usually gasoline) takes over. This dual-power capability provides greater flexibility, as they can use gasoline for longer trips or when the battery is depleted.

3. **Fuel Cell Electric Vehicles (FCEVs)** : FCEVs use hydrogen as fuel, and the vehicle's primary component is a stack of fuel cells. In a fuel cell, a procedure called reverse electrolysis occurs. In the process, oxygen and hydrogen interact. Whereas the oxygen comes from the surrounding air, the hydrogen originates from one or more of the car's tanks. This process creates pollutants , and only generates heat, electrical energy, and water which escapes through the exhaust as water vapour. There are two ways that the fuel cell's electricity can be used, depending on the driving scenario. It either charges a battery that temporarily stores the energy until it is required for a drive, or it flows to the electric motor and drives the car directly. These vehicles are less common and have limited access to hydrogen refueling stations.

Vehicle Chargers And Types

In India, the deployment of vehicle chargers has been a pivotal element in promoting electric mobility. Charging technology has evolved significantly in recent years and chargers come in various forms, primarily slow chargers, fast chargers, and ultra-fast chargers. The establishment of an extensive charging infrastructure network is vital to support the growing number of electric vehicles on Indian roads.

- Slow chargers or Level 1 chargers are typically used at homes and offer a standard 3-pin plug for convenience.
- Fast chargers or Level 2 chargers are stronger and commonly found in commercial settings. They significantly reduce charging times .
- Ultra-fast chargers or Level 3 chargers are being strategically installed along highways for rapid charging, making long-distance EV travel feasible.

The evolution of vehicle chargers has mirrored the growth of the electric vehicle market. Early EV adopters were mostly limited to using slow chargers. However, recognising the need for robust charging infrastructure, both the government and private sector have invested in developing and deploying faster, more accessible charging solutions. The ongoing expansion of charging networks, mainly focusing on fast and ultra-fast chargers, is essential to address the range anxiety associated with EVs and drive the broader adoption of electric mobility in India.

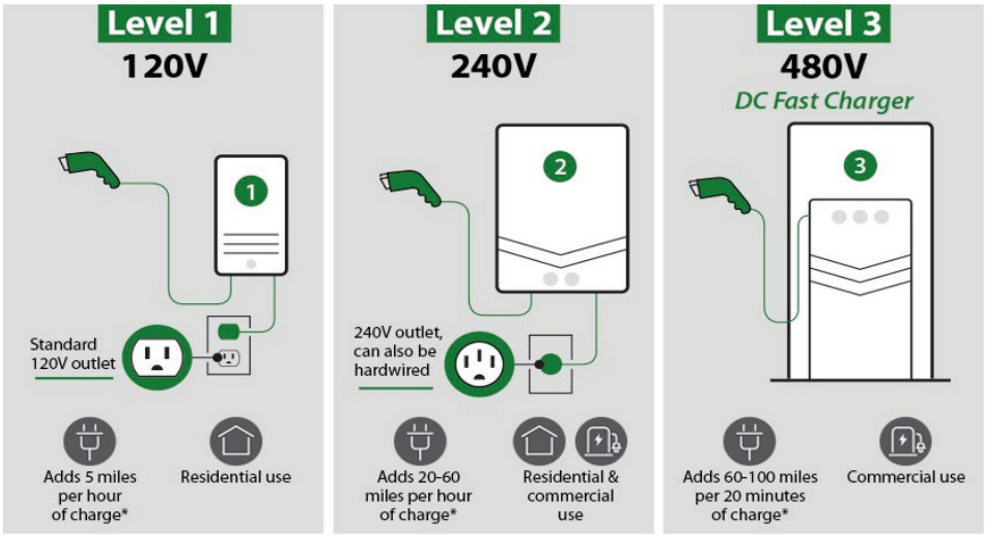

Figure 1: Levels of chargers based on power output

Charger Type	Charger Connectors	Rated Output Voltage (V)
Fast	Combined Charging System 2 (CCS 2) (min 50 kW)	200 - 1000 or higher
	CHArgedeMOve (CHAdeMO) (min 50 kW)	200 - 500 or higher
	Type - 2 AC (min 22 kW)	380 - 415
Slow	Bharat DC - 001 (15 kW)	72 or higher
	Bharat AC - 001 (10 kW)	230

Table 1: Types of EV chargers and their rated output

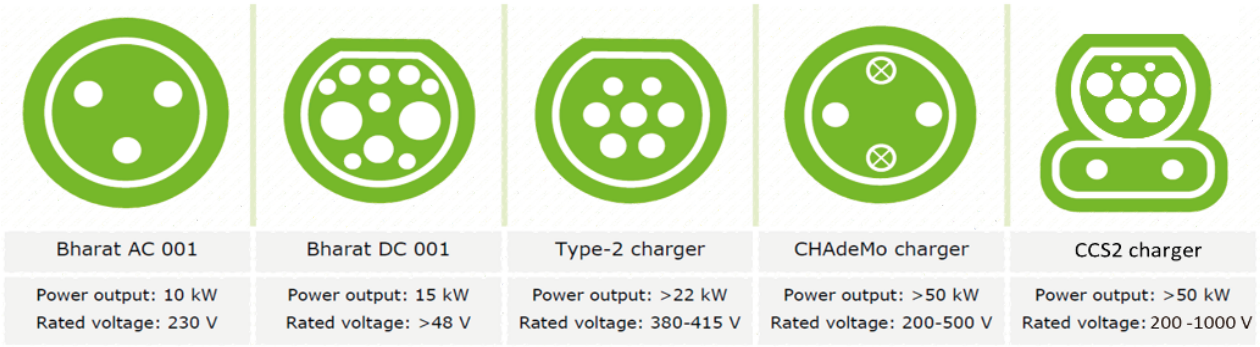

Figure 2: Graphical representation of types of EV chargers

1.3 TYPES OF EV CHARGING STATIONS

1. **Private charging stations:** Private charging stations are EV charging stations situated on private land, such as a home, company, or apartment complex. Private charging stations are usually owned and operated by the person or entity who owns the property where they are situated.

2. **Captive charging stations:** Captive charging is an EV charging station that is only available to consumers of a specific company or organisation. They are usually inside the company's premises and are exclusively accessible to customers who have a special account or keycard.

3. **Public charging stations:** EV charging stations are located in public areas such as parking garages, shopping malls, and highway rest stops and accessible by all EV users on payment. A government organisation, a utility corporation, or a private company often owns and operates public charging stations

4. **Semi-public charging stations:** Charging stations that are usually not owned by individuals, but located in spaces restricted only to residents, users and visitors. Example: Community charging spaces in apartments

Figure 3: A private EV charging station in an individual home (Photo: Team BHP)

Figure 4: BluSmart EV charging hub in Gurgaon (Photo: Tech Crunch)

Figure 5: A public charging station in Salem, Tamil Nadu[9]

Figure 6: Semi-public EV charging station in Nexus Vijaya Mall in Chennai[10]

5. **Battery swapping stations:** A battery swapping station is a facility where EV owners can swap out their depleted battery for a fully charged one. This can be done in a matter of minutes, as opposed to the hours it can take to fully charge an EV battery using a traditional charging station.

Figure 7: Battery swapping station in Bengaluru (Photo: ITDP)

1.4 COMPONENTS OF AN EVSE

In the context of electric vehicles, it is essential to understand the standard components of an Electric Vehicle Supply Equipment (EVSE). The standard components of an EVSE are described below.

- **Power input:** The power input is where the charging station connects to the electrical supply grid. It can be a standard AC power outlet or a higher-capacity connection, such as a dedicated charging circuit.

- **Power conversion system:** The power conversion system converts the AC power from the grid into the appropriate DC power required by the electric vehicle's battery. It typically includes rectifiers, inverters, and power electronics.

- **Connector and cable:** The connector and cable provide the physical connection between the charging station and the electric vehicle. The connector type can vary depending on the charging standard and region (e.g., Type 1, Type 2, CCS2, CHAdeMO). The cable length may also vary to accommodate different parking configurations.

- **Control and communication system:** The control and communication system allows the charging station to communicate with the electric vehicle and external networks. It facilitates data exchange for authentication, billing, and monitoring purposes. Common protocols include OCPP (Open Charge Point Protocol) and ISO 15118.

- **User interface:** The user interface provides interaction between the EV driver and the charging station. It typically includes an LCD or LED display, and buttons or touch screens to show charging status, session details, and user prompts. Some charging stations may have additional features like wireless connectivity for mobile apps or RFID card readers for authentication.

- **Safety and protection systems:** EVSEs include safety features to protect against electrical faults, overvoltage, overcurrent and short circuits. These safety systems can include ground fault protection, surge protection devices, circuit breakers and insulation monitoring.

- **Metering and payment systems:** Many charging stations incorporate metering capabilities to measure the amount of energy consumed during charging. This data is used for billing, especially in public charging networks. Payment systems, such as credit card readers or mobile payment platforms, may also be integrated for convenient and secure transactions.

1.5 INTEGRATING PARKING AND CHARGING

In the rapidly evolving landscape of electric mobility, a critical aspect that is often overlooked is the integration of parking management with public charging infrastructure. Many public charging stations are installed without adequate consideration for their strategic placement within parking facilities. As a result, EV owners frequently face challenges related to accessibility, convenience, and effective space utilisation.

Electric vehicle (EV) charging infrastructure and parking policy are two important and interconnected aspects of promoting EV adoption in India. According to a study by Centre for Science and Environment, cars in India are parked 95 per cent of the time in a year.[11] The average time of off-street parking (parking complexes, houses or apartment basements) is 6 hours, while the average on-street parking time is under an hour. Both figures are very critical in terms of charging a vehicle. Slow chargers on an average takes 6-8 hours to charge a vehicle completely while fast chargers take between 45 minutes to 1.5 hours to charge a vehicle (4-wheeler) up to 80 per cent State of Charging(SoC). So associating parking and charging can be financially productive while also making efficient use of space.

However, public charging stations are often installed without consideration for integration with parking management, resulting in inefficiencies, congestion, and under-utilisation of valuable curbside space.

Advantages of integration of charging and parking

- **Space optimisation:** Strategically locating charging stations within parking facilities such as multi-level garages or parking lots can make best use of limited space in urban areas.

- **On-street parking management:** Many EV users use street parking, especially in densely populated urban areas. Integration of on-street parking management with charging is can ensure convenient access to charging, encourage EV adoption and reduce the stress of finding a charging station.

- **User convenience:** By eliminating the need for separate charging trips, users can have a more seamless experience by combining charging with their other trips. This encourages more people to switch to electric vehicles, thereby reducing emissions and promoting sustainable urban transportation.

- **Data and resource optimisation:** Integrated systems can also collect valuable data on parking and charging patterns, helping cities optimise resource allocation. This data-driven approach allows for better-charging infrastructure planning, maintenance and expansion based on real-time demand

[11] A Roychowdhury, U Nasim and G Dubey(2018), 'How to manage urban India's parking needs', Centre for Science and Environment, New Delhi

To successfully integrate parking management with public charging, city planners, local authorities and stakeholders must work together to develop comprehensive strategies. This may involve revising urban planning regulations, investing in smart parking technologies, and collaborating with private operators to establish a cohesive ecosystem.

Integrating parking management with public charging is essential and a strategic move toward creating sustainable and user-friendly urban environments. As EV adoption continues to grow, this integration will play a pivotal role in shaping the future of urban mobility, ensuring accessibility, convenience, and environmental sustainability.

1.6 REQUIREMENTS FOR EV CHARGING

The following table outlines the spatial and power requirements according to the Final Consolidated EVCI Guidelines issued by the Ministry of Power in January 2022.[12]

Type of Charging Station	Dimensions (metres)	Area (sq.m)	Area (sq.ft)	Charger Type	Charger Specifications
Fast	15 x 7	105	~1130	1 CCS, 1 CHAdeMO	Minimum 100kW each
Public	13.5 x 5.5	74.25	~800		1 Fast Charger for every 10 EVs, 1 Slow Charger for every 3 EVs

Table 2: Spatial requirements for EV Charging

S.No	Charging Station	Voltage (V)	Power (kW)	Type of Vehicle	Type of Compatible charger
1	Level 1 (AC)	240	<=3.5 kW	4w,3w,2w	Type 1, Bharat AC-001
2	Level 1 (DC)	>=48	<=15 kW	4w,3w,2w	Bharat DC-001
3	Level 2 (AC)	380-400	<=22 kW	4w,3w,2w	Type 1, Type 2, GB/T, Bharat AC-001
4	Level 3 (AC)	200-1000	22 to 45 kW[10]	4w	Type 2
5	Level 3 (DC)	200-1000	Up to 400 kW	4w	Type 2, CHAdeMO, CCS1, CCS2

Table 3: Power requirements for EVs based on the revised EVCI guidelines

[12] Ministry of Power (2022), Charging Infrastructure for Electric Vehicles: Revised Consolidated Guidelines and Standards

[13] P = V * I * √3 (415 V * 63A * √3)

2 REPORT METHODOLOGY

India's transport situation is undergoing an enormous transformation with the shift towards electric mobility, driven by concerns about energy security, environmental sustainability, and technological advancements. Since EV charging infrastructure is a critical part of this shift, a detailed literature review was conducted. This section presents key findings and insights about EV charging infrastructure in India from the literature reviewed, and outlines key points from stakeholder consultations.

2.1 LITERATURE REVIEW AND KEY TAKEAWAYS

Takeaways from The Handbook for EV Charging Infrastructure Implementation and the Final Consolidated EVCI Guidelines (Jan 2022)

The development of the infrastructure for EV charging is largely attributed to government initiatives. To assist the building of EV charging infrastructure, the Ministry of Power and NITI Aayog have produced extensive policy documents and recommendations. These comprise the Handbook for EV Charging Infrastructure Implementation and the Final Consolidated EVCI Guidelines (January 2022)[14]

[14] https://powermin.gov.in/sites/default/files/Final_Consolidated_EVCI_Guidelines_January_2022_with_ANNEXURES.pdf

The Handbook uses a systematic approach to cover the planning, authorisation, and implementation of EV charging infrastructure , meant to be used by implementing authorities and stakeholders. It provides a broad overview of the governmental, regulatory, and technological frameworks required to enable EV charging, a step-by-step methodology for creating the roadmap for implementation, and planning for the future. The handbook briefs the readers on the basics of EVs, charging technologies, and standards defined by the Bureau of Indian Standards and notified by the Ministry of Power through the Final Consolidated EVCI Guidelines, revised in January 2022

Both these documents set the base for the establishment of public charging stations ensuring accessibility and useability of the charging stations established.

In September 2024, the Ministry of Power issued a new guideline titled "Guidelines for Installation and Operation of Electric Vehicle Charging Infrastructure-2024" to update and expand the existing policy framework. These guidelines build upon the January 2022 EVCI Guidelines by introducing clearer provisions for electricity connections, tariffs, and protocols aimed at accelerating deployment and improving usability. Key features include: mandating connection timelines from DISCOMs (shorter timelines in metros versus rural areas), simplified electricity tariffs for EV charging stations tied to the Average Cost of Supply until a transitional period, allowing residential users to use existing connections or opt for separate metered EV-charging tariffs, and promoting interoperable communication protocols (e.g. OCPP, OCPI, UEI) to ensure interoperability across charging stations.

These 2024 Guidelines also institutionalize models for land provision (including revenue-sharing with land-owning public entities) to reduce barriers in site acquisition and enable better coverage. Collectively, the 2024 Guidelines aim to tackle earlier bottlenecks—not just in regulatory authorisations and technical standards (as addressed in 2022), but also in operational, financial and locational aspects, to improve the viability and scale of public charging infrastructure across India.

Learnings from the Draft Policy on Battery Swapping (2022)

In 2022, NITI Aayog released the Draft Policy on Battery Swapping Infrastructure in India. This focuses on battery swapping as a workable way to overcome the issues preventing the mainstream adoption of electric vehicles (EVs). The policy delineates multiple components such as the regulatory structure, infrastructure configuration, instructions for operations, safety requirements, and incentives to encourage the development of battery swapping infrastructure.

[15] https://www.niti.gov.in/sites/default/files/2021-08/HandbookforEVChargingInfrastructureImplementation081221.pd

To make it easier for battery swapping stations to be established and run, the policy suggests amendments in existing regulations and highlights the importance of specific regulations for licensing, running, and maintaining safety requirements for swapping stations.

The proposed policy offers operational principles that address user experience, data management, and service processes for battery swapping stations. It highlights the significance of standardisation, quality assurance, and monitoring procedures to guarantee dependable and user-friendly services

Safety is a critical aspect of battery switching procedure due to the inherent danger of lithium-ion batteries and high-voltage systems. In order to reduce potential hazards, the draft policy mandates adherence to safety standards, emergency protocols, and periodic inspections.

Analysis of the report Evolving EV Charging Infrastructure in India (2021)

The literature review analysed this report[16] by JMK Research and Analytics which outlines the basics of charging and covers schemes and initiatives by both central and state governments to promote the adoption of EV in India.

An examination of India's main market drivers for EV charging infrastructure:

Strong government regulations and strong industry initiatives have an impact on the development of electric vehicle (EV) charging infrastructure in India. Collectively, these forces are forming a favourable atmosphere for the expansion of electric vehicles throughout the nation.

1. Vigorous Government Incentives

The Indian government has played a key role in encouraging the use of electric vehicles and the associated infrastructure. A comprehensive strategy comprising incentives, collaborations, and policy reforms has been devised to expedite the shift to electric vehicles.

a. Charging as a Service: The government has designated EV charging as a delicensed activity, acknowledging the necessity for a widely available and accessible charging infrastructure. This lowers obstacles to entry and promotes competition and innovation in the industry by enabling any business to install and run charging stations without the need for special licences.

b. Fiscal and Non-Fiscal Incentives: The government has implemented a number of incentives to increase the economic viability of EV charging.

[16] https://jmkresearch.com/electric-vehicles-published-reports/evolving-ev-charging-infrastructure-in-india/

These include the creation of distinct tariff schemes for EV charging stations and lower tariffs for the production and use of chargers. These actions lower operating expenses while simultaneously promoting infrastructure investment for charging.

c. GST Rate Reduction: The government has lowered the Goods and Services Tax (GST) rate from 18% to 5% in an effort to lower the cost of EV chargers and charging stations. The overall cost of installing and maintaining charging infrastructure is reduced by this large tax cut, which makes it a desirable choice for both individuals and enterprises.

d. Partnerships with Oil corporations: To take advantage of already-existing infrastructure, the government has established EV charging stations at gas stations through partnerships with oil corporations. This programme makes use of the extensive network of gas stations and incorporates conventional fuel suppliers into the developing EV ecosystem, making the transition easier for customers.

2. Business Proposals

The private sector has made major contributions to the construction and expansion of EV charging infrastructure in addition to government initiatives. Industry participants are improving EV charging's accessibility and convenience through partnerships and creative ideas.

a. Strategic Alliances: The sector has seen an increase in alliances with the goal of expanding the availability of EV charging stations. Famous partnerships include:

Fleet Operators: Partnerships with fleet operators provide a dependable and environmentally sustainable mode of transportation for workers at multinational corporations (MNCs).

Gas Pumps: Coordinating with gas pump managers makes it easier to place EV charging stations next to conventional gas stations, giving customers a smoother experience.

Shop owners: Collaborating with retail establishments gives them access to new revenue sources and gives customers easy ways to charge their purchases.

b. Community Charging Stations: The idea of installing charging stations in public and private spaces is becoming more and more popular. This encourages group use and increases charging accessibility for a larger group of people.

c. Charging Plazas: The creation of charging plazas, which provide numerous charging points in one area, is promoted in order to accommodate the increasing number of EV customers. These plazas offer an all-in-one EV charging solution, cutting down on wait times and enhancing consumer comfort.

The study proposes ideas under each of these market drivers. For governmental push, four points are suggested to improve EV adoption:

- Treating charging as a service and as a delicensed activity that can be taken up by anyone
- Introducing fiscal and non-fiscal incentives such as reduced tariff for the manufacture and operation of chargers, and separate tariff systems for EV charging stations
- Reducing GST rates on EV charging stations from 18% to 5%
- Partnering with fuel companies to set up charging stations at fuel refilling stations

It also proposes industry initiatives such as tie-ups with fleet operators for private companies, tie-ups with petrol pumps and shop owners, setting up community charging stations and charging plazas.

Takeaways from the study Financing India's Transition to Electric Vehicles

This 2020 study by the Centre for Energy Finance[17] assesses segment-wise EV sales, battery requirements, public charging infrastructure, and investments needed until 2030 to support India's EV transition. In addition to the 2030 target, the study models three transition scenarios. Further, it identifies the barriers to the investment flow and solutions to accelerate the flow of investments in the sector.

According to the report, India's 2030 vision of e-mobility[18] translates into 102 million EVs by this time. Under the high adoption scenario, which is 10 per cent above the vision, EVs are expected to account for 43 per cent of the total new vehicle sales. This could go down to 23 per cent in the case of low adoption scenario, which is 40 per cent below the vision

The report then identifies barriers and solutions to the investment flow in the EV sector. Investments required for India's mobility transition is enormous and mobilising the investments to finance Original Equipment Manufacturer (OEMs), battery manufacturers, charging stations, and end consumers will require targeted and systemic policy support and shifts in market design, business models, and financial structuring.

Review of reports on innovations in technology and grid Integration

Numerous publications that provide in-depth study of grid integration and electric vehicle charging technology have been issued by NITI and EY. Three connected publications were reviewed:

[17] CEEW-CEF-financing-india-transition-to-electric-vehicles.pdf

[18] The vision aims for 70 per cent of all commercial cars, 30 per cent of private cars, 40 per cent of buses, and 80 per cent of two-wheeler (2W) and three-wheeler (3W) sales to be electric by 2030

What are we solving?	Who are we solving for?	Policy	Financial
Barriers faced by OEMs in accessing capital for expansion into the EV space	Small OEMs and vendors	Industrial parks for SME OEMs in the auto sector. Scheme to set up venture capital and small enterprise assistance fund	Financing windows for small OEMs and small-scale component suppliers or vendors to the OEMs, e.g., a partial credit guarantee scheme or carving out limits within existing programmes in this segment to allow for increased finance flows
The weak business case for charging infrastructure business	Charging infrastructure business holders	Capping rental cost for public charging stations State EV policies that combine incentives for EVs with disincentives for ICE vehicles	A charging infrastructure investment facility capitalised partly with public money
The high upfront cost of EV	End Consumers	Policy development around battery reuse, recycling, and leasing	Annualisation in a phased manner

Table 4: Key recommendations to address barriers in accessing capital

Report 01: Fundamentals of Electric Vehicle Charging and its Grid Integration,
Report 02: International Review of Electric Vehicle Charging Infrastructure and Grid Integration
Report 03 Electric Vehicle Charging Infrastructure and Grid Integration in India: Status Quo, Critical Analysis and Way Forward.[19]

The studies cover a variety of subjects, including the fundamentals of EV charging infrastructure, grid optimisation strategies, and worldwide best practices. Demand-responsive mechanisms, smart charging systems and grid management algorithms are emphasised as critical components in reducing the impact of EV charging on energy distribution networks.

Understanding Infrastructure Protocols and Standardisation

For the EV ecosystem to be reliable and compatible, standards must be established in terms of the minimum space requirement and configuration of charging stations. The Amendments to Model Building Bye Laws issued by the Ministry of Housing and Urban Affairs in 2019 provide these technical

[19] https://changing-transport.org/publications/fundamentals-of-electric-vehicle-charging-technology-and-its-grid-integration/

requirements. The Amendments also encompass the previous standards for charging stations issued by Ministry of Power in 2018 and was further revised in 2022

2.2 STAKEHOLDER CONSULTATION

A set of stakeholder consultations were carried out with the objective to comprehensively understand the issues that they face in the process of EV Charging.

Objectives of the consultation

The aims of the consultation were to understand:

- The process of setting up a public charging station (PCS)
- Hurdles faced to execute business plans
- Details of the working process (such as methods of identification of land)
- Current condition of public EV charging infrastructure in the state
- Ground level challenges and opportunities
- Plans for future development
- Hurdles for faster adoption of EV vehicles
- Public awareness, usage, and satisfaction with the existing public EV charging infrastructure
- Expectations and priorities for future development

Identification of stakeholders

The important parties in the creation of the infrastructure needed for EV charging in the state were identified, and their roles are described in the following table.

EV Stakeholder	Major Role
EVSE and Charging Station OEMs	Manufacturer of chargers and all the sub-components of the supply equipment
Charging Point Operators (CPOs)	Companies or groups who procure EVSEs, set up, run, and maintain electric vehicle charging stations
Owners of petrol pumps	Proprietors and managers of currently operating petrol stations where EV chargers are planned or operational
Tamil Nadu Power Distribution Corporation Limited (TNPDCL)	The state-owned power distribution company identified as the nodal agency by the state EV policy 2023. The company is in charge of distributing energy throughout the state

Table 5: Identification of stakeholders in the state

Techniques used for consultation:

Multiple targeted stakeholder consultation meetings were conducted to get the necessary inputs, identify major impediments or hurdles in the EV ecosystem and areas of interest with the development of EV charging infrastructure. Different subjects were covered for each stakeholder group.

- Manufacturers of EVSEs (OEMs): Infrastructure requirements for high-speed charging, technology developments, and compatibility with current and future EV models.

- CPOs: Pricing structures, grid infrastructure access, rules and permissions, and business models.

- Owners of petrol bunks: Suitability of the site for charging stations, integration with the current fuelling infrastructure, possible advantages and difficulties of having chargers on site.

- TNPDCL: evaluation of grid capacity, cooperation in providing electricity to charging stations, and incorporation of renewable energy sources.

3
MARKET ANALYSIS

3.1 REASONS FOR POOR ADOPTION OF EVS

Some of the major reasons for the poor adoption of EVs are cost, range anxiety, lack of public infrastructure and challenges of technology becoming obsolete.

1. High cost of adoption

The key factors contributing to high EV costs in India are:

- Battery Expenses: The lithium-ion battery pack is the most expensive component of an EV. India presently relies heavily on importing battery cells and raw materials. Even though battery prices have fallen globally, they remain high for Indian standards.

- Limited Manufacturing Scale: The Indian EV market is still in its early stages. Local manufacturing of EVs and their components aren't at the same scale as ICE vehicles. The higher production costs thus get passed on to the consumer.

- Charging Infrastructure: India still lacks a widespread, robust network of charging stations. Expanding the charging infrastructure requires significant investments, which indirectly contribute to the cost of EVs.

- Import Duties: Many EV components and raw materials are imported, attracting import duties that increase the final vehicle price.

- High-Tech Features: EVs often come equipped with advanced technologies like sophisticated battery management systems, touchscreen displays, and connected car features. While offering benefits, these add to the vehicle's cost.

At present, the cost is being mitigated by government Initiatives. These include the Fame 11 Scheme that offers subsidies and incentives to EV manufacturers and buyers, production-linked incentives (PLI) schemes that focus on establishing domestic manufacturing capabilities for EVs and batteries, and through reduced GST (5 per cent) for EVs. The Tamil Nadu EV policy also incentivises retrofitting of vehicles, and has waived off road tax, registration charges and permit fees, further reducing the cost.

2. Range Anxiety

While the range of EVs is constantly improving, they typically have a shorter range than ICE vehicles. The average range of a new EV car sold in India in 2024 was 507.86 km across all price points, which reduces to 371 km for cars under INR 25 lakhs.

3. Lack of public charging infrastructure and slow charging speeds

Lack of charging infrastructure: Although the number of EV charging stations is growing rapidly, they are still not as ubiquitous as petrol bunks. This can be a concern for drivers who are worried about finding a place to charge their cars on long trips, especially in rural areas.

Unfamiliarity with charging: The majority of the population is unfamiliar with how to charge an EV in a public charging station, are unaware of details of installation of charging stations at their homes, and may also lack space to install chargers.. EV charging stations are presently unmanned, leading to hesitation to use the facility, especially for first-time users or those not comfortable with technology.

4. Obsolescence

Technological developments: Older, slower chargers (50 kW) may become outdated for those requiring faster charging times as ultra-fast chargers (350 kW+) become more common.

Challenges with standardisation: Different manufacturers utilise different standards for charging connectors, which could cause compatibility problems as technology advances.

Infrastructure constraints: It may be costly and time-consuming to upgrade current charging stations to support new technologies, which might lead to abandoning some older stations in the process.

3.2 ASSESSMENT OF THE CURRENT CHARGING INFRASTRUCTURE IN TAMIL NADU

Modern battery designs reduce the need for 'opportunity charging', i.e charging enroute or at end stops where charging stations are available. Charging at the source or destination can be adequate for operations particularly in urban areas for intra-city trips. However, lengthier trips between cities make public charging stations and opportunity charging necessary. A higher number of charging stations increases the confidence of buyers to invest in an EV over an ICE vehicle. DC fast chargers and rapid chargers ensure faster turnaround times for vehicles at charging stations, since their battery size accommodates rapid charging.

According to data in the EV Yatra Portal maintained by the Bureau of Energy Efficiency, the current number of EV Public Charging stations in Tamil Nadu is 1,413, while the number of EVs registered in the state as of August 2025 is 4,47,469. The ideal ratio of chargers to EV is 6 to 30 vehicles for every public charger,[20] but the ratio in Tamil Nadu at present is 316 vehicles per charging station.

This makes the status report an important tool to assess the existing charging stations and understand the usage pattern of the general public. To make ends meet, more charging stations should be installed. The report highlights the need for scientifically locating the upcoming charging infrastructure in the state and boosting the pace of establishing stations through the implementation of the revised state EV policy.

3.3 ANALYSIS OF ECONOMIC AND FINANCIAL FACTORS

1. Types of costs

Installing charging stations necessitates a substantial initial outlay of funds, particularly for fast chargers. The two main costs are:

- Infrastructure costs: This comprises the cost of the land as well as the cost for the facility, charging equipment, electrical systems and other associated costs that become a part of the Capital Expenditure(CapEx). Finding suitable land in urban areas can be particularly difficult and expensive.
- Operating costs: The cost of electricity, maintenance, customer service and support, and the expense of monitoring and managing the network of charging stations all come under the Operation Expenditure(OpEx).

2. Revenue sources

[20] Alvarez and Marsal(2022)

- Charging fees: Owners of charging stations and CPOs run their business by charging EV users for their usage. The cost structure can be impacted by several factors, such as membership plans, the length of the charge, and the rate of charging.

- Idling fees: Combining parking and charging can be a potential revenue stream for the CPOs. As the industry is still in the nascent stage, parking can be complementary with charging. As the number of EVs grows or when queuing happens, this could be modified. For instance, if a vehicle at a charging station is connected to a charger even after 80 per cent State of Charge and other vehicles are in queue, then idling fees could be added. This can potentially decongest charging stations and help create another source of revenue for the CPO.

- Subscription models: Offering subscription-based plans can increase revenue streams and cultivate a dedicated customer base.

- Partnerships and sponsorships: By collaborating on sponsorship or advertising campaigns with businesses, communities, or other organisations, CPOs would be able to generate additional revenue.

- User amenities: Providing user amenities such as a place for refreshment, a restaurant, or even play areas and retail outlets can increase footfall, and rent from these outlets can be a stream of revenue.

3. Profitability

- ROI analysis: A thorough analysis of the anticipated return on investment is necessary to determine the economic viability of EV charging infrastructure projects. Timelines for cost recovery, potential revenue, and projected utilisation rates are all crucial considerations.

- Long-term sustainability: When assessing the long-term economic sustainability of EV charging networks, several factors need to be considered, such as evolving consumer preferences, alterations in regulations, and advancements in technology.

4. Consumer behaviour and market demand

- Market demand analysis: To make wise investment decisions, the demand for EV charging infrastructure in particular regions must be properly studied.

- Consumer behaviour: Pricing strategies and service offers can be optimised by examining consumer preferences, charging behaviour, and willingness to pay for charging services.

- Customer willingness to pay: The total cost of ownership andper-kilometer costs associated with electric vehicles are lower than those of their internal combustion engine (ICE) equivalents. Additionally, an EV can be charged while ICE fueling is limited to public petrol stations. Hence to ensure the viability of the public charging network, it is important to understand user willingness, which factors like charging speed and ease of use.

5. Policies and incentives by the government

- Subsidies and grants: Several governments offer incentives, subsidies, and grants to promote the development and installation of EV charging infrastructure. Understanding and utilising certain benefits might help projects become more financially viable by helping to offset the costs of initial investment.

- Environment standards and regulations: Maintaining current knowledge of regulations about electric car charging, electricity pricing, environmental standards, and safety requirements is essential to ensure compliance with the law and reduce any potential hazards.

6. Competitive environment

- Market competition: Knowing the competition landscape is useful for understanding how to differentiate services, set prices, and identify potential market niches.

- Strategic alliances: Forming strategic relationships with automobile manufacturers, technology suppliers, and utilities can increase competitiveness and create new business opportunities.

7. Taxation, licenses and tariffs

- Licensing: Under the 2003 Electricity Act, the Ministry of Power stated that using a charging station to charge an EV battery is a 'service' that requires the consumption of energy. The activity would not allow any electricity sale and is not a 'good'. Thus, the Act does not mandate a license for the charging stations.

- Good vs service: Since EV charging is considered a service rather than a good, it would attract 18 per cent GST. If it was being considered a good, the tax would have been 0 per cent as electricity is exempt from taxation.

- Place of supply: Electricity is classified as a movable good that can be supplied anywhere. This could lead to some GST and regulatory

complexities based on the place of supply for both battery swapping and charging. In few Indian states, multiple registrations in GST are required for operation.

- Tariff Systems: A few states for example in Gujarat enforce the operators to purchase a separate connection for operations of a public charging station or a sub-connection from the existing connection under EV tariff orders. This will ensure lowered tariffs in most cases. But in a few other states, DISCOMs deny issuing a separate connection if a previous connection exists. This complicates the billing for the CPO and forces them to pay more for electricity, even if a separate EV tariff exists. This in turn increases the supply cost to the consumers.

3.4 CYBER-SECURITY AND GROWING DIGITAL THREATS

As with any new technology, EV charging appliances are prone to cyber-security threats.

Potential cyber-security threats

- Malware and viruses : Through sophisticated bot attacks, injections, and compromised third-party services inside the EV charging station supply chain, malware and viruses can be injected into an EV charging application. The entry point could be just one standalone charging station, one automobile computer, or an infected end-user device. This could result in data theft, application damage, or unwarranted access to the charging infrastructure.

- Lack of encryption: User data can be intercepted and compromised if data is not properly encrypted during transmission between the EV charging application and the charging station.

- Abuse of API: EV charging stations depend on a multitude of internal and external Application Programming Interface(API) services for processing payments, finding charging stations, facilitating device communication, managing accounts and balances and other functions. Thus, they could be prone to bot attacks, malicious code injection attacks, unauthorised access to sensitive data, and even tampering with the charging station's functionality. Proper enforcement of security policies is essential to validate and sanitise the EV charging app APIs.

- Insufficient authentication: Unauthorised users may be able to access the EV charging application and infrastructure due to inadequate authentication procedures. This results in abuse, theft of data, or harm to the application.
- Privacy risks: Applications for EV charging gather and retain private user information, including credit card numbers and location data.

Identity theft, financial fraud, and privacy violations can result from improper data security.

Examples of cyber attacks on EV charging stations

- Rogue EV charging stations: It is possible to hack or tamper with EV charging stations and steal user data or harm cars. A device can be physically connected to the charging station or the firmware can be changed to accomplish this. A rogue charging station can be used to launch more attacks once it is linked to the network.

- Billing fraud: Applications for EV charging usually involve processing payments and billing. Billing fraud is possible using bots to establish fake charging sessions or charge inflated prices.

- Location spoofing: The process of deceiving the EV charging application on the location of the user is known as location spoofing. This can be utilised to bypass location-based pricing schemes or get entry to charging stations that are exclusive to specific areas.

- Denial of service attacks: The EV charging application is overloaded with traffic on the underlying network in a denial-of-service (DoS) assault. It makes the application useless or unavailable. DoS attacks have the potential to extort money from the application provider or interfere with the infrastructure that supports billing.

The following table based on the type of attack, helps to understand who is the target, what is the security issue and what is the impact of the security lapse or attack, with an example for each type of attack

Attack Type	Specific Target	Security impact	Impact	Example
Denial of Service (DoS)	General	Integrity, Availability	Cyber	Communication broken either at aggregator level or broader, causing potential disruptions.
Bruteforcing	EV	Confidentiality, Integrity	Cyber	Guessing passwords used in the charger's network to gain unauthorized access.
Delay Attack	General	Availability	Cyber	Power requests at incor rect timing may cause breakdowns

Table 6: Classification of cyber-attack types their risk areas and potential impact

Attack Type	Specific Target	Security impact	Impact	Example
Replay Attack	General	Integrity, Availability	Cyber	Incorrectly replaying power requests may lead to operational failures.
Snooping	General	Confidentiality	Social	An attacker may link messages to track, profile, or learn about user habits.
Sybil Attack	Aggregator	Integrity, Availability	Cyber	Copying ID tokens to multiply energy charge fraudulently.
Impersonation	EV, Aggregator	Confidentiality, Integrity	Cyber	Stealing energy by posing as a legitimate entity
Cloning	EV Owner	Confidentiality	Physical	If an RFID tag is cloned, an intruder could impersonate the legitimate user.
Man-in-the-Middle	General	Confidentiality, Integrity	Cyber	Tampering with communications to send incorrect control commands.
Repudiation	EV	Integrity	Cyber	Denying a legitimate EV access by tampering with validation data.
EV Misbehavior	Aggregator/ Billing	Integrity	Social	Adding noise to data, leading to incorrect billing or operational decisions
Misinformation	EV Owner	Integrity, Availability	Social	Feeding false information to EV owners to influence charging behavior.
Load-Changing Attack	EV, Aggregator	Integrity, Availability	Physical	Synchronizing charging/ discharging operations to destabilize the power grid.

Table 6: Classification of cyber-attack types their risk areas and potential impact

4

TECHNOLOGICAL ADVANCEMENTS

The electric vehicle revolution is fueled by technology, and this section explores the major technological forces influencing this emerging field. For any technological advancement, a few issues will need to be overcome to ensure a seamless process:

- Standardisation: It is essential to have established charging standards to avoid user confusion due to lack of compatibility between different EV models and charging stations.
- System integration: To maintain stability and manage peak charging times, the electrical systems will need to be suitably modified to allow integration of a large number of EV chargers.
- Data management and security: Securely managing and storing user data gathered at the charging stations is essential to guard against cyberattacks and guarantee user privacy.
- Innovation in charging technology: It is essential to keep abreast of innovations in technology, as faster charging methods and improvements in battery technology can greatly enhance user experience and EV adoption. There have been several innovations in technology of EV charging, such as Panto-based charging, e-highways and wireless charging.

4.1. PANTO-BASED CHARGING

Pantographs are high-capacity chargers, ranging between 150 kW to 650kW. They are generally used as temporary connections at designated charging locations, usually used on the routes of electric buses(e-buses) for opportunity charging. The system evolved from the light rail or tram system and comprises of scissor-like arms, which are used to make contact from the top of the bus to a stationary mast at a charging station. When the two components make electrical contact, the e-bus battery gets charged.

There are two types of pantograph chargers: Panto-up (mounted on the roof of the bus) and Panto-down (mounted on the charging station).

Roof-mounted Panto-based charging

In this system, the pantograph is mounted on the roof of the bus. When the bus reaches the charging station, the pantograph rises and makes contact with the connectors at the station. This is considered a simpler system to implement, and the driver operates the pantograph from inside the bus.

Inverted Panto-based charging

An inverted or reverse pantograph system is dropped from the top of the charging station and attaches to the rails on the roof of the bus. In this system, the connection is made through a wireless system and the charging process is automatically initiated when a bus approaches the station.

Figure 8: A hess bus using a roof-mounted Pantograph in Bern[21]

[21] https://www.sustainable-bus.com/electric-bus/bern-is-converting-line-to-electric-bus

E-highways

E-highways are segments of roadways which have overhead power lines installed, and allow electric and hybrid heavy duty vehicles to draw power while driving. They can be a viable method of electrifying transportation infrastructure, particularly vehicles that used pantograph-based charging systems.

Figure 9: E-highways in Germany established by Siemens[22]

This system is being tested out in Germany as a method to reduce reliance on fossil fuels and reduce GGHs. Germany is known for its sophisticated automotive sector and its extensive national motorways known as the Autobahn. The integration of e-highways into the Autobahn, could result in considerable benefits.

Teams from construction company Costain and Siemens Mobility have developed an Electric Road System (ERS) for the A5 motorway in the Autobahn, to power Heavy Duty Goods Vehicles (HGVs) to recharge their batteries as they drive along the motorway. The A5 motorway spans 445 kilometers, from the Hattenbach Triangle Intersection near Kirchheim to the Germany-Switzerland border near Basel. It is one of the busiest and most polluting roads in Germany, with 135,000 vehicles passing through every day, including 14,000 HGVs. Since July 2020, a portion of this route has been utilised for ERS testing. A total of 10 km (5 km in each direction) have been electrified, while 7km more are being installed presently.

[22] https://www.mobility.siemens.com/global/en/portfolio/road/ehighway.html

The ERS system comprises three primary parts: charging stations, and an overhead catenary system and wires. Feed-in masts, tensioning poles, anchors, and support columns form the overhead catenary system. To support the catenary system, steel columns (around 12 to 14m high) along the side of the motorway at approximately 50m intervals. They have a 2m driven foundation.

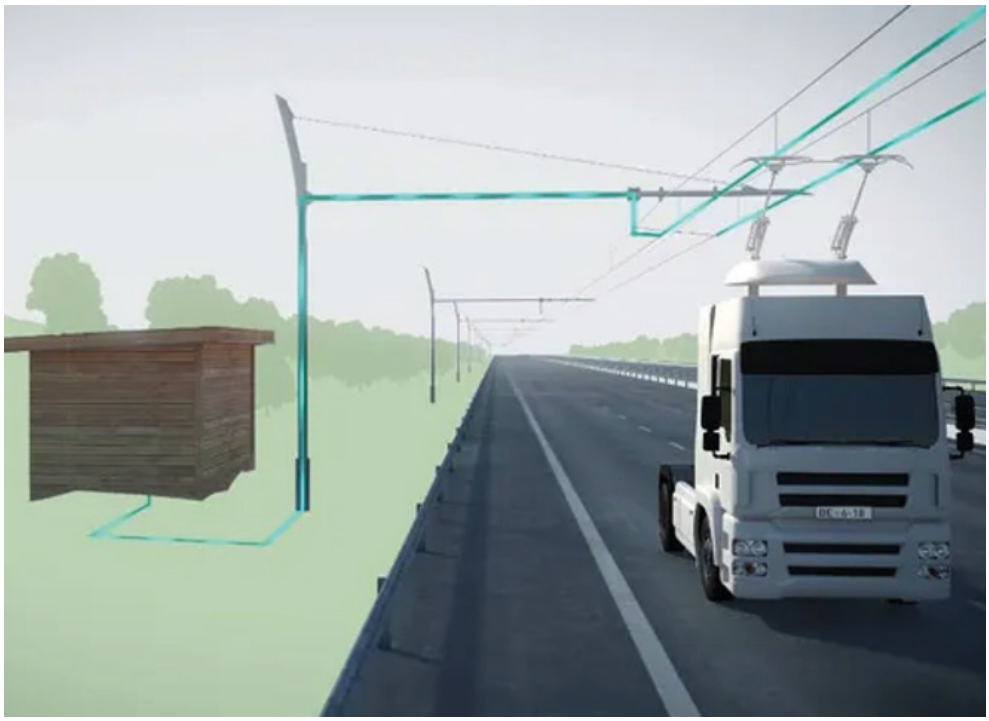

Figure 10: Power supply mechanism in the e-highways[23]

The average height of the cables above the road is 5.1 m, and they have a carrying capacity of 670 V. DC. About two thirds of the way up each column, a series of cantilevered arms attach themselves to the cables. Two feed-in substations provide the power from the grid. A lithium battery, commonly found in small electric trucks, is installed in an ERS HGV. In addition, the vehicle will have pantographs like those used on tram buses and electrified trains.

When the HGVs are on the ERS, they are powered by the overhead cables. The batteries of the vehicles also get charged to allow them to continue operating after the leave the ERS.

The ERS system has dynamically charged batteries. When the driver pushes a button within the vehicle, the pantograph rises to make contact with the overhead cables, and lowers itself automatically when it senses that the stretch of overhead wires is about to end. This poses significant advantages for situations such encountering low bridges or tunnels, or for any portions where overhead cables are not required.

[23] https://www.mobility.siemens.com/global/en/portfolio/road/ehighway.html

The ERS HGV may be charged while being loaded, or through carefully positioned charging outlets at depots and logistical hubs that complement the on-road system.

The Autobahn des Bundes has declared the experiment a success since the electric trucks have performed as predicted. In order to test the charging capability across a longer stretch of motorway, it is now being enlarged.

4.2. WIRELESS ELECTRIC ROADS

Electric roads are a futuristic e-mobility plan where the roads themselves act as electrified rails that charge vehicles that drive along it. They use an inductive charging system where the power is transferred between coils embedded in the road and the battery in the electric vehicle.

Electric roads are being explored in places like Sweden and the USA. [24]Sweden is also experimenting with a conductive charging electric road system where a lever from the vehicle comes in contact with the strip embedded at the center of the lane. An antenna guides the vehicle to run exactly in the center using green lights.

Sweden is currently converting a highway into the world's first permanently electric road, which will allow users to skip waiting at charging stations, and use smaller batteries to drive longer distances, which helps reduce the weight of the vehicle and decreases tire drag. The electrified route is planned between Hallsberg and Örebro, a heavily used route for the commercial transportation of commodities.

According to a recent study, it is not only trucks that would benefit from this system but also private cars, because of the benefits of reducing the battery size. The study simulated real world driving patterns of cars in Sweden, and concluded that only around 25 per cent of roads would need to be electrified in the country for the system to work effectively.

Worries about adverse weather conditions are addressed through real-time monitoring, ensuring that e-roads remain reliable year-round.

Estimates by the Swedish Transport Administration predict that electrifying roads could cost 1.2–2.0 million Euros per kilometre for electrifying both directions, while estimates from the German Institute for Energy and Environmental Research put the infrastructure cost for catenary ERS in the range of 1.7–3.1 million Euros per kilometre[25].

[24] https://www.bbc.com/future/article/20240130-wireless-charging-the-roads-where-electric-vehicles-never-need-to-plug-in

[25] https://www.mdpi.com/2032-6653/13/11/197

4.3 BENEFITS AND IMPEDIMENTS OF PANTO BASED E-HIGHWAYS AND ELECTRIC ROAD SYSTEMS

Benefits

1. Decreased emissions and better air quality: E-highways can drastically cut air pollution and greenhouse gas emissions by using electricity to power cars instead of fossil fuels. This can help improve air quality, particularly in cities close to highways.

2. Energy efficiency: EVs, particularly for use in long distances, can be more energy efficient than ICE vehicles.

3. Noise reduction: Because electric and hybrid vehicles are quieter than conventional vehicles, there is less noise pollution in and around the highways.

Key impediments

1. Infrastructure costs: For installing and maintaining the infrastructure for e-highways, the cost of procuring power lines and related technologies is heavy.

2. Technological harmony: For wide e-highway adoption, inter-operability between various vehicle manufacturers and the infrastructure is essential.

3. Regulatory framework: It is crucial to create suitable rules and guidelines for the safe functioning of e-highways.

4. Public acceptability: For e-highway technology to be implemented successfully, public perception and acceptability in terms of safety, dependability and aesthetic impact are essential.

5
STAKEHOLDERS

There are two primary stakeholders in the EV ecosystem: the policymaking and regulatory authorities, and the executing or implementing authorities.

5.1 POLICYMAKING AND REGULATORY AUTHORITIES

Both state level and central level authorities are responsible for framing necessary policies to define the fundamentals of e-mobility, and define the parameters under which policymaking is delegated to the regulators.

National stakeholders

The stakeholders at the central level are responsible for creating policies, regulations and guidelines, which act as guides for states. They could sometimes be overarching to the state's policy. The following are the identified national stakeholders responsible for charging infrastructure.

1. Ministry of Power: The legislative authority provides guidelines and standards for public charging infrastructure, enables their framework for implementation

2. Ministry of Environment, Forest and Climate Change: The body is responsible for prevention and control of pollution. Policies such as the Draft End-of-Life Vehicles (Management) Rules, 2024, which included the components of battery recycling and scrapping of ICE vehicles were framed by the ministry.

3. Ministry of Finance: The ministry approves budget for various central schemes towards manufacturing and selling electric vehicles such as the Production Linked Incentives (PLI) Scheme and the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles(FAME) scheme.

4. Ministry of Heavy Industries and Public Enterprises: The body is responsible for creation of central schemes such as FAME, incentivising production of EV through PLIs and boosting the manufacturing of EV in the country. There is an ambitious target to achieve annual sales of 60 to 70 lakh hybrid and electric vehicles from year 2020.

5. Ministry of Road Transport and Highways: The ministry sets the rules, regulation and guidelines towards sales, registration and record keeping of the electric vehicles in the country.

6. Ministry of Science and Technology: The Bureau of Indian Standards (BIS) and Department of Science and Technology under this ministry work together on improvements such as indigenous charging standards, charger manufacture, OEMS, and working with DISCOMS and policy makers. They also deploy charging stations in public parking slots and collaborate with industry and academia on R&D focused on EVs.

7. National Automotive Board: The body was part of implementing and framing FAME I and FAME II.

8. Central Electricity Authority (CEA): The authority defines technical standards and regulations for EV charging.

9. Ministry of Housing and Urban Affairs (MoHUA) : MoHUA amended the Model Building Bye-laws 2016 in the year 2019, the Urban and Regional Development Plans Formulation, and the Implementation Guidelines 1996 (URDPFI) in 2014 to include provisions for EV charging

10. Bureau of Indian Standards (BIS) : The BIS defines EV charging standards for chargers and connectors

State-level stakeholders

1. GUIDANCE Tamil Nadu, Ministry of Heavy Industries : The state-level policy-making and coordinating body works towards bringing in investment in the sector

2. Housing and Urban Development Department (HUD), Tamil Nadu: The body advises the governor and other officials on federal policy. It also conducts programs and activities relating to housing and community development, which includes public charging infrastructure.

3. Tamil Nadu Electricity Regulatory Commission (TNERC): The TNERC has the powers to determine the electricity tariff, regulate electricity purchase and procurement process, issue licenses, facilitate intra-state transmission and wheeling, promote cogeneration, specify the State Grid Code, specify or enforce standards of performance, and adjudicate upon disputes.

5.2 EXECUTING OR IMPLEMENTING AUTHORITIES

The executing authorities are responsible for putting the policy into action. They ensure that the policy is administered and enforced to bring about the change envisioned by the policymakers and meet the public's expectations. .

National stakeholders

1. Bureau of Energy Efficiency (BEE): The BEE is the central nodal agency (CNA) for the rollout of EV public charging infrastructure implementation across the country

2. Department of Heavy Industry (DHI): The DHI, under National Automotive Board, is responsible for schemes such as FAME I and FAME II and other national missions on electric mobility

3. Power Grid Corporation of India Ltd: The body contributes in the establishment and operation of regional and national power grids, to facilitate the transfer of power within and across regions with reliability, security, and economy on sound commercial principles

State level stakeholders

1. Energy Department, Tamil Nadu: Analyses the power demand and supply of the states facilitates seamless provision of affordable, reliable and quality power.

2. Transport Department, Tamil Nadu: Issues guidelines and undertake capacity building of RTOs to enable registration of commercial EVs, including electric two- wheelers for commercial use.

3. State and Regional Transport Authorities: An important stakeholder in planning for public charging infrastructure, as this agency holds information on EV penetration trends in the city or region through vehicle registration data.

4. Tamil Nadu Power Distribution Corporation Ltd (TNPDCL): State nodal agency (SNA) responsible for facilitating the development of charging infrastructure in the Tamil Nadu state.
   Provides electricity connections for EV charging, implementing EV tariff, ensuring that EV charging infrastructure is connected and operating properly, preventing improper use of EV connections, managing the distribution network, and undertaking grid upgrades based on growth in load including from EV charging.

5. Tamil Nadu Green Energy Corporation Ltd (TNGECL): Leads the implementation of initiatives to strengthen EV charging infrastructure across the state. Works closely with stakeholders to ensure coordinated deployment, operational efficiency, and policy alignment.

6. Municipal Corporations and Municipalities: Various corporations and municipalities are responsible for amendments to building bye-laws and urban planning frameworks to include provisions for EV charging.

7. Municipal Administration and Water Supply (MAWS): The department is responsible for the development of urban areas in the state.

6

CASE STUDIES

6.1 DELHI: SWITCH DELHI CAMPAIGN

Delhi’s efforts towards EV adoption have resulted in a notable increase in EV’s in the city. In 2023, EVs comprised of 11.23 per cent of all vehicles, as compared to 3 per cent in 2020. This substantial growth reflects the positive impact of supportive policies and incentives.

The learnings from Delhi's approach to electric vehicle (EV) adoption and charging infrastructure can serve as a valuable model for other regions.

Key features of Delhi’s EV policy

1. Capital subsidies and concessional land rates for public charging and swapping infrastructure: The Government of the National Capital Territory of Delhi (GNCTD) incentivised investment in charging networks. As per the 2020 EV policy, 100 per cent of the net SGST accrued to the GNCTD for the purchase of advanced batteries for swapping and charging stations shall be provided as reimbursement to energy operators. Concessional locations for charging stations mapped with utilisation were provided at a bare minimum lease. . Additionally, GNCTD provides capital subsidies for installation expenses based on the cost of chargers to selected Energy Operators.

2. Charging equipment incentives: To encourage expansion of charging infrastructure, up to INR 6,000 was offered as a purchase incentive oncharging equipment per charging point for the first 30,000 charging points. Simplified installation mechanisms streamlined the process.

3. Parity for battery-swapping EVs: It was ensured that battery-swapping EVs received incentives on par with fixed-battery vehicles, which helped promote battery swapping as a viable alternative. Favorable tariffs for EV charging further incentivised the use of EVs.

4. Incentives for energy operators: Incentives were offered to energy operators for EVs sold without batteries, creating a symbiotic ecosystem that encourages battery swapping and operational support.

5. Mandatory EV-ready parking: Building bye-laws were amended to mandate EV-ready parking spaces in new buildings, to prepare the infrastructure for future EV growth.

6. Renewable energy charging: Incentives were given for renewable energy charging, to align with sustainability goals and reduce the carbon footprint of EV charging.

7. Unified infrastructure: The creation of an open database and a unified payment infrastructure simplified the user experience, making it more convenient to access charging services.

8. Institutional setup: A dedicated state EV cell was established from the outset, along with a Working Group for Accelerated Rollout of Charging Infrastructure . This ensuring focused efforts and efficient execution.

Organisational structure for EV implementation in Delhi

Figure 11: Organisational structure of the Delhi EV cell

A working group headed by the vice chairman of the DDC was created as per the recommendations of NITI Aayog to create a State Charging Infrastructure Committee (SCIC) to accelerate the rollout of charging infrastructure in Delhi. The role of the working group was also to obtain a holistic view of charging infrastructure in the region and to recommend strategies to accelerate the deployment of charging infrastructure. The EV cell was set up to help implement the EV policy by carrying out functions including:

- Facilitating deployment of demand incentives through a common platform
- Facilitating deployment of EV charging stations in collaboration with both public and private stakeholders
- Identifying ways to prepare further policy interventions to accelerate EV adoption in the state

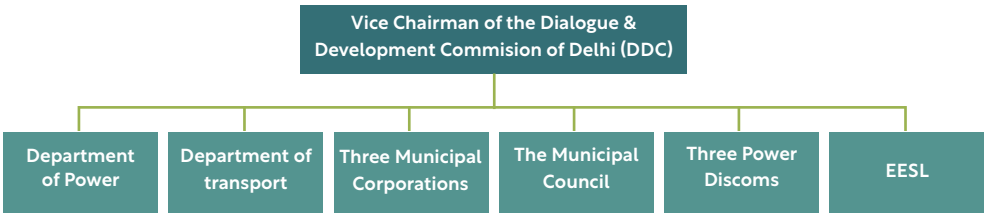

Figure 12: Organisational structure of the working committee

9. Dedicated funding source: Delhi established a special State EV Fund that is non-lapsable and is funded by cess money obtained by discouraging the use of conventional vehicles. This was done using an Environment Compensation Charge (ECC) and an Air Ambience Fund collected per-liter basis of diesel usage, for heavy-duty vehicles entering the city. . The budgetary allocation is used to cover the remaining shortfall. In addition, the State EV Cell of the Department of Transport, GNCTD, keeps an eye on the daily account balance.

10. Conversion of government fleet (Vehicles specifically cars): With a deadline of six months, the GNCTD in February 2021, issued an order[26] to convert its complete existing fleet to EV, applicable to all departments, autonomous bodies, and grantee institutions under the purview of GNCTD. The state created specific service level agreements (SLAs) for hiring and leasing of EVs, as they might widely differ with the SLAs for ICE vehicles. The following parameters in addition to the SLAs for ICE vehicles are applicable for EVs
    a. Provision of space and exclusive electric connection for charging space
    b. Inclusion of operation costs as there is a high CAPEX involved in purchasing of EVs, thus bringing the cost of lease or hire at par with ICE vehicles
    c. Disclosure of lack of information on resale value of the EVs in the calculation of bids
    d. Charger usage policy and billing process

11. Contribution from General public and EV stakeholders: Frequent roundtables with experts, EV stakeholders and the general public were conducted to understand and improve the policy and its implementation methods.[27] Importance was given to paying attention to people, and understanding public issues and developing answers to these was a

[26] As per official memorandum No.F.20/02/2021/689-698 dated 25.02.2021 of Finance Department

[27] https://cleanmobilityshift.com/policy-regulation/how-delhi-government-was-able-to-achieve-an-ev-penetration-rate-of-nearly-20/

part of the first draft of the policy. It was essential that major actors in the EV ecosystem, including OEMs, DISCOMS, CPOs and service providers get involved. Suggestions were invited through a year-long engagement process, a practice that continues to this day. This constant communication can help continued innovation and prompt policy modifications based on shared understanding.

Land-Owning Agency	No. of Sites
Delhi Metro Rail Corporation (DMRC)	71
Delhi Transport Corporation (DTC)	11
Transport Department	4
BSES Rajdhani (BRPL)	3
BSES Rajdhani (BRPL)	3
Tata Power Delhi Distribution (TPDDL)	3
Delhi State Industrial & Infrastructure Development Corporation Ltd. (DSIIDC)	3
Delhi Jal Board (DJB)	1
Irrigation and Flood Control (I&FC)	1
Total	**100**

Table 7: Aggregation of available land parcels from various land-owning authorities

This 'i3' model of Delhi i.e., Inclusion, Incentivisation, and Innovation has been essential in encouraging high adoption rates of electric vehicles.

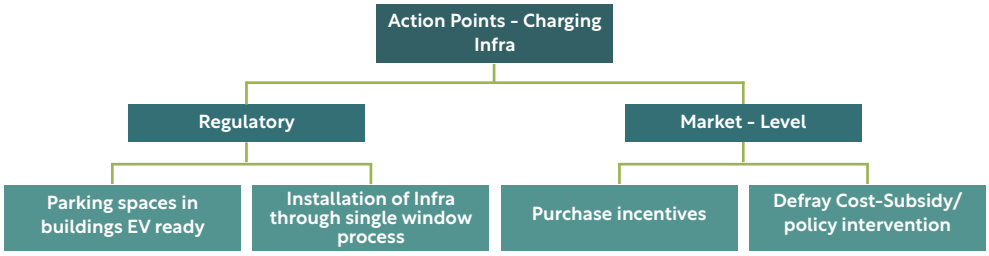

Figure 13: Action points for establishing charging infrastructure

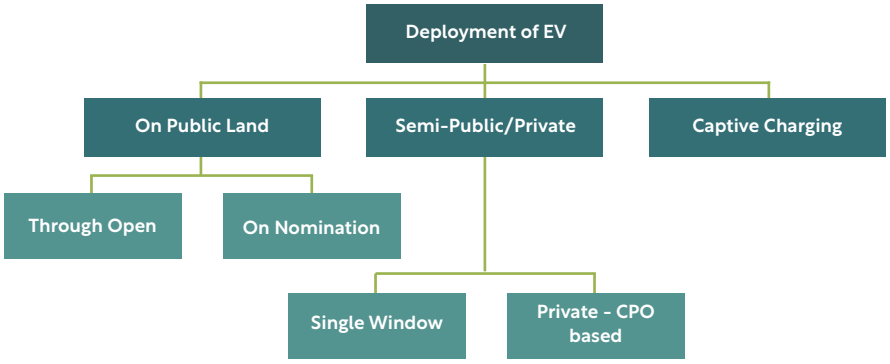

Figure 14: Process for deployment of PCS based on land types

Guiding principles for the action plan

The following points were the guiding principles for formulating the action plan.[28]

- Aligning incentives to charging solutions for priority vehicle segments (2- and 3-wheelers)
- Defraying the cost of land by linking lease with revenue and providing upstream electrical infrastructure
- Ensuring that the public charging stations and battery swapping facilities have features such as accessibility, electrical infrastructure and feasibility.
- Ensuring that the following spaces have charging points of at least 3.3 kW output (5 swap points will be considered as one charge point)

Parking Type	Percentage of parking for EV ready
New Buildings	20%
Existing Buildings	5%

Table 8: EV Mandate for buildings

- Based on the number of available parking Equivalent Car Space (ECS), it also mandates a percentage segregated for EVs

Area	Proportion	Minimum Number of Charging Points and/or Swapping Stations	Minimum Number of Battery Swapping Station(s)
<20 ECS	10%	1	-
Between 20 to 100 ECS	20%	4	1
>100 ECS	25%	25	3

Table 9: Mandate on segregation of existing parking spaces to be EV ready

[28] https://ev.delhi.gov.in/files/Delhi%20Shopping%20Mall%20EV%20Charging%20Guidebook.pdf

6.2 KARNATAKA

The Bengaluru Urban district leads in terms of public charging stations with a total of 4,281 stations, accounting for 85 percent of Karnataka's charging infrastructure.[29]

Karnataka has also introduced a variety of initiatives which can be learnings for application in other states.

1. **Initiatives by the nodal agency:** Bengaluru Electrical Supply Company Limited (BESCOM) was appointed as the nodal agency by the state EV policy. Charging stations were established under the national government's FAME program. BESCOM also installed charging infrastructure using funding sources including its own capital expenditure and green cess funds from the state transportation department through a public-private partnership model. The EV cell under BESCOM will monitor the growth of EV in Karnataka.

2. **Focusing on green corridors:** The state identified corridors with existing charging stations and boosted the number of charging stations in those routes. The Bangalore - Mysore Expressway and Bangalore - Chennai Highways presently have the largest number of charging stations.

3. **Mandates to establish charging stations in commercial buildings:** The state has mandated charging stations in buildings such as IT parks and large offices, malls, high-rise buildings and apartments.

4. **Long lease:** The state government assisted in identifying land on a long lease basis for setting up charging stations and battery swapping stations.

5. **Targets for different modes:** The state has targeted 100 percent electrification of auto-rickshaws, cab aggregators, corporate fleets, school vans and buses by 2030.

6. **Electric mobility research and innovation Centre:** Karnataka setup an EV research and innovation center under the state fund for innovations such as improved battery technologies and charging and developing new vehicles etc.

6.3 SINGAPORE

Singapore's first Intelligent Transport System Master Plan, 'Smart Mobility 2030', was created in 2014 by the country's Land Transport Authority (LTA). The authority is responsible for planning, operating and maintaining Singapore's

[29] https://www.thehindu.com/news/cities/bangalore/karnataka-boasts-highest-number-of-ev-charging-stations-in-india/article67860642.ece)

land transport infrastructure and systems. The Intelligent Transportation Society of Singapore brings together the professional interests of those in public and private organisations, practitioners, academics and researchers related to Intelligent Transport Systems (ITS) electric mobility and create opportunities for networking and interaction. With the aim to address the new mobility issues that Singapore would face until 2030, the plan defined target areas and synthesised opinions from a variety of agencies and stakeholders. Green Mobility is designated as one of the four key areas under Smart Mobility 2030, which also included EVs and hybrid-vehicles as an economical and environmentally better alternative to ICE vehicles.

To encourage fresh initiatives that improve sustainability and liveability in Singapore, the Sustainable Singapore Blueprint (SSB) 2015 was set forth with ambitions goals to reduce its land transport emissions by 80 percent by 2030. As part of its goals, SSB supports environmentally friendly automobiles to help overcome resource limitations and enable the growth of a sustainable economy. Additionally, the SSB also emphasised 'Sharing Electric Vehicles at our Doorstep', a car-sharing program designed to increase public access to EVs.

Keeping with these aims, the LTA commissioned the Nanyang Technological University's (NTU) Energy Research Institute (ERIN) to create an Electromobility Roadmap. This roadmap will act as a guide for the creation of laws and infrastructure linked to electric vehicles (EVs) in Singapore through 2050.

The roadmap took into account the rates of increase in Singapore's vehicle population and developed several electrification scenarios based on changes in battery and EV pricing trends, advancements in charging technology and speed, and the availability of sensible policies to encourage the use of EVs. The strategy also proposed important research and policy proposals for Singapore to support the adoption of electric vehicles.

There are over 1,600 public EV charging points in Singapore, including AC and DC fast chargers. These charging points are spread across various locations, including shopping malls, commercial buildings, public car parks and residential areas.

Initiatives like electrification, active mobility, and public transport can help Singapore achieve its lofty objective of reducing land transport emissions by 80 percent from 2016 to 2030. EV adoption can reduce CO2 emissions by 50 percent and help achieve national sustainability goals. To promote the adoption of EVs, the Singaporean government has created a system of rules and incentives.

To overcome the challenge of limited land availability, Singapore has implemented solutions to maximise the use of existing infrastructure. For example, the Housing Development Board (HDB) has installed EV charging points in over 60 residential car parks, and these charging points are shared between residents and the public.

In addition, the Land Transport Authority (LTA) has implemented a pilot program to test the use of lamp post charging points in public areas. These charging points are mounted on existing lamp posts and provide EV drivers with a convenient and accessible charging option.

Key initiatives in Singapore

1. **Incentives for EV purchases:** The Singaporean government implemented several incentives for EV purchases, such as a zero-percent Additional Registration Fee (ARF) for electric cars and rebates of up to Singaporean Dollar 20,000 for electric motorcycles.

2. **Road tax exemptions:** Electric vehicles in Singapore are exempt from road taxes, which can make them more affordable to own and operate.

3. **Rebates for EV charging installations:** The government provides rebates of up to 50 percent for the installation of EV charging infrastructure in public car parks and private residences. The government of Singapore has invested heavily in the development of public charging infrastructure. The government of Singapore provides subsidies for EV owners who install charging stations at home. This has helped to make it more affordable for EV owners to charge their vehicles.

4. **Public-private partnerships:** The government has partnered with private companies to develop and operate EV charging infrastructure. For example, the state-owned utilities company, SP Group, has partnered with various businesses and organisations to install and operate charging stations.

   The government of Singapore has also encouraged private sector investment in the development of charging infrastructure, which has resulted in the installation of charging stations in locations including shopping malls, parking garages, and apartment complexes. The government is leveraging public-private partnerships to spur investment into EV charging infrastructure. It conducted several tenders to invite the private sector to invest in and operate EV charging stations in public car parks. In 2022, the Land & Transport Authority (LTA) in Singapore launched a tender for the installation of up to 22,600 EV charging points at 1,964 public housing (HDB) car parks across the island.

5. **Innovative solutions to maximise land use:** Singapore has implemented innovative solutions to maximise the use of existing infrastructure for EV charging such as lamp post charging points.

6. **Providing information and education:** The government of Singapore has also provided information and education to EV owners about charging infrastructure. This has helped to raise awareness on the availability and

usage of charging stations.
Despite a high vehicle-to-public charging point ratio (ie the number of EVs in the car park divided by the number of public charging points), EV adoption in Singapore is still yet to take off. Many of its residents live in apartment blocks, making it harder to install enough private charge points.

Takeaways from the Singapore approach

1. **Investing in public charging infrastructure:** The government of Singapore has invested heavily in the development of public charging infrastructure. As of the end of 2023, there are over 3,600 public charging stations in Singapore, with plans to increase this number to 12,000 by 2025 and 60,000 by 2030 as part of the Singapore Green Plan 2030. Of this, 20,000 would be on private premises and 40,000 in public car parks.

2. **Encouraging private sector investment:** Singapore has also encouraged private sector investment in the development of charging infrastructure. To leverage public-private partnerships to spur investment in EV charging infrastructure, it put out several tenders to invite the private sector to invest in and operate EV charging stations in public car parks. In 2022, the Land & Transport Authority (LTA) in Singapore launched a tender for the installation of up to 22,600 EV charging points at 1,964 public housing (HDB) car parks across the island.

3. **Providing subsidies for EV owners:** The government provides subsidies for EV owners who install charging stations at home, making it affordable for EV owners.

6.4 AMSTERDAM

By 2025, Amsterdam hopes to achieve its lofty aim of being an entirely emission-free city. The Dutch government uses the 'right-to-charge' and demand-driven approach for EVs, i.e it requires the municipality to set up a charging point free of cost if there is a request for it from an EV user and the user doesn't have a charging point in the required proximity. In 2016 , the city of Amsterdam signed a new seven-year contract with and Nuon/Heijmans for the installation of our charging infrastructure, with the company 'EV Box' as the primary charger station supplier. Constructing a charging network that can handle new standards and developments in the future was crucial to this tender.

Netherlands has one of the highest density of charging systems, and its infrastructure, protocols, payment methods and grid integration are significantly standardised.

Concession-based market mechanisms are an effective and economical means of creating a high-quality, uniform charging network for people and logistics firms

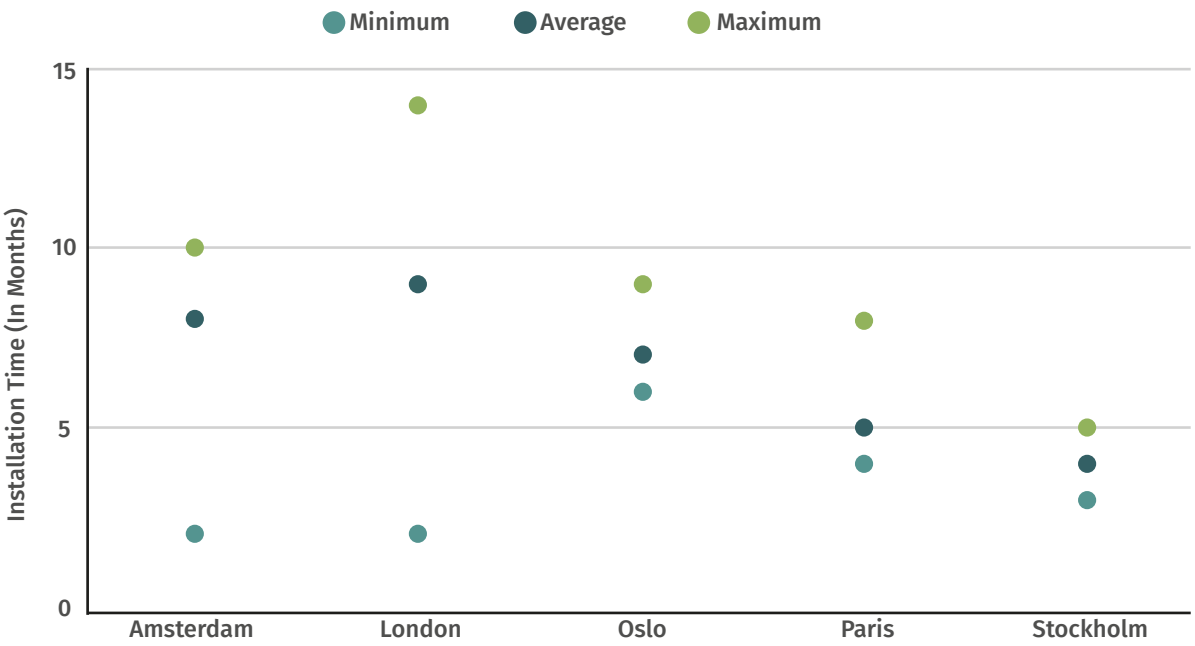

Figure 15: Time frame for installation of public EV charging stations in the European countries[30]

to decarbonise. Technology testing and piloting are crucial to gaining practical application insights.

Key features of Amsterdam's approach

1. **Basic charging infrastructure network:** Amsterdam created a basic network of charging stations as early as 2009 to spur the growth of EV.

2. **Demand-driven right-to-charge approach:** The demand driven approach is one of the distinct characteristics of Amsterdam's EV policy. The policy mandates that municipalities must install public charging stations within 250 meters of a residence upon request from the concerned EV user. The CPOs are expected to verify the demand, and then finalise the location for the charging station using general standards such as availability, ease of use, visibility and local effects of setting up the station. Distribution system operators (DSO) or DISCOMs and governmental organisations then work together to set up the charging station, guaranteeing grid stability and the transfer of EV charging data to all involved parties. The towns collaborate closely with DSOs and CPOs, who establish the network on their behalf and guarantee standard compliance and interoperability with current payment models.

   There are established processes and timelines in place that need to be followed if a charging station is set up using the demand-driven approach.

[30] https://theicct.org/sites/default/files/publications/European-cities-charging-infra-feb2021.pdf

Step	Duration	Details
Application	1 Week	A request is received from the EV driver and assessed by the city.
Location and Operator Suggestion	Minimum 2 Weeks	If the request is approved, the city chooses the exact location based on maps provided by stakeholders.
		The city assigns the work to a charging station operator either pre-determined or through a case-by-case tender process (pre-determined considerably saves time).
Installation Plan	3 to 20 Weeks	The charging station operator, in collaboration with the grid operator and the road authority, develops the installation plan.
		The city reviews (and approves) the plan.
Site Preparation	2 to 12 Weeks	The charging station operator together with the grid operator prepares the area (wiring, foundation, and any other civil work).
Installation	1 day	The charging station operator installs the charger(s), and they or the grid operator connect it/them to the electricity network.
		The charging station operator registers the charging station on a database and frequently uploads charging data.

Table 10: Process for establishing charging station through demand driven approach[31]

3. **Establishing a long-term investment environment:** CPOs receive concessions from local authorities through open auctions. Instead of having to provide subsidies, Dutch municipalities receive EUR 500 from the public-private partnership for each charging station. The money raised is put back into creating smart charging trial programs. The right to charge creates guaranteed demand, and the CPOs profit from the demand as well as the long-term investment horizon.

   To increase their negotiating power, municipalities and regions frequently collaborate on joint tenders. A ten-year concession was granted in 2016 to Rotterdam and sixteen other nearby communities.Based on several action plans that evaluated organizational characteristics, communications, user

[31] https://theicct.org/sites/default/files/publications/European-cities-charging-infra-feb2021.pdf

service, innovation and sustainability, and economic factors, the operators were ranked and chosen.

4. **Standardisation, Open Protocols, and Collaboration:** Importance was given to standards in EV charging in the Netherlands right from the early days of EV adoption. ElaadNL is a 2009 DSO-funded knowledge and innovation institute focused on smart charging infrastructure. This equipment certification centre ensures that standards are met and interoperability of all equipment is guaranteed. Additionally, ElaadNL is in favor of the advancement of open protocols and charging standards, both of which are essential to the growth of open markets.

5. **Grid Integration and Integrated Planning:** The National Charging Infrastructure Agenda of the Dutch government places a strong emphasis on standards and open protocols. The multi-year policy program is an integrated strategy to accomplish the rapid upscaling of charging infrastructure. The agenda aims to promote smart charging in addition to open protocols, open marketplaces and price and implementation transparency. The stakeholders work together to create market models, technical frameworks, and legislative and regulatory frameworks.

7

INTERACTIONS with Stakeholders and Findings

Interactions were conducted with a variety of stakeholders such as Original Equipment Manufacturers (OEMs) for EVs, CPOs, state government authorities.

7.1 LEARNINGS FROM OEMS FOR ELECTRICAL VEHICLE CHARGING SUPPLY EQUIPMENT

A discussion was conducted with the CEO of Tirex, a manufacturer of EV charging equipment. Several learnings and insights emerged from this discussion.

Challenges to be overcome in Tamil Nadu

- **High tariff:** From the discussion, it emerged that the current EV tariff is a key consideration for CPOs when evaluating Tamil Nadu as a potential market.

- **Involvement of DISCOMs:** Involvement from the government encourages private companies and helps viable businesses. A boost from the government side will increase the number of chargers in the state.

- **Speed of charging:** Even if the capacity of the charging input is good, the size of the battery on the EV restricts the speed of charging. For example, Tata Nexon is the most sold EVs but can support a maximum input of only 30-35 kW.

Operationalising Public EV charging stations

- Cost of the Equipment, useful life and maintenance
  The cost of supplying the charging equipment to the CPOs is as follows:
  - Chargers up-to a capacity of 60kW - INR 8-9 lakh
  - Up to 120kW - 11-13 lakh
  - Up to 240kW - 20-24 lakh

- There are two kinds of chargers in terms of capacity: standard capacity chargers or conventional chargers and convertible chargers. In a convertible charger, the capacity of the chargers can be upgraded, say from 30 kW to 60 kW. These would cost a lakh or two over conventional chargers.

- The life of the charger can be between 8-10 years if maintained well

- The cost of maintenance each year would be around 2 percent of the cost of the charger.

- Fast and smart charging stations are the upcoming technology in terms of the constant upgradation that the industry is prone to.

- A 60 kW charger is the ideal charger in the current scenario. This capacity can be upgraded in the future on a need basis.

- E-bus operators tend to be concerned about the reliability of public infrastructure and prefer to set up their own charging network. This requires a HT connection and establishing a distribution transformer to begin operation.

- For cars, one 60 kW charging equipment with two charging points shall be more than sufficient.

- The standard charger that is suggested by the government is the Combined Charging System (CCS) charger for four-wheelers and CCS 2 for buses.

- In India, the prices for charging using both AC and DC are usually fixed. But globally, DC chargers are generally more expensive, while AC chargers are cheaper.

7.2 LEARNINGS FROM CHARGING POINT OPERATORS

Insights were sought from CPOs in Bengaluru and Delhi to understand their perspective and experiences in the EV eco-system.

Involvement of CPOs in EV policy formation to address operational challenges

Throughout the formulation of Bengaluru's EV policy, CPOs actively contributed their valuable insights to enhance the policy's practicality and feasibility. Their strategies were intricately designed to align with the state's EV policy decisions. A similar approach was also found in Delhi, where multiple stakeholder consultations and target meetings were conducted to get inputs from CPOs. These helped directly address the major concerns and operational impediments.

Standardisation issues in battery swapping infrastructure

One of the biggest problems the CPOs from Bengaluru pointed out was the diverse array of battery models and the absence of uniform standards. Achieving battery standardisation across automobiles and two-wheelers would be problematic due to variations in manufacturer's designs and perspectives. Presently, establishing battery swapping stations might be most viable when it is used primarily for shared transportation modes, intermediate public transport (IPT) and for business-to-business (B2B) users.

Occupancy issues in off-street EV charging infrastructure

The deployment of off-street EV charging stations is contingent upon the CapEx. The allotment of space for station installation also differs for each setup. According to the CPOs, the market currently consists of early adopters and value seekers, and EV sales have not fully taken off. As a result, occupancy rates of public charging stations remain under 10 percent, and operators would be able to break even on their investment only after another 5-7 years.

CPOs highlighted an interesting observation that while occupancy rates in Delhi and Bengaluru are around 1.5 percent, they tend to be higher in tier-2 cities such as Mysuru, Tirunelveli, and Madurai, as well as in the outskirts of larger cities.

Space utilisation through on-street EV charging infrastructure

The CPOs suggested the establishment of 7.5-15 kW charging stations, designed to be pole-mounted could help efficient space utilisation. An output of 7.5-15 kW may necessitate a considerable time to fully recharge a vehicle, but this could be addressed by implementing time-based recharging alternatives. Such an approach would facilitate short-term parking while ensuring that the vehicle is adequately charged to reach nearby off-street charging hubs.

Figure 16: EV charging hub at Marathahalli (Photo: ITDP)

Figure 17: User feedback discussion at a battery swapping station (Photo: ITDP)

Challenges in charging and payment models

Vehicle charging can be approached through three methods: based on time, a fixed price, or kilowatt usage. The choice of recharge method is at the discretion of the consumer. However, a significant drawback arises when the user aims for a completely charged vehicle. This results in the charging slot being occupied for a long period, leading to decreased turnover rates.

B2B tie-ups with malls difficult to implement

Integrating charging with parking at places like shopping malls could be convenient for users and operators. The access to charging stations in malls is through payment of parking charges. While B2B tie-up-based utilisation can be effective by directing charging points to malls rather than charging hubs, parking charges and lack of response from malls towards B2B operators are hurdles in implementation.

Lack of inclusive ergonomics charging point design.

The charging plug access is positioned at a height of 1.5 m from the base of the charging station. To prevent contact with water, the charging station is further elevated by 1 meter. This arrangement put the height of the charging plug height above average user height, making it difficult to access for many users.

Figure 18 & 19: User feedback discussion at a battery swapping station (Photo: ITDP)

Figure 20,21 & 22: EV Charging stations(7.5 kw, 30kw, and 60 kw) (Photo: ITDP)

7.3 LEARNINGS FROM THE TAMIL NADU PETROLEUM DEALERS ASSOCIATION (TNPDA)

Consultations were carried out with the president of the Tamil Nadu Petroleum Dealers Association and Treasurer (TNPDA). Petrol stations are one of the biggest aggregators of readily available land in Tamil Nadu where charging stations can be established. Since vehicles already stop here for re-fuelling, , it would be accessible and easy to locate for EV drivers.

Around 30 petrol stations in the state have already installed charging stations and are operating them. In the interactions with TNPDA, some of the operational constraints were highlighted by the association.

1. **Reimbursement delays:** Oil companies installing charging stations do not reimburse fixed charges promptly, leading to operational losses for petrol bunk owners. As per TNPDA, fixed charges are reimbursed only after 18 months from bill payment.

2. **Demand charges:** Petrol bunk owners are expected to pay demand charges for power connections, blocking their working capital.

3. **No separate connections:** Charging stations do not have separate connections or submetering for charging infrastructure, making it harder for owners and operators. Presently, HT connections are used for larger bunks while LT connections are used for smaller ones.

4. **Difficulties in handling solar units:** Installation of rooftop solar units is prohibited under HT connections, hindering sustainable power sourcing.

5. **Limitation of net metering mechanism:** LT Domestic customers have limited options for the net metering mechanism, affecting billing for solar energy. If the installed capacity of the rooftop solar system exceeds 10 kW, 75 per cent of the network charge is applied. The cost of network charges for LT commercial category is Rs. 1.27 per kWh.

6. **Higher Costs:** The net metering mechanism may result in customers paying up to 50 per cent more annually, and the net feed-in mechanism may lead to 29 per cent higher costs annually, including network charges.

Key Takeaway

1. **Operational constraints:** Petrol station owners face significant operational challenges in operating charging stations due to reimbursement delays and demand charges. The operators receive a margin of INR 2 per kW of energy sold through charging, which does not offset the fixed charges, resulting in operational losses.

2. **Sustainability barriers:** Prohibition of HT for solar units and limitations in net metering mechanisms pose barriers to sustainable energy sourcing. Network charges for LT commercial category and limitations in net metering options impact the feasibility of adopting solar energy.

8

STATUS OF THE EV CHARGING SECTOR & Recommendations for the future

8.1 THE CURRENT SCENARIO

Tariff analysis of the revised tariff order in Tamil Nadu:
In June 2025, the Tamil Nadu Electricity Regulation Commission (TNERC) revised the tariff order for the supply of electricity to the state with lower tariffs for public charging.

8.1.1 IMPLICATIONS OF THE RATE REVISION

Negative Implications

- Commercial tariffs: Charging facilities in commercial complexes will have to use LT connections, which have a higher price. This may discourage users from using such charging infrastructure.

- Potential congestion: Charging at non-peak hours are presently priced lower. If EV users respond to these signals, it could lead to local network congestion of the existing charging stations, which already have limited availability of charging network.

EV Charging Stations								
	Old (Till July 2024)				New (from 1st July 2025)			
LT-VII	05:00-10:00hrs and 14:00-18:00hrs	9.45	0-50 kW	26.00	06:00-09:00 hrs and 18:00-22:00 hrs	9.75	0-50 kW	55
	18:00-23:00hrs	6.3	Above 50-112 kW	79	09:00-16:00 hrs	6.5	Above 50-112 kW	165
	10:00-14:00hrs and 23:00-05:00hrs	7.85	Above 112 kW	145	16:00-18:00 hrs and 22:00-06:00 hrs	8.1	Above 112 kW	304
HT-V	05:00-10:00hrs and 14:00-18:00hrs	9.45	Rs/kVa/ Month	145	06:00-09:00 hrs and 18:00-22:00 hrs	9.75	Rs/kVa/ Month	304
	18:00-23:00hrs	6.3			09:00-16:00 hrs	6.5		
	10:00-14:00hrs and 23:00-05:00hrs	7.85			16:00-18:00 hrs and 22:00-06:00 hrs	8.1		

Table 11: A glimpse of the revised tariff order from the TNERC website, valid from July 1st, 2025

- Lack of provisioning for innovative business models: Business models that combine other aspects of charging such as overnight parking do not have any separate provisions, and would be charged a higher price range during the nighttime.

- Community charging: There is no separate classification of tariff systems for charging at houses and apartment complexes. Housing societies that have a common utility meter have a higher electricity tariff compared to domestic charges. This may demotivate community charging and setting up of charging stations by Resident Welfare Associations(RWAs).

- Automated meter Readings: While 'time of day' charges are issued in the tariff, the functioning would depend on having an Automated Meter Reading, which is still not prevalent in Tamil Nadu. Thus, the computation of correct charges could be a challenge.

- Grid Segregation: The grid is not segregated into green grids and non-green grids to distinguish power generated using renewable and non-renewable sources. Additionally, green energy is currently being charged a 10 per cent higher than using non-green energy. This could demotivate green power utilisation for EV charging.

Positive implications

- Percentage of opportunity charging (charging at the destination or during the journey when a convenient charging point is encountered) could increase, since the period between 9 AM and 4 PM has the lowest pricing bracket (INR 6 per unit).

- The fixed charges for HT connections has been reduced from INR 550 to INR 138, significantly lowering the cost for users and incentivising EV adoption.

- Given that there are wider tariff options for the public to choose from, this could increase the number of players in the public charging business.

8.1.2 KEY CHALLENGES IDENTIFIED FOR DIFFERENT STAKEHOLDERS

Each set of stakeholders face a different set of issues when it comes to EVs and charging infrastructure. As mentioned in Chapter 2, a report[32] by JMK Research and Analytics discusses some of the primary challenges for each set of stakeholders.

For End Users:

1. **Range anxiety :** Similar to drivers of ICE vehicles who expect a good mileage, Indian users tend to keep the range of the EV and number of kilometres an EV will run on a single battery charge as a critical factor if they decide to purchase one. A study by Castrol[33] on 1000 consumers, fleet managers, and industry specialists across India indicates that drivers expect a range of 401 km from a single charge

2. **Time anxiety :** Consumers expect to charge their vehicles as quickly as they can refuel an ICE vehicle, with the study putting the expected average charging time at 35 minutes. Thiscurrently is not possible with current technologies in the charging industry.

3. **Charge anxiety :** 'Charge anxiety' revolves around concerns like locating a locate a charging station, the station's operational status, the compatibility of chargers with the EV model, and whether the station has a seamless payment mechanism for easy transactions.

For CPOs

1. **Sub-optimal usage rates :** The usage rates at public stations stands just at around 10 to 15 per cent of the capacity[34], making it financially unviable

[32] https://jmkresearch.com/electric-vehicles-published-reports/evolving-ev-charging-infrastructure-in-india/

[33] https://www.castrol.com/en_gb/united-kingdom/home/electric-vehicle-fluids/electric-vehicle-adoption.html

[34] The number has been arrived at considering that a fast charging station has not more than 2 or 3 cars coming in every day and takes 1.5 hours to charge a vehicle.

unless incentives and subsidies are provided. The current CapEx per station excluding land costs for a station with six charging points comes to around INR 1.2 crore, considering that the cost of one charging gun is around INR 20 lakh.

2. **Land banks:** State enterprises find it difficult to procure land, though they are technically supposed to get the land for free. With high rents that even surpass operational costs (some CPOs indicated that the land cost constituted over 40 per cent of operational costs), CPOs would need an alternative solution for real estate.

For private fleet operators:

1. Operators are concerned about obtaining a reliable electrical connection or a separate electric connection for an EVSE installed at the charging station that they own and operate.
2. When cab operators and aggregators function in more than a state, they face the issue of varying EV tariffs and policies in different states, affecting their business.

For DISCOMs:

1. Frequent overloading of system components and distribution network can be a major concern.
2. Unpredictable electricity demand can affect the operations.

8.1.3 STATE-WISE COMPARISON OF THE RATIO OF CHARGING INFRASTRUCTURE TO ELECTRIC VEHICLES

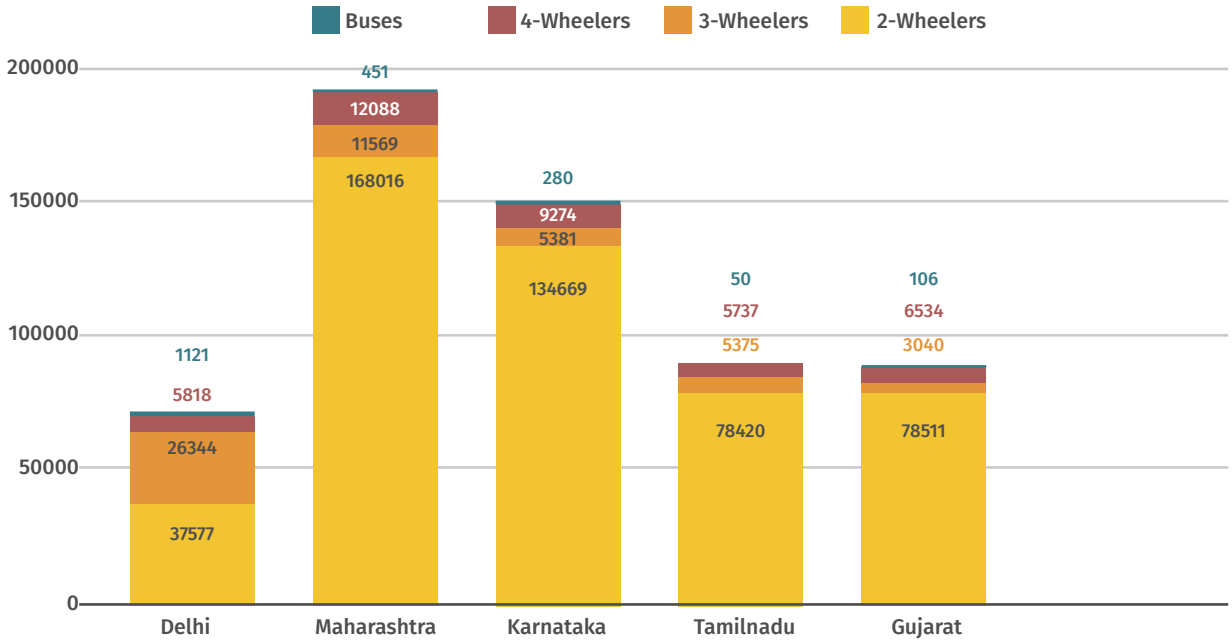

Figure 23: Adoption of EV in leading states by modes(as of Dec'23)[35]

[35] https://vahan.parivahan.gov.in/vahan4dashboard/vahan/view/reportview.xhtml

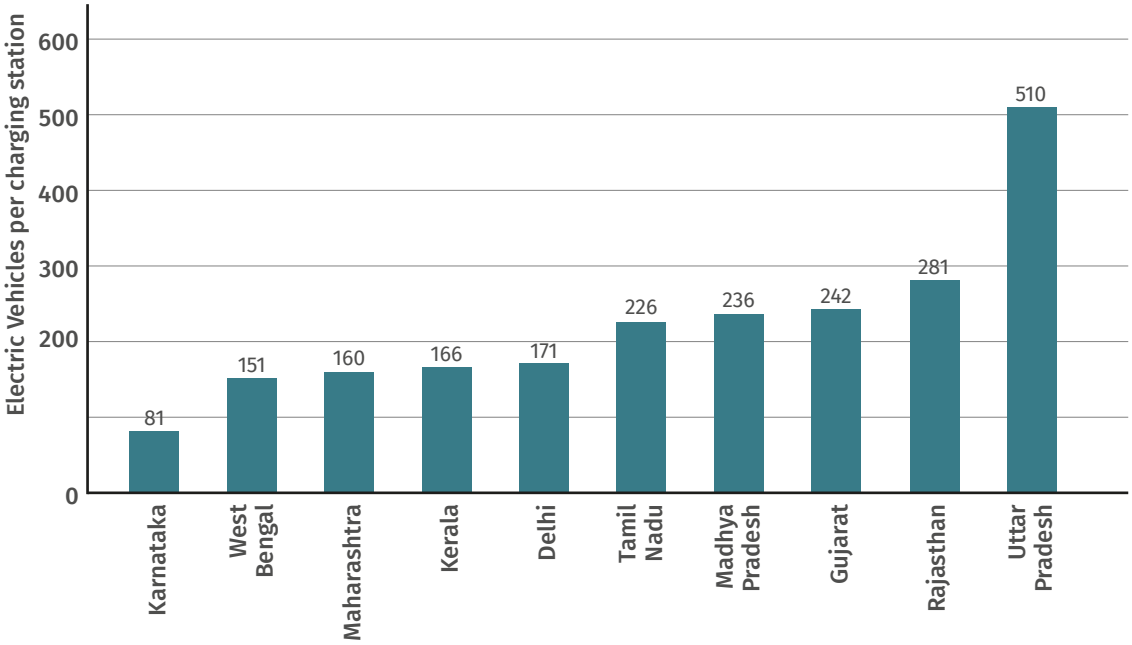

Figure 24: Number of charging stations in comparison with the number of vehicles per charger(as of Oct '24)[36]

Figures 23 shows the EV adoption rate of the major EV-leading states in India in comparison to Tamil Nadu while Figure 24 narrates the number of vehicles per charger. The two graphs can be correlated in terms of the direct relation existing between EV adoption and the number of charging stations on the ground. This highlights that a push to increase the number of charging stations is likely to fuel the growth of EVs.

Cost calculations for installing a public charging station, based on different demand requirements

For the upstream connection to the charging station, the DISCOM charges different tariffs based on the demand requested and type of connection (overhead or underground).

Application Category:	New Service Connection
Applied Load in KW	200.0
Phase	3
Tariff applied	Public EV Charging Stations (PCS)
Service Category	General public
Owner type	Owner

Sl.No	Description	Amount (Rs.)
1	Meter Caution Deposit	11085
2	CC Deposit	184000
3	Development Charges	409000
4	Service Connection Charges	2045
5	Registration cum Processing Charges	205
	GST Charges	**37/-**
	Total Amount (Rs)	**606372/-**

[36] https://evyatra.beeindia.gov.in/

Application Category: New Service Connection
Applied Load in KW 30.0
Phase 3
Tariff applied Public EV Charging Stations (PCS)
Service Category State Government
Owner type Owner

Sl.No	Description	Amount (Rs.)
1	Meter Caution Deposit	7255
2	Development Charges	153300
3	Service Connection Charges	1535
4	Registration cum Processing Charges	205
	GST Charges	**37/-**
	Total Amount (Rs)	**162332/-**

Application Category: New Service Connection
Applied Load in KW 60.0
Phase 3
Tariff applied Public EV Charging Stations (PCS)
Service Category General public
Owner type Owner

Sl.No	Description	Amount (Rs.)
1	Meter Caution Deposit	11085
2	CC Deposit	55200
3	Development Charges	306600
4	Service Connection Charges	2045
5	Registration cum Processing Charges	205
	GST Charges	**37/-**
	Total Amount (Rs)	**375172/-**

Application Category: New Service Connection
Applied Load in KW 30.0
Phase 3
Tariff applied Public EV Charging Stations (PCS)
Service Category General public
Owner type Owner

Sl.No	Description	Amount (Rs.)
1	Meter Caution Deposit	7255
2	CC Deposit	27600
3	Development Charges	153300
4	Service Connection Charges	1535
5	Registration cum Processing Charges	205
	GST Charges	**37/-**
	Total Amount (Rs)	**189932/-**

Figure 25, 26, 27 & 28: Cost calculations for installing a public charging station, based on different demand requirements (30 kW overhead, underground, 60 kW, 200 kW)

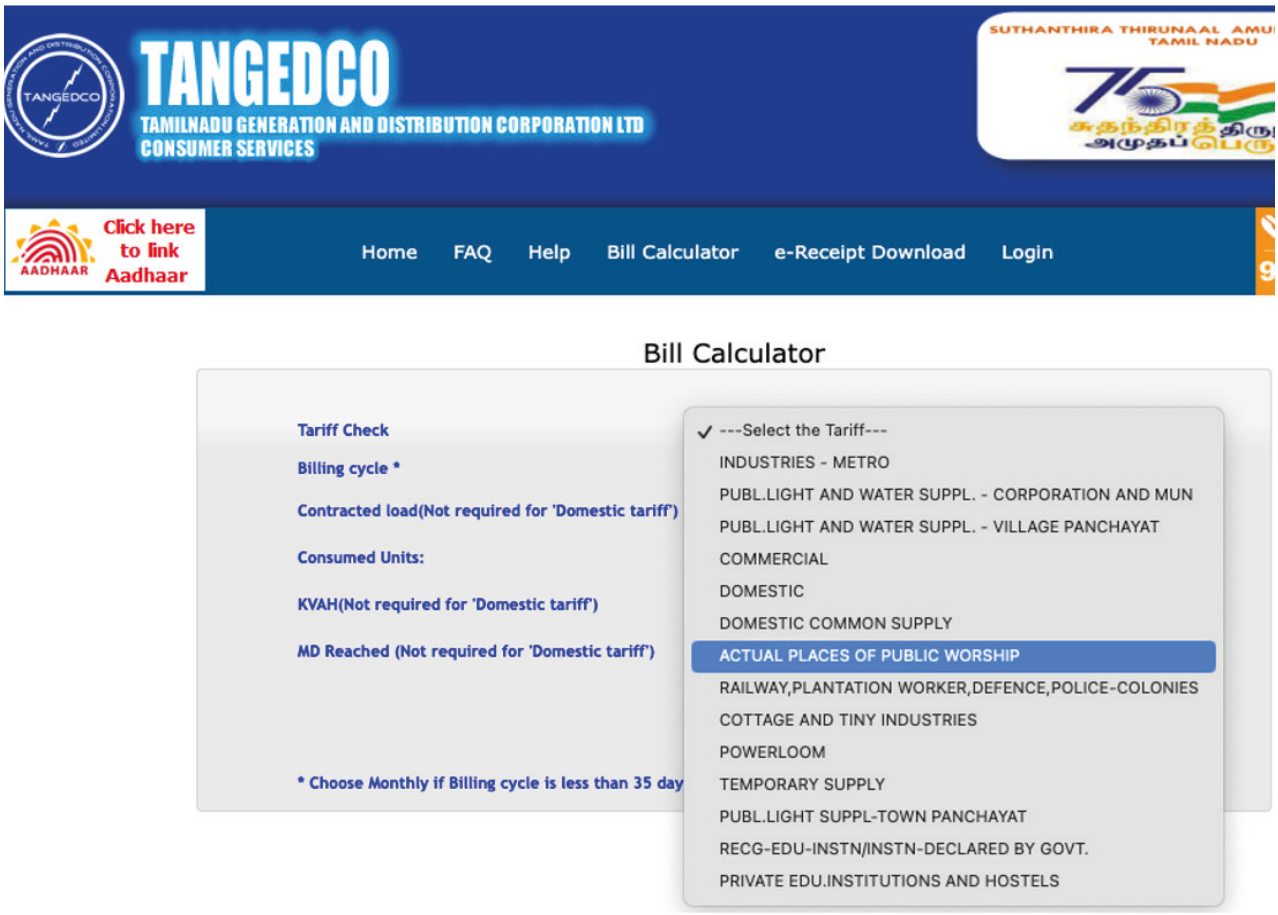

Figure 29: Bill calculator on the TNPDCL website, which is missing a provision for public charging stations

As per inputs from CPOs and as per the TNPDCL website, the cost for upstream infrastructure for installation of charging stations is much higher as compared to other competing and neighbouring stations.

On an average the cost per kW spent on electrical upstream infrastructure in the state is 3.6 times of that of Karnataka.

To understand the billing pattern and budget the same, TNPDCL has designed an helpful bill calculator, but it does not have provision for calculating bills for a public charging station.

8.3 KEY ISSUES HIGHLIGHTED DURING THE CPO ROUNDTABLE

A roundtable along with Guidance Tamil Nadu at the Industries Conference Hall, at the Tamil Nadu Secretariat was conducted on 30th April 2024 with all the major CPOs, government stakeholders and bus operators. The following issues were highlighted in the discussion:

1. Higher EV tariff in comparison to other states and erroneous tariff calculations
2. Unstable electric connection with constant phasing out and poor quality of supply
3. Lack of clarity in the utilisation of renewable energy for EV charging
4. Non-standard process and procedures, leading to various complexities including longer gestation periods and higher development costs
5. Multiple connections not being allowed in a single land parcel or establishment
6. Difficulties in identification of land parcels and associated business models
7. Classification of slabs for EV specifically in terms of LT/LTCP
8. No standard charging station composition planning for different modes of electric vehicles

Figure 30: State-level Roundtable on Scaling EV Charging Infrastructure in Tamil Nadu

8.4 PROSPECTS FOR THE FUTURE

The electric vehicles market in India is expected to reach 1.7 crore units by 2030. The forecasted EV charging market size in 2030 is INR 4727.1 crore. The EV charging market globally is expected to grow at a CAGR of 25.4 percent by 2030[37]. According to an analysis by Bain & Co[38], electric two-wheelers would account for 40 to 45 percent of all EVs sold in India by 2030, while electric passenger cars might make up 15 percent.

Nonetheless, by that time, the Indian government aims to see 40 percent of buses, 30 percent of private automobiles, 70 percent of commercial vehicles, and 80 percent of two-wheelers adopting electric vehicles, according to a report by Niti Aayog[39].

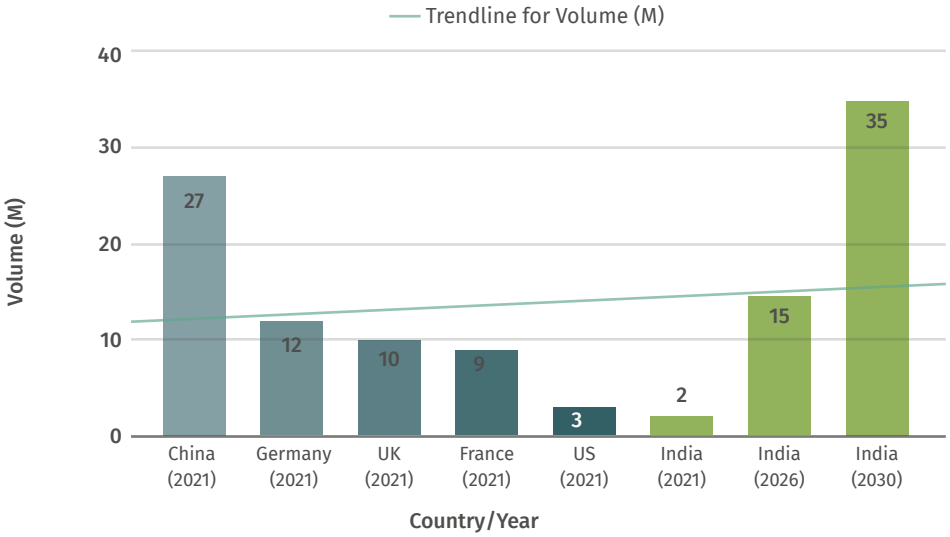

Figure 31: Share of EV in Vehicle Sales (%)

Battery technology

A significant development in EV batteries is the move to solid-state technology. Solid-state batteries use a solid-state electrolyte in place of the liquid electrolyte present in conventional lithium-ion batteries. Because solid-state batteries are less likely to have thermal runaway, this enables quicker charging, increased range and enhanced safety. Solid-state batteries are a relatively recent development but are likely to be seen in commercial EVs by 2030.

[37] EV Charging Infrastructure Market Size & Share Report 2030 - Grand View Research

[38] https://www.bain.com/insights/electric-vehicles-are-poised-to-create-a-$100-billion-opportunity-in-india-by-2030/

[39] https://e-amrit.niti.gov.in/assets/admin/dist/img/new-fronend-img/report-pdf/rmi-niti-ev-report.pdf

Exploration of new raw materials

Silicon is one of the most promising materials since it can lower costs and improve battery energy density. Graphite is currently used as the anode in the majority of lithium-ion batteries, which reduces energy density. On the other hand, anode materials made of silicon can boost energy density by a factor of 10. This might make EVs even more useful and consumer-friendly since they could last for a longer distance on a single charge. Tesla has been investigating the use of silicon in EV, and has already made headway in incorporating it in modest amounts into its batteries.

Other materials, like lithium-sulfur (Li-S) and lithium-air (Li-Air), are also being researched for use in EV batteries in addition to silicon. Li-Air batteries may have an even better energy density than Li-S batteries, have the potential to store more energy and be lighter than conventional lithium-ion batteries. But since the technologies are still in their infancy, it might not be realistic and economically feasible to expect them to be functioning by 2030.

Economies of scale and battery costs

The EV battery technology is presently also concentrating on reducing prices. Lithium-ion battery prices have dropped significantly in recent years, but the price remains an obstacle preventing the broad adoption of EVs. Enhancing the production process is one approach to cut expenses. For instance, Tesla has created a brand-new battery production method known as the 'Tab-less' design, which does away with the tabs that are required to join battery cells, increasing productivity and cutting expenses.

Improved charging technology

As covered in Chapter 3, the charging technology is constantly evolving and a varied technologies from catenary-based e-highways to conductive wireless charging on the go are under development and trials in various global countries. These can be the future of charging EVs, thus reducing the size of the battery resulting in lowered Gross Vehicle Weight. Lowered weight in turn increases the efficiency of an EV.

9

CONCLUSION

The way ahead for Tamil Nadu in its pursuit of becoming a global leader in electric transportation is to tackle complex issues and seize distinct chances. To reduce greenhouse gas emissions, improve air quality, and achieve sustainable urban mobility, a strong public charging infrastructure must be developed together with a broad adoption of electric vehicles (EVs). This report has presented a thorough analysis of the existing situation, pinpointed important obstacles, and offered practical suggestions to improve Tamil Nadu's EV ecosystem. The analysis's conclusions highlight the criticality and tactical significance of ongoing initiatives to assist the shift to electric vehicles.

Current EV adoption and infrastructure:

Tamil Nadu has started to move forward with governmental efforts and incentives to encourage the use of electric vehicles. But the adoption rate is still modest, with EVs making up a very small portion of all registered vehicles. Despite its growth, the current public charging infrastructure is not sufficient to fulfil the predicted and current demand, and a major increase in charging infrastructureis required.

Barriers to EV adoption

1. **High cost:** Due to the high cost of battery components and the scarcity

of local manufacturing, EVs continue to be prohibitively expensive up front.

The current incentives have not reduced these prices enough to encourage widespread adoption.

2. **Range anxiety and infrastructure gaps:** Potential EV purchasers are discouraged by range anxiety, which is exacerbated by the absence of a robust and widespread public charging network.

3. **Concerns about technology and cybersecurity:** Fast technological development puts current infrastructure at risk of becoming outdated. Additionally, there may be cybersecurity risks brought about by the growing digital integration of EV charging infrastructure.

4. **Policy and regulatory framework:** Although the present policy framework is progressive, it requires more improvements to offer all-encompassing support for the deployment of electric vehicles. This entails raising financial incentives, assisting with the construction of infrastructure, and promoting involvement from the business sector.

5. **Stakeholder engagement:** Successful implementation of EV policy and infrastructure projects depends on efficient cooperation between public, private, and governmental sectors. Consultations with stakeholders have brought attention to the necessity of concerted efforts to address market, regulatory, and infrastructure concerns.

Recommendations for Future Action

1. **Modernisation and Extension of the Charging Infrastructure Expand the number of charging stations:** It is imperative to quickly and significantly expand the number of public charging stations, particularly fast and ultra-fast chargers. Range anxiety will be reduced and long-distance travel will be supported with strategic installation along highways, in rural and urban areas.

2. **Integrate with current infrastructure:** Installing charging stations in existing petrol stations, businesses and apartment buildings helps hasten the construction of infrastructure and improve accessibility.

3. **Embrace cutting-edge technologies:** Accepting cutting-edge innovations like wireless charging and battery swapping can expedite charging and increase convenience.

Improvements to Financial Incentives and Policy

1. **Boost subsidies and financial support:** Reducing the cost barrier and promoting wider adoption can be achieved by increasing financial

incentives for EV purchases and infrastructure development. This entails giving tax breaks to EV makers and prolonging incentives for upgrading current automobiles.

2. **Adopt EV-friendly rules:** To guarantee that infrastructure keeps up with rising demand, building codes and urban planning rules should be updated to require EV charging stations in new construction.

3. **Promote public awareness and education:** It is essential to start extensive public awareness campaigns to educate people about the advantages of electric vehicles and the availability of charging infrastructure. Adoption will increase if the benefits—economic, environmental, and convenient—are emphasised. This will change public opinion.

4. **Training programmes:** By putting in place training programmes, charging station operators and users can ensure the safe and efficient use of charging facilities while also improving their awareness of EV technology.

Boosting Cybersecurity Measures

1. **Establish sturdy cybersecurity protocols:** It's critical to create and enforce strict cybersecurity measures to guard charging infrastructure against potential threats. Data will be protected and the integrity of the charging network will be guaranteed by routine monitoring, upgrades, and adherence to best practices.

2. **Improve public-private partnership:** Overall system resilience shouldbe improved by promoting cooperation between public and private organisations to exchange knowledge and resources for tackling cybersecurity issues.

Promotion of Investment in the Private Sector

1. **Encourage public-private collaborations:** Encouraging collaborations with private enterprises to create and manage charging infrastructure can expedite its implementation and alleviate the fiscal strain on public coffers.

2. **Encourage private investments:** More companies will join the EV ecosystem if incentives such as grants, tax breaks, and expedited regulatory procedures are made available for private investments in EV infrastructure.

The strategic significance of persistent efforts

Making the switch to electric vehicles is crucial for both establishing Tamil Nadu as a leader in the rapidly expanding EV market and for attaining environmental sustainability. Becoming a centre for EV adoption and manufacture will boost the economy by generating jobs, advancing industry, and create healthy

international competitiveness. The societal advantages, which include better air quality and a decrease in the health hazards linked to air pollution, emphasise the necessity of taking swift action in this area.

To overcome present obstacles and guarantee the long-term viability of Tamil Nadu's EV programmes, more work needs to be done to improve policy support, involve stakeholders, and increase infrastructure.

The report's suggestions offer a thorough road map for accomplishing these objectives and taking big steps in the direction of a cleaner, more sustainable future.

In conclusion, by spearheading the advancement of electric mobility, Tamil Nadu has the potential to become an example for other Indian states. Through resolving existing obstacles, capitalising on technology developments, and cultivating a policy climate that is conducive to EV adoption, the state could meet its ambitious objectives for EV adoption and make a substantial contribution to both national and international sustainability objectives. The dedication to developing the EV ecosystem would improve the lives of Tamil Nadu's citizens and the environment, opening the door to a successful and sustainable future.

10
ANNEXURE

ANNEXURE 1: QUESTIONNAIRE FOR THE STAKEHOLDER INTERACTIONS

QUESTIONNAIRE FOR STAKEHOLDERS

Charging Point Operators (CPOs)

1. Do you have any public charging stations in the state?

2. What is the application process by different agencies (Private landowners, state government, etc.)?

3. What are the impediments you see in Tamil Nadu for setting up the public charging infrastructure?

4. What governmental procedures do you have to follow to set up a charging station? - (What are the main challenges you face in operating charging points in India (e.g., finding suitable locations, getting permits, maintaining equipment), and how have you addressed these challenges?)

5. In contrast to other states, what regulatory gaps do you see in Tamil Nadu, if so how do you suggest they can be addressed?

6. Few cities have installed PCS, yet they are underutilized because of ICE vehicles parked in front, how do you think this could be avoided or regulated?

7. How can parking and public charging be integrated?

8. What are the different business, and financing models deployed by you in the development, operations, and maintenance of charging infrastructure (outright purchase by third party, service charge basis per kWh, monthly/daily lease of equipment, etc)? Please also mention if and how these models are different for different end-users/clients. - (What types of partnerships have you established with other stakeholders in the electric vehicle ecosystem (e.g., EV manufacturers, government agencies, utilities?)

9. Please provide details of broad costs/methods of estimating, involved, i.e. development cost for different charger types (60 kWh, 150 kWh, 200 kWh, 360 kWh, etc.) with cost/lease value of land and without it, and number of chargers/peak energy demand per location.

10. How do you manage access control for PCS (to ensure it is accessible at all times to EVs)? - How do you ensure the safety and security of your charging points, and what measures do you have in place to prevent unauthorized access or damage?

11. How many PCSs (of different types) have you installed in the state? Please provide a breakup by different charger types, location types, and business/financing models involved. - (What types of charging points do you offer (e.g., slow charging, fast charging), and how much do you charge per session?)

12. How do you perceive the future of the PCS market? What is the EV demand trajectory (for different modes) that you are planning for in the state? - (What are your plans for future development of charging infrastructure in India, and how do you prioritize these plans?)

13. What impediments do you see in the growth of EV demand (for different modes) in the state and in your opinion what actions can help mitigate it?

14. How do you perceive the growth in the PCS market (by different charger and station type) and what impediments to this growth do you foresee? What actions from different stakeholders can help mitigate these bottlenecks?

15. What are the utilization levels (average no. of EVs served at all stations per day divided by total EVs that can be served at all stations at peak utilization) of the deployed PCS? Please specify by the type of PCS, their

location, etc. - (What types of customer service do you offer (e.g., 24/7 support, remote monitoring), and how do you handle customer complaints or issues?) - (How do you ensure that your charging points are compatible with different types of EVs and charging technologies?)

16. What are the current charging tariff at different types of charging stations and how are these calculated? What factors can help bring down these costs (for example higher utilization, lower energy cost, etc.)?

17. What is the energy rate category applicable to a CPO operator in the state and what is the cost that you pay to the Discoms for per kWh energy consumed?

18. What are your expectations from a charging infrastructure design guideline?

19. Who would be the likely audience for these guidelines and what should it cover?

Government Sector (CPOs)

1. Under the FAME II scheme, 281 charging stations in Tamil Nadu, and 141 in Chennai were sanctioned. How many charging stations are there in Tamil Nadu?

2. What is the procedure for a private entity to set up a charging station in the city?

3. Is there a process of allocating land to the private sector for setting up the PCS?
4. What impedes scaling up the charging stations in the state?

5. Year-wise breakup of the number of chargers installed in the state and further plans

6. What is the status of the tender which was supposed to be out in the second half of 2022, for the installation of chargers as part of the central government's FAME - II scheme

7. What is the plan ahead in terms of collaborating with BPCL and other such energy providers to establish chargers?

8. What types of partnerships between the government and private sector stakeholders do you think would be most effective in promoting the development of public EV charging infrastructure?

Questionnaire for TNPDCL (Tamil Nadu Power Distribution Corporation Ltd)

1. If the capacity of a transformer is 200kW and is 100 percent utilized then if a 50KW charger is added to the same grid, should the transformer be upgraded to manage the new load or is there any other alternative?

2. Requirements for 50 KW charger

3. Requirements for 200 KW charger

4. Actual utilization in TN for public charging infrastructure
   a. Average
   b. Minimum
   c. Maximum

5. Is there any record or data of the number of charging stations established in the state with the classification of Private, Public, and Captive and their capacities

6. Ownership details of the PCS - to study the pattern

7. Major challenges faced by the DISCOM in implementing and maintaining public charging station

8. Any plans to develop a single window portal for applications and processing

Questionnaire/Discussion pointers for Tamil Nadu Petroleum Dealers association

1. What role do you see petroleum dealers playing in the development of EV charging infrastructure in TN?

2. What steps is the Petroleum Dealers Association taking to prepare its members for the EV era?

3. What is the Petroleum Dealers Association's current stance on electric vehicles (EVs) and EV charging infrastructure?

4. What are the Petroleum Dealers Association's recommendations for the development of EV charging stations in TN?

5. How many CO-CO bunks are in TN - do they have charging stations?

6. Is there any scheme by Bharat/IndianOil/HP to establish PCS?

7. Are there any hazards in establishing PCS in petrol bunks?

8. The charging time of EVs is high, does it result in congestion in the petrol stations? -smaller spaces -have constraints - highways space high - cities constraints

9. Any issue in the allocation of space for setting up PCS?

10. Space constraints and longer EV charging times are two barriers to setting up PCS in petrol bunks - what is your perception?

11. 6542 bunks in the state, how many have charging stations?

12. Safety Considerations taken to mitigate black swan events

13. What support is needed from the government?

14. Average cost of installing a charger?

15. Utilization rates of the chargers at the pumps?

16. Any in-house technical expert on installing charging stations

17. Any strategy for marketing and promotions?

18. Is there any tie-up between the OEMs (Vehicle manufacturers) and petrol pumps in the state?

ANNEXURE 2: LIST OF KEY STAKEHOLDERS AND CONTRIBUTORS DURING STAKEHOLDER ENGAGEMENT

S.No	Stakeholder	Designation of the person interacted with
1	TNPDCL	Chief Engineer
2	TEDA	Senior Manager
3	Tirex chargers	CEO
4	Zeon Charging	MD
5	Relux Electric	MD
6	Tamil Nadu Petroleum Dealers Association	President and Secretary
7	Planning, Development and Special Initiatives Department, Government of Tamil Nadu	Additional Secretary


ITDP
INDIA