CEEW THE COUNCIL | Centre for Energy Finance

EDRV

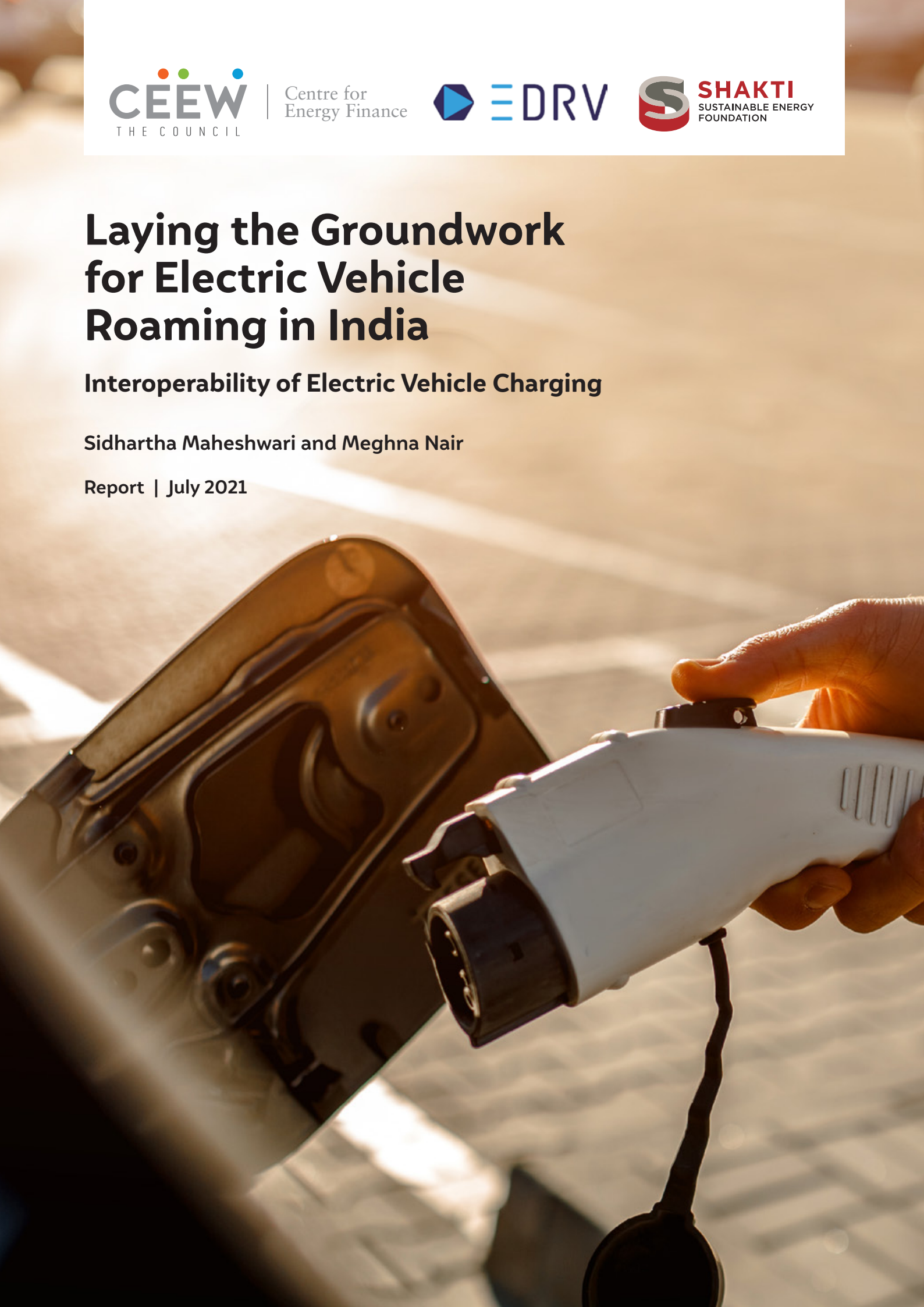
SHAKTI SUSTAINABLE ENERGY FOUNDATION

Laying the Groundwork for Electric Vehicle Roaming in India

Interoperability of Electric Vehicle Charging

Sidhartha Maheshwari and Meghna Nair

Report | July 2021



Interoperability and EV roaming are compelling instruments to resolve the confusion and fragmentation surrounding EV charging.

Image: iStock

Laying the Groundwork for Electric Vehicle Roaming in India

Interoperability of Electric Vehicle Charging

Sidhartha Maheshwari and Meghna Nair

Report
July 2021
ceew.in | edrv.io

Suggested citation: Maheshwari, Sidhartha, and Meghna Nair. 2021. *Laying the Groundwork for Electric Vehicle Roaming in India: Interoperability of Electric Vehicle Charging*. CEEW-EDRV Report. New Delhi: Council on Energy, Environment and Water.

Disclaimer: This report is the result of a collaborative effort between eDRV and the CEEW Centre for Energy Finance (CEEW-CEF) and was produced by CEEW-CEF. The views expressed in this report are those of the authors and do not necessarily reflect the views and policies of the Council on Energy, Environment and Water or CEEW-CEF or eDRV. The report does not constitute professional advice on any specific issue or situation and also does not guarantee the accuracy of any data included in this publication nor does it accept any responsibility for the consequences of its use.

The views/analysis expressed in this report also do not necessarily reflect the views of Shakti Sustainable Energy Foundation. The Foundation also does not guarantee the accuracy of any data included in this publication nor does it accept any responsibility for the consequences of its use. For private circulation only.

Cover image: iStock.

Peer reviewers: Nehmat Kaur, Head - Global Government Relations, The Climate Group; Roland Ferwerda, Board Member, EVRoaming Foundation; Rupul Safaya, Chief Technology Officer, eDRV; Sajid Mubashir, Scientist G, Dept. Science and Technology; and Karthik Ganesan, Fellow and Director-Research Co-ordination and Himani Jain, Programme Lead, both from CEEW, and Rishabh Jain, Manager – Market Intelligence CEEW-CEF.

Publications team: Alina Sen (CEEW), The Clean Copy, Aspire Design, and Friends Digital.

Organisations/initiatives: The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain and change the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions and engages with the wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*. It has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

The **CEEW Centre for Energy Finance** (CEEW-CEF) is an initiative of the Council on Energy, Environment and Water (CEEW), one of Asia's leading think tanks. CEF acts as a non-partisan market observer and driver that monitors, develops, tests, and deploys financial solutions to advance the energy transition. It aims to help deepen markets, increase transparency, and attract capital in clean energy sectors in emerging economies. It achieves this by comprehensively tracking, interpreting, and responding to developments in the energy markets while also bridging gaps between governments, industry, and financiers.

eDRV is an electric vehicle charging technology venture based in the Netherlands. eDRV's software platform makes EV charging networks simple to set up and operate. Established in 2019 in Amsterdam, eDRV is a part of the Rockstart Energy Accelerator, Europe's leading technology program for clean energy startups. eDRV's investors include the Dutch Pension Fund, senior professionals formerly with Tesla Motors; and other investors from development finance institutions and venture capital. eDRV's application programming interface-focused, API-first architecture levels the playing field by making accessible technology for network operators and distribution utilities. In India, eDRV spearheaded roaming for electric vehicle charging infrastructure and is embarking upon the nation's first utility-managed charging project for electric vehicles in collaboration with CEEW.

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

Council on Energy, Environment and Water
Sanskrit Bhawan, A-10 Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India

eDRV
Cannenburg 22, 1081 GZ Amsterdam, The Netherlands

CEEW Centre for Energy Finance

The CEEW Centre for Energy Finance (CEEW-CEF) is an initiative of the Council on Energy, Environment and Water (CEEW), one of Asia's leading think tanks.

CEEW-CEF acts as a non-partisan market observer and driver that monitors, develops, tests, and deploys financial solutions to advance the energy transition. It aims to help deepen markets, increase transparency, and attract capital in clean energy sectors in emerging economies. It achieves this by comprehensively tracking, interpreting, and responding to developments in the energy markets while also bridging gaps between governments, industry, and financiers.

The need for enabling an efficient and timely energy transition is growing in emerging economies. In response, CEEW-CEF focuses on developing fit-for-purpose market-responsive financial products. A robust energy transition requires deep markets, which need continuous monitoring, support, and course correction. By designing financial solutions and providing near-real-time analysis of current and emerging clean energy markets, CEEW-CEF builds confidence and coherence among key actors, reduces information asymmetry, and bridges the financial gap.

Financing the energy transition in emerging economies

The clean energy transition is gaining momentum across the world with cumulative renewable energy installation crossing 1000 GW in 2018. Several emerging markets see renewable energy markets of significant scale. However, these markets are young and prone to challenges that could inhibit or reverse the recent advances. Emerging economies lack well-functioning markets. That makes investment in clean technologies risky and prevents capital from flowing from where it is in surplus to regions where it is most needed. CEEW-CEF addresses the urgent need for increasing the flow and affordability of private capital into clean energy markets in emerging economies.

CEEW-CEF's focus: analysis and solutions

CEEW-CEF has a twin focus on markets and solutions. CEEW-CEF's market analysis covers energy transition–related sectors on both the supply side (solar, wind, energy storage) and demand-side (electric vehicles, distributed renewable energy applications). It creates open-source data sets, salient and timely analysis, and market trend studies.

CEEW-CEF's solution-focused work will enable the flow of new and more affordable capital into clean energy sectors. These solutions will be designed to address specific market risks that block capital flows. These will include designing, implementation support, and evaluation of policy instruments, insurance products, and incubation funds.

CEEW-CEF was launched in July 2019 in the presence of H.E. Mr Dharmendra Pradhan and H.E. Dr Fatih Birol at Energy Horizons.

cef.ceew.in

Acknowledgments

The authors would like to thank Kanika Chawla, Programme Manager, UN-Energy Sustainable Energy for All, and Bhaskar Deol, Chief Executive Officer, eDRV, for their support and guidance while working on this report. This report would not have been possible without their deep involvement.

We thank our advisers – Abhishek Ranjan, Vice President, BSES Rajdhani; Aditya Ramji, Economist, ex-Mahindra & Mahindra; Aishwarya Raman, Head - Research, Ola Mobility Institute; Anil Srivastava, EV Policy Expert, ex-NITI Aayog; Awadhesh Jha, Vice President, Fortum Charge & Drive; Bjørn Utgård, Vice President, EVBox; Chetan Maini, Vice Chairman, SunMobility; Jitendra Nalwaya, Vice President, BSES Yamuna, N. Mohan, Head - EV charging, Energy Efficiency Service Limited; Roland Ferwerda, Board Member, EVRoaming Foundation; Sajid Mubashir, Scientist G, Department of Science & Technology, Thomas Daiber, CEO and Founder, Cosmic Cat; and Vignesh Nandakumar, EV Expert, ex-Lithium Urban Tech for their valuable inputs, comments, and feedback.

We thank our reviewers – Nehmat Kaur, Head - Global Government Relations, The Climate Group; Roland Ferwerda, Board Member, EVRoaming Foundation; Rupul Safaya, Chief Technical Officer, eDRV; and Sajid Mubashir, Scientist G, Dept. Science and Technology for their critical insights and comments, which helped in refining the report.

We thank our colleagues at CEEW, particularly Rishabh Jain (CEEW-CEF), for their help while conducting the research.

Lastly, we would like to thank the Outreach team at CEEW for helping us with the design, publishing and dissemination of the report.

The authors

Sidhartha Maheshwari
sidhartha.maheshwari@ceew.in

As lead project consultant, Sidhartha focuses on bridging the market gaps for electric mobility in India through targeted interventions. He has significant experience in the cleantech industry, including electric mobility and renewable energy, and has worked extensively in the Indian and Asian markets. He holds an MBA from the Indian School of Business and a Mechanical Engineering degree from Birla Institute of Technology, Mesra.

"For public charging to become popular, it needs to address long-standing barriers that hinder users and providers alike. Interoperability and electric vehicle (EV) roaming offer a means for various stakeholders in the EV charging ecosystem to connect and collaborate."

Meghna Nair
meghna.nair@ceew.in

An economist by training with a master's in Public Policy, Meghna works as an Analyst at the CEEW-Centre for Energy Finance where she tracks India's electric vehicle market and monitors key policies in the sector. By developing market solutions for this sector, she hopes to encourage a faster and more informed mobility transition in India.

"Prevention is better than cure – by introducing interoperability and EV roaming early on, we learn from the experiences of other markets, avoid course correction, and speed up India's mobility transition. Roaming is the obvious next step for the EV charging sector, because it makes the EV driver's experience comparable to that of internal combustion engine (ICE) drivers."

Sparse and inaccessible charging infrastructure has repeatedly been cited as a key barrier to EV adoption.

Image: iStock

Contents

Figures

Tables

Glossary

Charge point management system (CMS)	CMS is the cloud-based backend IT system that manages charging hardware. The CMS is used by the operator to remotely monitor, operate, and maintain multiple charging stations.
Connector	A connector is an electrical outlet through which electricity is delivered from the charger to the electric vehicle (EV).
Charging network	A charging network consists of a charge point operator (CPO) that operates and makes available charging stations and a mobility service provider (MSP) that allows the EV driver to charge as a service at these stations.
Charge point operator (CPO)	CPOs are responsible for the management, maintenance, and operation – technical and administrative – of charging stations. CPOs may also own charging stations.
ETD 51	A work committee under the Bureau of Indian Standards led by the Department of Science & Technology to define and publish domestic standards for mobility electrotechnology.
Electric vehicle supply equipment (EVSE)	Electric vehicle supply equipment is the multiple hardware components that supply electricity to EVs. Also known as chargers.
EV roaming	EV roaming is a system by which users can access charging stations from multiple providers through an application or platform of their choice.
Inbound party	The inbound party owns the charger accessed by the user.
Interoperability	Interoperability is the compatibility of key hardware and software system components, thus enabling the ecosystem to function seamlessly.
Mobility service provider (MSP)	MSPs provide the EV driver with charging services across multiple CPOs on a subscription or fee basis. MSPs form two-sided marketplaces for drivers and CPOs.
Outbound party	An outbound party has a roaming arrangement with the inbound party with whom the user has an account or subscription.
Protocol	A roaming protocol allows two or more system components to communicate with each other by exchanging information.
Roaming fee	An additional charge levied by a CPO or MSP to cover the operational and maintenance costs of the roaming arrangement.
Roaming hub	A roaming hub is a central clearinghouse that facilitates roaming transactions between multiple CPOs and MSPs without participating itself.

Acronyms

BIS	Bureau of Indian Standards
CEA	Central Electricity Authority
DC	direct current
DHI	Department of Heavy Industries
Discom	distribution company or utility
DST	Department of Science & Technology
E2W	electric two-wheeler
E3W	electric three-wheeler
E4W	electric four-wheeler
EV	electric vehicle
FAME-II	Faster Adoption and Manufacturing of Electric Vehicles in India II scheme
ICE	internal combustion engine
MoP	Ministry of Power
OEM	original equipment manufacturer
P2P	peer-to-peer
PCS	public charging station

For users, roaming eases the discoverability, access, and convenience of charging their electric vehicles.

Image: iStock

Executive summary

India's electric vehicle (EV) space is in its infancy, with EVs forming less than one per cent of total vehicle sales - according to the CEEW-CEF EV dashboard. The government's hopes of electrifying 30 per cent of all vehicle sales by 2030 is both encouraging and ambitious. However, achieving this will require significant effort in tackling barriers, especially those in the sector's charging infrastructure.

The CEEW Centre for Energy Finance in collaboration with eDRV conducted a public policy consultation exercise to examine the state of the Indian EV charging space and identify its many gaps. This was done through:

1. Primary research including 42 bilateral stakeholder consultations, 2 closed door roundtables, 1 public webinar, and a survey of 13 public charging stations.
2. Secondary research examining 12 roaming networks, 5 research papers, 17 reports and an extensive study of 4 roaming protocols.

Sparse and inaccessible charging infrastructure has repeatedly been cited as the key barrier that the sector faces. And while cumulatively, the total number of public charging stations may be sufficient, high market fragmentation often creates problems.

EV roaming: addressing the charging sector's needs

Interoperability and EV roaming are compelling instruments to resolve the confusion and fragmentation surrounding EV charging. Interoperability is the compatibility of crucial hardware and software components, allowing seamless communication between different systems in EV charging. While multiple protocols exist at the interface of the stakeholders involved in this ecosystem, this report specifically focusses on the interoperability of the various charging networks within an EV ecosystem. This is also referred to as EV roaming. The standardisation that results from interoperability enables EV roaming, which then enables users to discover and access charge points by different operators – thus building a denser charging network.

Market participants involved in EV roaming can be:

1. Direct participants such as charge point operators (CPO), mobility service providers (MSP), and (optionally) roaming hubs.

"The first stage of a charging network development is not about revenue generation as the number of transactions aren't as many, but about information exchange to make sure that the presence of a charging station is widely accessed and communicated."

Bjorn Utgard
Vice President, EVBox

2. Indirect participants such as navigation service providers, network service providers, electric vehicle supply equipment (EVSE), original equipment manufacturers (OEM), and distribution companies (Discom).

Taken together, interoperability and EV roaming can bridge the gap between the consumer's expectations and the existing market offering. Therefore, it is essential that the government includes this in its larger plan to shift to electric mobility. For market participants, EV roaming reduces barriers to entry, improves monetisation, and provides operational flexibility. For users, roaming eases the discoverability, access, and convenience of charging. Like telecom roaming, the introduction of EV roaming can stimulate growth and bring mass adoption to a nascent sector.

Customise learnings from other markets to fit India's needs

Although new to India, EV roaming is not a recent phenomenon. India can bank upon the experience of other countries that have implemented this, to tailor roaming to the realities of its market. EV charging in the Indian context has multiple use-cases. However to avoid overwhelming an upcoming market, we recommend that EV roaming be selectively introduced – to wired and public charging, first. Other forms – such as captive charging and battery swapping, can build on the experience of these.

For market participants, EV roaming reduces barriers to entry, improves monetisation, and provides operational flexibility. For users, roaming eases the discoverability, access, and convenience of charging.

Introducing EV roaming to the Indian market

EV roaming requires an examination of the policy, technology, and business of charging. A typical roaming transaction involves an exchange of electrons, money, and information – each of which operate in a regulated sphere. India should accommodate EV roaming by suitably tweaking existing policies. Creating open databases for public charging, opening government-supported charging stations to third-party aggregation, including roaming fees in service charges, and introducing regulations to safeguard personal data are some of the boundary conditions required to make EV roaming viable.

On the technology front, India needs to establish a single standard for roaming by selecting a protocol. This decision should not be left solely to market forces and merits urgent inclusion in the government's efforts to define domestic charging standards. Several existing standards must be examined to find the most appropriate one. Adopting an existing roaming protocol, such as the Open Charge Point Interface (OCPI), appears to be the best choice for India.

On the business side, EV roaming requires selective collaboration between market participants who will otherwise compete against one another. Business models for roaming tend to be bilateral (customised peer-to-peer agreements) or hub-based (a centralised clearinghouse connecting several nodes), with some hybrid business models mixing these two approaches. Each business model has its pros and cons, and the business of roaming continues to evolve rapidly in step with the dynamic market for charging. The ideal EV roaming market should be inclusive, user-centric, and open, allowing market participants flexibility to innovate to better garner user attention.

EV roaming requires the implementation of five core functionalities:

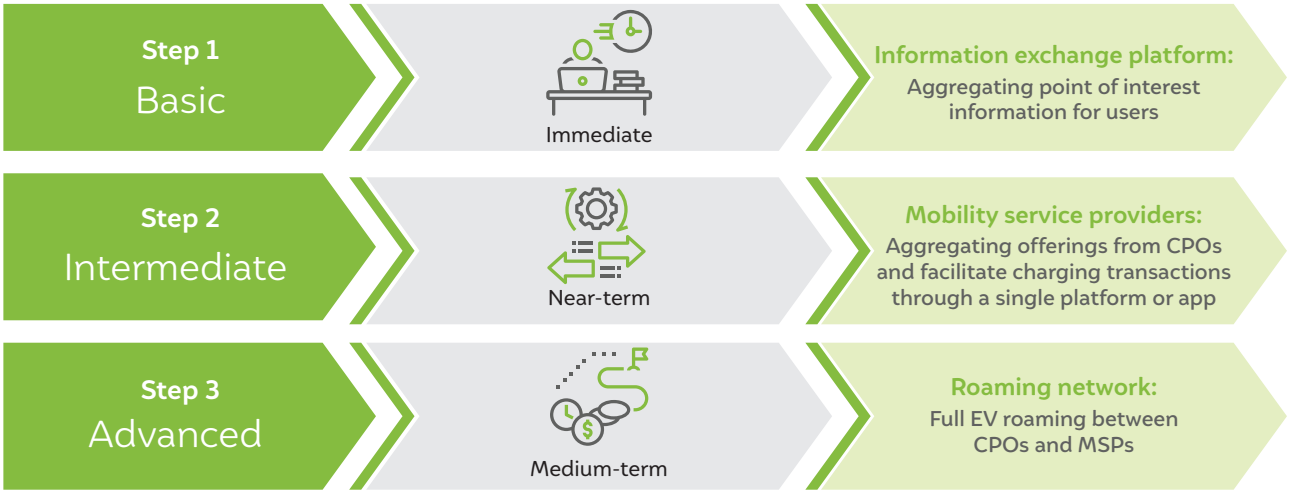
1. Authentication: means of user identification
2. Authorisation: means of permitting user action
3. Information recording and exchange
4. Monetary exchange: payments, billing, and settlements
5. Data privacy and security: protection of data

While public charging in India already has many of these features, harmonising them may be required to bring consistency and completeness. We recommend a three-step plan to build traction for EV roaming in India. Each step should improve upon the core functionalities, unlocking a more capable charging ecosystem.

Once introduced, full-scale EV roaming can also build on its functionalities in subsequent phases. A first phase would include basic features such as single point identification, whereas an advanced phase would incorporate functionalities such as plug-and-charge.

Interoperability and EV roaming are proven interventions that enable the scaling-up of charging without the associated complexities. India has a clear and time-sensitive opportunity to leverage standardisation and collaboration to advance its charging ecosystem. A better charging experience will attract user interest and boost industry confidence, providing a much needed push to electric mobility.

Figure ES 1 A three-step plan is recommended to introduce EV roaming in India



Source: CEEW-CEF analysis

1. Introduction

India has ambitious targets for electric mobility. The government aims for 30 per cent EV sales in all vehicle sales by 2030 and has made significant efforts to achieve the same (Arora 2018). Although the government has implemented some supply-side interventions, much remains to be done to stimulate demand for electric vehicles (EV). EV buyers, users, and drivers need to be at the centre of these efforts. Consumers expect EVs to be comparable with existing internal combustion engine (ICE) vehicles. The charging experience needs to mimic or improve upon that of refuelling at a petrol pump. Interoperability and EV roaming offer a compelling opportunity to enhance EV charging capabilities as they stand today.

Interoperability is the use of standardised infrastructure that allows different market participants to work together seamlessly. By standardising technology, interoperability makes it possible for EV drivers to access charging stations operated by different providers through a single application or platform. EV roaming results from business and technical collaboration between charge point operators (CPO) and mobility service providers (MSP). The integration helps users break through existing layers of clutter and complexity. EV roaming allows the user universal access to, and complete information on, all charging stations around him/her. It is enabled when different stakeholders within the EV charging ecosystem selectively share information among themselves.

An analogy can be drawn to telecom roaming allowing users to use the same phone number across multiple networks and countries. In EV roaming, users can avail of charging across multiple CPOs without subscribing to each one individually. Like in the case of mobile telecommunications, shifting from closed to open networks can bring about the EV sector's mass adoption and growth.

EV roaming is not a new phenomenon. Countries across the world have used roaming to trigger EV adoption. In response to increased participation from various stakeholders, several mature EV markets have instituted standards and created a conducive environment for roaming, benefitting from its knock-on effects. The Indian EV market can learn from the lessons of other markets to boost its EV ecosystem.

2. Project methodology

This is a qualitative study undertaken to encourage the introduction of EV roaming in India. The aims of this public policy exercise were:

1. To examine the need and importance of interoperability in India
2. To understand the experience of other markets in EV roaming
3. To understand the barriers to interoperability and EV roaming in India
4. To recommend pathways for the implementation of EV roaming in India

Figure 1 Our 13-member advisory board

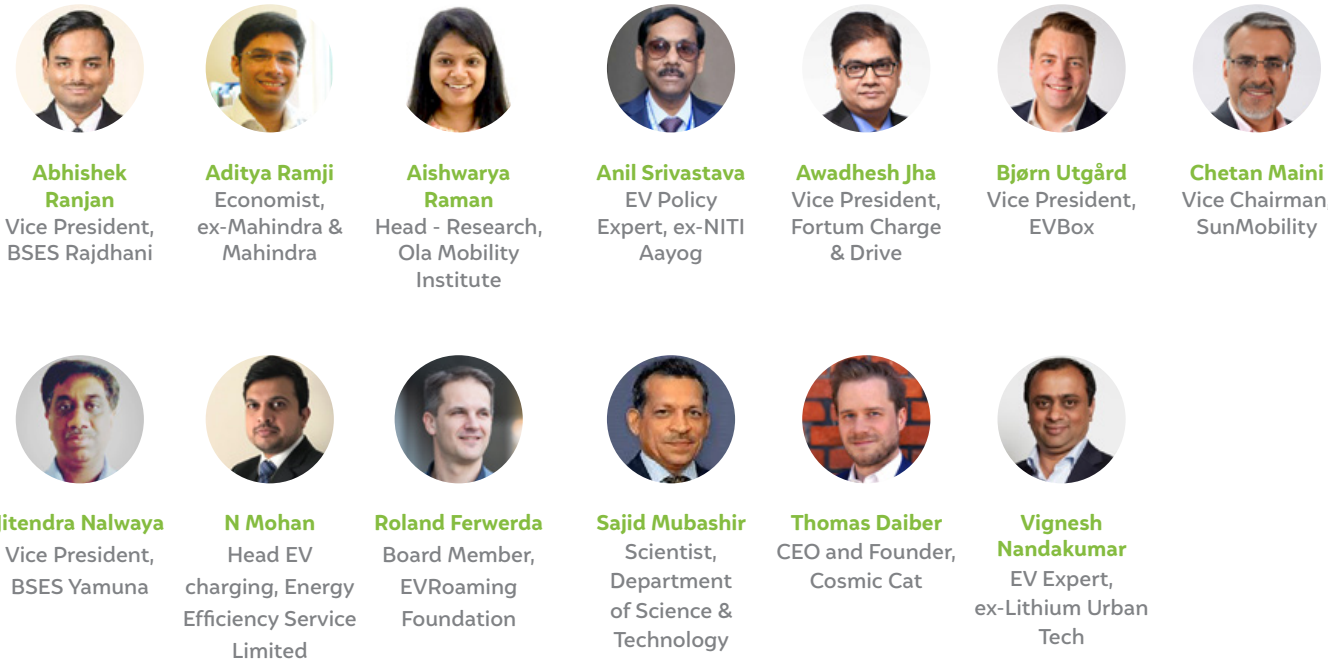
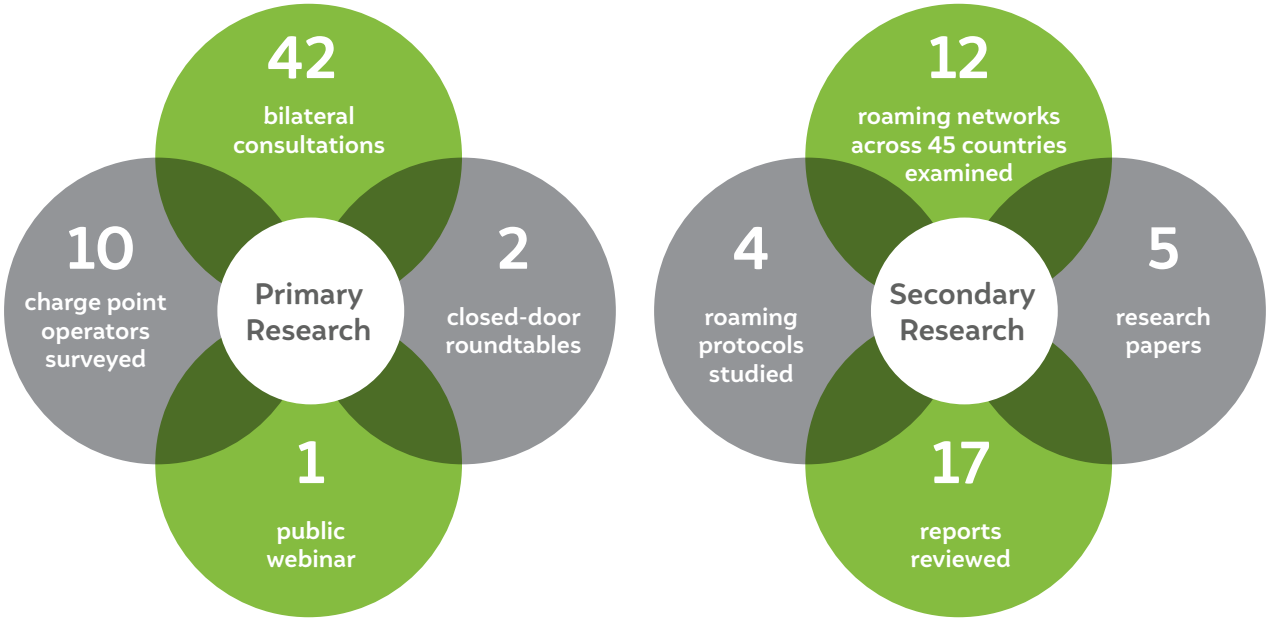


Figure 2 Methodology followed for this study



EV roaming is an upcoming sector globally, and a combination of primary and secondary research was conducted to understand the latest developments in making EV charging interoperable. The primary research benefited from the expert inputs and high-level guidance of a 13-strong advisory board. The advisory board of e-mobility experts from India and abroad represents the government, CPOs, OEMs, fleet operators, think tanks, and discoms.

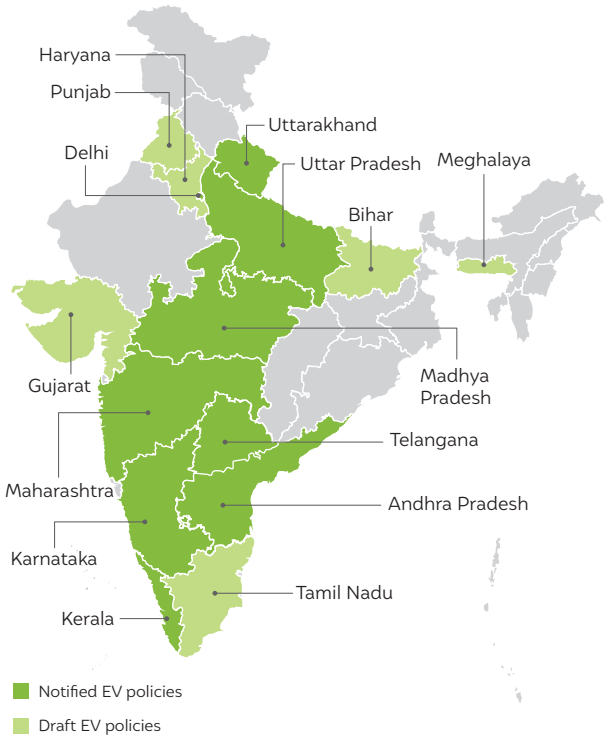
The project outcomes are this report and a forthcoming pilot, which shall demonstrate collaboration between EV charging participants in India.

3. The Indian electric mobility ecosystem

India's automobile sector is the fourth largest globally and contributes to nearly 7–8 per cent of the country's gross domestic product (GDP), creating almost 35 million direct and indirect jobs (Invest India n.d.). This sector accounts for a significant share of industrial investment and domestic manufacturing as part of the 'Make in India' initiative. And while EVs remain a minuscule part of this pie – 1.68 lakh EVs registered in FY19–20, accounting for less than one per cent of all automotive sales – this upcoming sector represents a massive opportunity. (CEEW-Centre for Energy Finance n.d.). The EV sector's progress depends on resolving several barriers such as the lack of dense and accessible charging infrastructure, high upfront vehicle costs, limited choice of EV models, and limited financing options.

The Indian government has a massive role to play in setting targets for India's e-mobility transition and laying down a pathway to achieve the target. NITI Aayog – the central government's think tank –aims to electrify 70 per cent of all commercial cars, 30 per cent of private vehicles, 40 per cent of buses, and 80 per cent of two- and three-wheelers by 2030 (NITI Aayog and Rocky Mountain Institute 2019). It runs the *National Mission on Transformative Mobility and Battery Storage* to interface with the industry and coordinates the government's response. The central government has rolled out numerous fiscal and non-fiscal incentives to promote EVs. The *Faster Adoption and Manufacture of Electric Vehicles in India II (FAME-II)* scheme is the largest. The USD 1.5 billion (INR 109 billion) scheme provides demand incentives and funds public charging infrastructure (Ministry of Heavy Industries and Public Enterprises 2019). Additionally, 15 Indian states and union territories (UTs) have announced state-level EV policies as of February 2021 (CEEW-Centre for Energy Finance n.d.).

Figure 3 Indian states with EV policies



Source: CEEW-CEF analysis

Some EV segments are experiencing early success. Electric three-wheelers (e3w) account for nearly 83 per cent of all EV sales in India, having achieved total cost of operations (TCO) parity with their ICE counterparts (Kumar and Kanuri 2020). They are followed by the electric two-wheeler (e2w) segment, which accounts for almost 15 per cent of the EV market (CEEW-Centre for Energy Finance n.d.). E-buses have received strong government backing for use in public transport. Electric four-wheelers (e4w) have seen the slowest uptake, with most of the demand concentrated among fleets and commercial vehicles such as cabs and cargo vehicles.

Of the many hurdles for EV penetration, charging remains one of the most significant. Increasing the number and density of chargers will increase the confidence of EV consumers. The central government has a phased plan to install public charging stations every 3 km in nine major cities and every 25 km on highways connecting these cities (Ministry of Power 2019a). Various government agencies are involved in implementing this plan, such as the NITI Aayog, the Ministry of Power (MoP), the Department of Heavy Industries (DHI), the Central Electricity Authority (CEA), and the Bureau of Energy Efficiency (BEE).

EV charging qualifies as a service, and its delicensing has encouraged many stakeholders – such as original equipment manufacturers (OEMs), Discoms and start-ups – to become CPOs. Fleet operators are increasingly leading the push to set up charging infrastructure, albeit for their EV fleets' personal use. The business viability of public charging stations (PCS) has remained modest due to low revenue realisation. Industrial stakeholders find it challenging to balance high capital and operational expenditure with low pricing expectations and utilisation levels, leading to a dependence on government resources. The lopsided economics has led industry players to regard unmanned PCS favourably. Charging in India has been made available as a commercial service to EV drivers through mobile applications, requiring users to register and subscribe. While this is a one-time registration process, there are approximately 30 networks in India, each of which is exclusively available only through subscriptions – this may make charging highly tedious for the user. Ad-hoc payment methods, alternatively, may be difficult-to-near impossible to implement in the current public charging infrastructure. This is a function of EVs' selective compatibility with only some charging connectors, the above-mentioned subscription model, and their high capital and operational costs.

Standardisation in EV charging has been limited to hardware connectors. Five types of wired charging hardware connectors have been authorised for use in public charging. Electrical sockets are often used for low-speed EVs, and proprietary plugs are allowed for non-public charging stations, such as bus depots. Additionally, battery swapping is increasingly gaining traction as a form of charging for e2w and e3w. The sheer diversity in charging methods and vehicle form factors – due to the unique use case of each of the four vehicle segments and the five connectors made available to them – complicates discussions around standardisation. A work programme called ETD 51 is being jointly led by the Bureau of Indian Standards and Department of Science & Technology to further standardise the hardware and software aspects of EV charging in India (Bureau of Indian Standards n.d.).

> **Increasing the number and density of chargers will increase the confidence of EV consumers.**

Table 1 Use-case of Indian chargers

Type	Connector	Vehicle type	Standards notified
Wired	Bharat AC-001	e2W, e3W, e4W	Yes
Wired	Bharat DC-001	e2W, e3W, e4W	Yes
Wired	Type 2	e2W, e3W, e4W	Yes
Wired	Combined Charging System 2 (CCS2)	e4W	Yes
Wired	CHAdeMO	e4W	Yes
Wired	5 Amp & 15 Amp plugs	e2W, e3W	No
Wired	Proprietary	e2W, bus	No
Battery Swapping	Proprietary	e2W, e3W	No

Source: CEEW-CEF analysis

4. Scope: wired and public charging

To avoid overwhelming the market, interoperability is best introduced in selective charging categories. The process of selecting the ideal category should take into supply-side and demand-side considerations.

To avoid overwhelming the market, interoperability is best introduced in selective charging categories. The process of selecting the ideal category should take into supply-side and demand-side considerations.

This section identifies the segments best suited for introducing interoperability – keeping in mind potential benefits, the use case, and amenability for standardisation. Success in one category can encourage standardisation in other parts of the EV charging value chain.

Method of charging: wired charging

Wired (or conductive) charging and battery swapping are the two main methods of charging used in India. Wireless (or inductive) charging and pantograph charging are excluded from our analysis as they lack the requisite capacity for commercialisation in India.

Several sources confirm that wired charging is the most common method used for charging EVs worldwide, including in India. Markets in which EV roaming has found the most traction – such as Europe and China – almost always use wired charging. The frameworks for interoperability for wired charging readily exist, allowing for easier adoption in a new market like India.

Battery swapping is another charging method that is becoming popular in India. While interoperability

Table 2 Categorisation of charging accessibility

Charging type	Public charging	Semi-public charging	Captive charging
Access	Universal access	Access restricted by the type of driver	Restricted access
Cost of charging	Can be paid, subsidised or free	Can be paid, subsidised or free	Free to driver
Usage	Non-discriminatory	Conditional usability	Private use only
Location	Located in easily accessible public places	Located in commercial buildings, workplaces, institutions	Located in private property
Network	Typically networked	May or may not be networked	May or may not be networked
Use case	All use cases	Employee transport,	Fleets, Taxis, Public Transport,
Vehicle type			

Source: CEEW-CEF analysis

brings choice and flexibility to battery swapping, discussions around technical standards have been slow in India and globally. Achieving standardisation, technology maturity, and industry collaboration have been slow for battery swapping compared to wired charging, making it harder to implement EV roaming for this charging method.

Accessibility: public charging

Another standard categorisation is by the degree of access to charging infrastructure.

While public charging and captive charging are both seeing an increasing uptake in India, only public charging is mandated to implement government-notified standards, features, and amenities. Government guidelines make public charging better suited for interoperability in comparison to captive charging due to:

- Unrestricted user access
- Availability of standardised connectors
- Mandatory internet connectivity with charge point management systems (CMS)
- Used by the broadest category of users by volume and variety
- Location in high-traffic areas

By focusing on wired and public charging, interoperability, and EV roaming in India implies focus on the e4w and high-speed e2w segments. This is because they are the heaviest users of wired and public charging. With increased market maturity and technological innovation, it is expected that other vehicle types – such as low-speed e2w, e3w, and buses – will adopt high-power, safe, and networked charging infrastructure.

This convergence towards standard connectors will increase the importance of, and dependence on, public charging in the longer run, making interoperability and EV roaming applicable to an increasing number of vehicles.

Interoperability refers to the compatibility of key system components in the EV ecosystem – whether hardware or software – allowing all components to work seamlessly together.

5. Introducing interoperability and EV roaming

Charging an EV – at its most basic – involves the flow of electrons from the electric vehicle supply equipment (EVSE) to the EV. When EV charging is conducted as a commercial activity, the transaction also includes the exchange of money and information between the EV user and CPO.

As the electric mobility sector grows, charging too is expected to become more multifaceted. The number of stakeholders involved is expected to increase, with charging taking significantly more steps. These stakeholders may include Discoms, OEMs, MSPs, network service providers, navigation service providers, and roaming hubs. To avoid complexity while scaling up, EV charging must be made interoperable.

Interoperability refers to the compatibility of key system components in the EV ecosystem – whether hardware or software – allowing all components to work seamlessly together (Electric Power Research Institution 2019). Standardisation lies at the heart of interoperability. By creating standard technical protocols – a standard set of rules – all components involved in charging can speak the same language. By designing for compatibility from the start, interoperability helps create a well-integrated and easy-to-use charging ecosystem.

Protocols not only provide backend integration to components but also patch together a fragmented market for the end-user. Specialised protocols exist at the interface between each pair of stakeholders in the EV ecosystem (ElaadNL 2017). By taking care of the heavy-lifting of coordinating between stakeholders, protocols reduce the complexity involved in charging and enable new value-added services such as managed charging, vehicle-to-everything (V2X), plug-and-charge and EV roaming. In this report, we emphasise the

"Interoperability creates more access to a network of charging station for drivers. Currently the charge point operators are operating in silos. These are completely disconnected and there is a difficulty that drivers feel in accessing the non-networked charging stations."

N. Mohan
Head – EV charging, EESL

interoperability of multiple charging networks within an EV ecosystem – also referred to as EV roaming.

Information silos, as they exist today, pose the risk of locking-in valuable usage and performance information into proprietary, closed technology platforms. EV infrastructure includes diverse stakeholders, ranging from automobile OEMs to telematics providers, EVSEs, CPOs, and MSPs. The sheer multitude of actors involved increases the risk of creation and entrenchment of data silos. Preventing the emergence of walled data gardens is critical to fostering innovation and facilitating a quick and efficient transition to electric mobility in India.

EV roaming is a system wherein users can access charging from any provider through an application or platform of their choice (Netherlands Enterprise Agency 2019). While existing structures restrict users to CPOs with which they have an account or subscription, roaming enables users to discover, access, and charge at multiple CPOs using the same log-in credentials. EV roaming is enabled by the shared use of charging infrastructure and through information exchange facilitated by contractual tie-ups between CPOs and MSPs on business and technology.

EV roaming is an outcome of technological integration and information exchange. It requires the CMS of various CPOs and MSPs to communicate with each other – creating an accessible network of charging stations. But at its core, EV roaming is inherently a business proposition – wherein CPOs and MSPs cooperate by exchanging information on a commercial basis instead of competing with each other. Transparency can facilitate growth of the sector. Instead of competing for a larger slice of the same pie, market participants can expand the pie by attracting new customers with better charging services.

The direct participants in the EV roaming space are:

Charge point operators (CPOs): Commercial entities that manage, maintain, and operate charging stations. Their responsibilities are both technical and financial. These companies may or may not own the charging stations they operate.

Mobility service providers (MSP): Commercial entities that provide charging-as-a-service to EV drivers by aggregating charging stations from multiple CPOs. They manage billing and payment settlements for EV drivers. MSPs may or may not own charging stations themselves.

It is important to note that the distinction between CPOs and MSPs remains blurry in the Indian context. Companies may assume both of these entities' roles by installing and maintaining charging stations and providing charging as a commercial service to EV drivers.

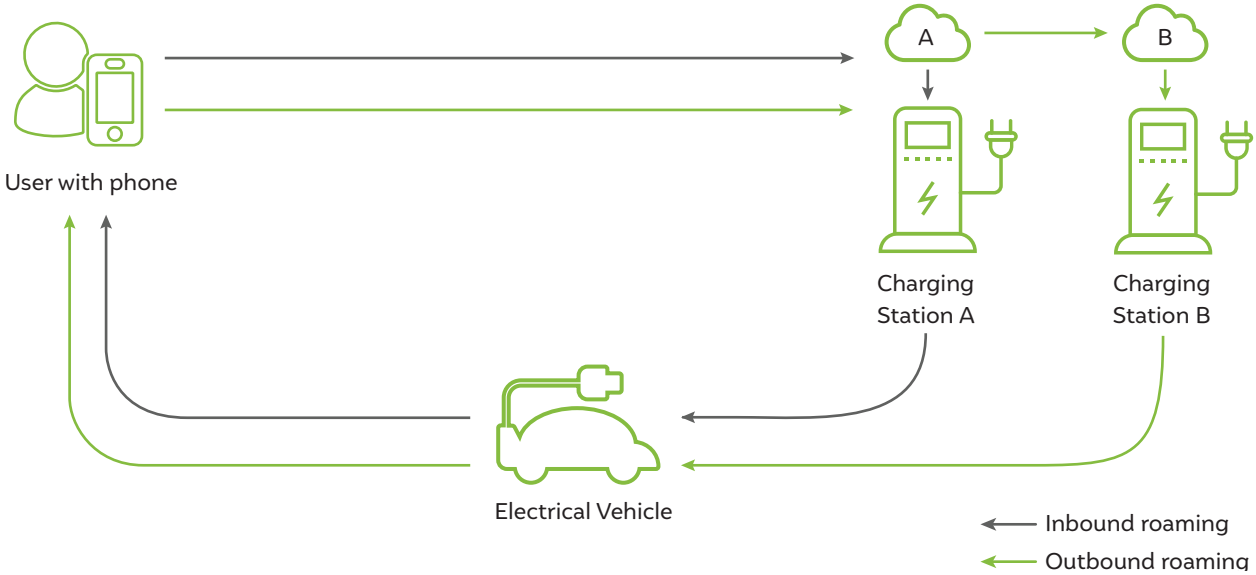
Roaming platforms (optional): A central business-to-business entity that acts as a bridge that facilitates roaming transactions between CPOs and MSPs. They are inherently neutral and act as non-partisan middlemen for roaming transactions.

Besides the direct participants, a larger set of stakeholders are indirectly involved in EV roaming:

Figure 4 Key stakeholders in EV roaming

Source: CEEW-CEF analysis

Figure 5 CPOs and MSPs may play the role of an inbound or outbound party in a roaming session



Source: CEEW-CEF analysis

Navigation service providers: Provide mapping and navigation services such as MapMyIndia and Google Maps.

Network service providers: A business-to-business entity that provides CMS, mobile applications, and other IT services to CPOs and MSPs. In India, most backend IT services are outsourced to these entities.

EVSEs: Electric vehicle supply equipment is the multiple hardware components that supply electricity to EVs. Also known as chargers.

OEMs: Manufacturers of electric vehicles.

Discoms: Distribution companies or utilities that supply electricity to charging stations.

An EV roaming session can be thought of as a more complex version of an EV charging session, with additional transactions. Each roaming session involves two charging providers:

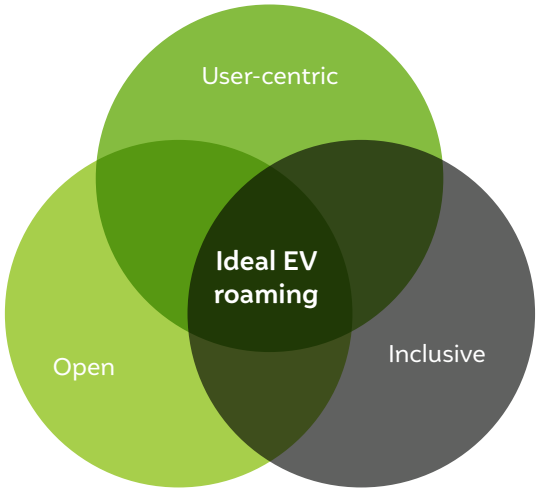
1. An inbound party, typically a CPO or MSP, which owns the charger accessed by the user
2. An outbound party, typically a CPO or MSP, with a roaming arrangement with the inbound party and with which the user has an account or subscription.

The above figure assumes that the EV driver has a user-subscription with network A. He/ she can avail of charging stations belonging to network B – the outbound party, only if roaming exists.

The ideal EV roaming ecosystem is:

- User-centric: solves for the charging needs of EV consumers
- Inclusive: facilitates the participation of new stakeholders in EV roaming
- Open: allows market participants the flexibility to compete and collaborate

Figure 6 The ideal EV roaming ecosystem



Source: CEEW-CEF analysis

Although market participants are motivated to offer roaming to improve their business proposition, policy and regulation increasingly play an essential role in enabling EV roaming. By implementing necessary legislation and removing any rules that act as barriers, the government can facilitate EV roaming and create a vibrant and transparent EV charging ecosystem.

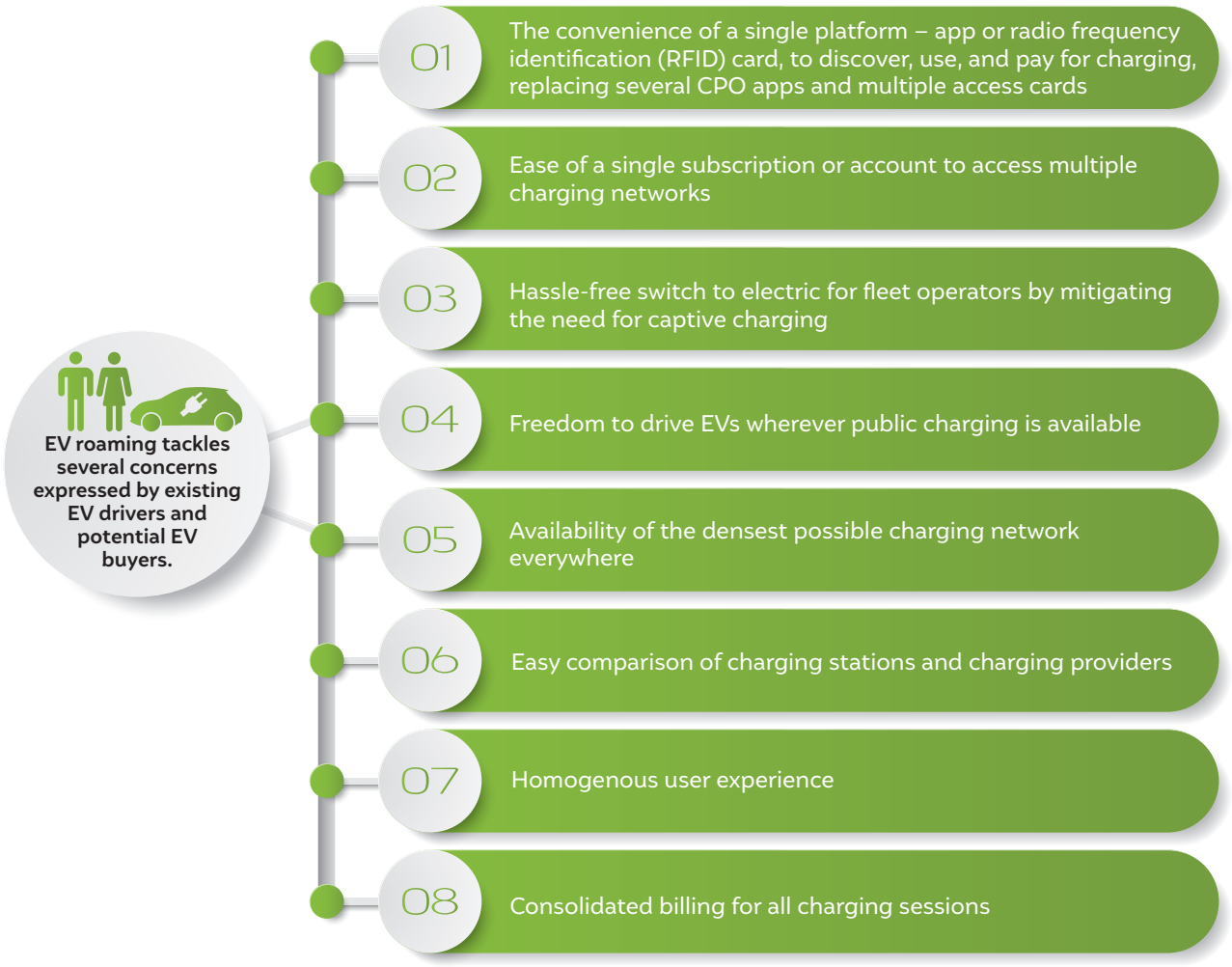
6. Benefits and challenges of EV roaming

The impact of EV roaming is best examined by looking at three distinct groups: first, the users, then, direct participants in roaming, and lastly, the wider charging ecosystem (Ferwerda et al. 2018).

"While the immediate benefits of expansion – profitability, more customers, more user-retention and experience, are obvious; it is i mportant to understand the cost implications of EV roaming on users and the industry, as well."

Dr Shalini Sarin
Director, Elektromobilitat

Benefits of EV roaming



Source: CEEW-CEF analysis

For CPOs and MSPs, EV roaming helps through (IHS Markit 2019)

01 Faster monetisation of charging infrastructure through increased usage

02 Attracting a new and broader set of consumers

03 Easy expansion into new territories through partnerships

04 Operational flexibility to create new value-added services

05 Flexibility in selecting EVSEs and network service providers without comprising on technology

06 Easy technical integration with other stakeholders

07 Reduced risk of technology obsolescence and stranded assets

By boosting user demand and aggregating the supply of chargers, EV roaming induces network effects and catalyses the entire EV ecosystem (Ferwerda et al. 2018)

01 Early-on investment in standardisation allows for efficient scaling-up of the total market

02 Wider compatibility for OEMs and EVSE manufacturers

03 Easy addition of PCS information into public databases

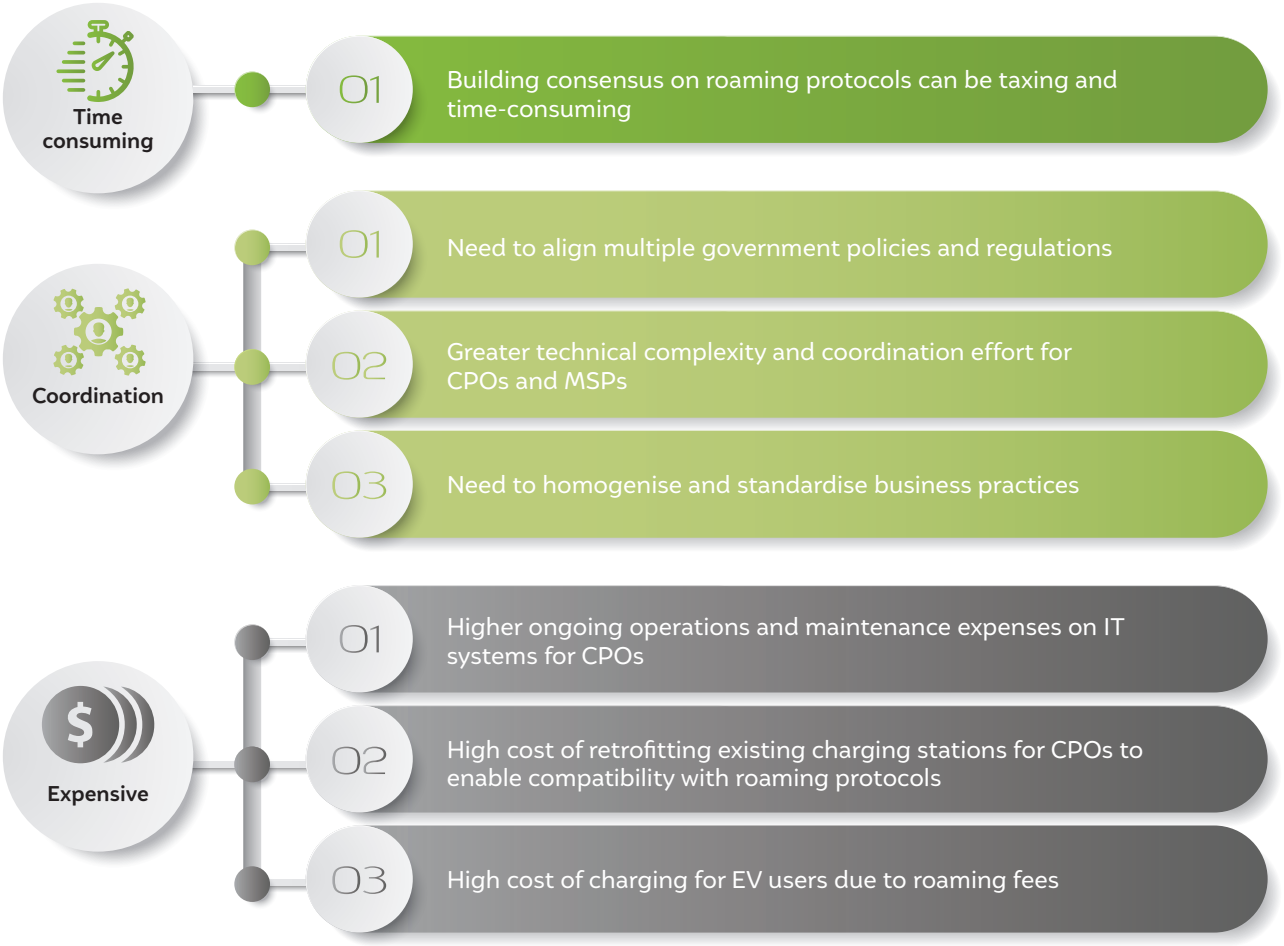
04 Efficient allocation of public resources by the government

05 Tighter integration between stakeholders on EV charging

06 Boosting investor confidence in electric mobility

Source: CEEW-CEF analysis

Challenges to EV roaming



Source: CEEW-CEF analysis

7. The need for EV roaming in India

Due to the early state of the market, India's charging ecosystem is known more for what it lacks than what it has. Charging is repeatedly cited as one of the most significant barriers to EV adoption in consumer and industry surveys in India (Singh 2020). Public charging is barely five years old and already considerable attention is being paid to increasing the country's total number of PCSs. Consequently, less attention is being paid to charging station utilisation. It is no surprise that gaps remain between consumer expectations and the market offering in the case of public charging (IEMF and BSES Rajdhani Power Limited 2020). EV roaming offers a means to bridge this gap by making PCS operationally useful.

The importance of EV roaming becomes clear when we consider the expectations of current and potential EV consumers (Castrol 2020; Soman, Kaur, and Ganesan 2019). It starts with availability, i.e., making public charging available to everyone, irrespective of the application, platform, or subscription. India is estimated to have installed just 0.1 per cent of its public charging target for 2030 (EESL 2020; Ministry of Heavy Industries and Public Enterprises 2019). Moreover, many stations are concentrated in certain areas due to the limited geographic reach of CPOs, e.g., New Delhi Municipal Corporation in New Delhi (NDMC n.d.). EV roaming allows for the aggregation of charging stations from multiple CPOs in one place, making public charging available regardless of travel distance, regional boundaries, or application used.

The next challenge is discoverability: consumers expect public charging to be easy to find. India has more

EV roaming allows for the aggregation of charging stations from multiple CPOs in one place, making public charging available regardless of travel distance, regional boundaries, or application used.

than 20-odd CPOs (EVReporter 2019), and almost all display only their own stations on their apps. These information silos breed a perception of shortage – both for existing drivers and potential EV buyers. Even if the cumulative number of charging stations were to rise, the perceived lack of charging stations due to segregated information would discourage drivers from relying on public charging and deter consumers from buying EVs. EV roaming makes the entire charging network readily available to consumers.

Moreover, no definitive database of public charging stations exists in India. Though the government is trying to solve this through a regulatory 'push', EV roaming offers a more elegant 'pull' by incentivising CPOs to exchange information for commercial benefit. Breaking down the barriers to information exchange can make the combined public charging network greater than the sum of its parts.

Information access is critical to consumers. Each EV player uses separate channels for user communication – CPOs use applications, car manufacturers use dashboards, and governments use lists. Ideally, updated charging information needs to be visible on numerous platforms (e.g., charger displays, the internet, car dashboards, and mobile apps) and in multiple iterations on the same platform (e.g., various mobile apps). EV roaming makes it easy to cross-publish static and dynamic information in real-time, helping consumers access accurate and up-to-date information from a source of their choice.

Consumers also expect charging to be easy-to-use with minimal technical know-how. Today, consumers have to undergo a steep learning curve in differentiating between the five types of connectors (Ministry of Power 2019a). The user interface of charging software should be simple and easy to follow. The need of the hour is software charging standards, to be adopted universally by the industry and government. Standardising information exchange at the backend will simplify EV charging for the user, mimicking other interoperable travel standards such as FASTag or the Delhi ONE card.

As EV roaming gains traction, the pool of charging stations available to the public would increase. Fleets are the early adopters of EVs in India and are building significant charging infrastructure for self-use (WBCSD 2020). Similarly, many e2w and e4w OEMs have installed home chargers for their customers. EV roaming offers a reliable pathway to open such captive chargers to the public, generating additional revenue for owners with minimal effort.

> **EV roaming offers CPOs a means to uniformity in customer service levels and government regulation, thereby benefitting charging as a whole - Add thereby in the end**

EV roaming also presents an opportunity to forge consensus within the EV industry. The charging market is witnessing increased competition as the number of CPOs rises. The real competition for EV charging is not with other players in the same industry, but against fossil fuels, which the industry cannot displace without a certain degree of cooperation. EV roaming offers CPOs a means to uniformity in customer service levels and government regulation, thereby benefitting charging as a whole.

Any discussion on the EV industry cannot ignore the export potential of products developed in India. India is a global leader in software development, automobile manufacturing, and auto ancillaries, and the government has communicated its intent to secure market leadership in the EV sector as well. Implementing global charging standards in India will automatically qualify homegrown EV chargers and charging software for export. India can create jobs, build domestic expertise, and expand its global leadership in automobiles by aligning Indian charging standards with international norms.

8. Pathways to EV roaming

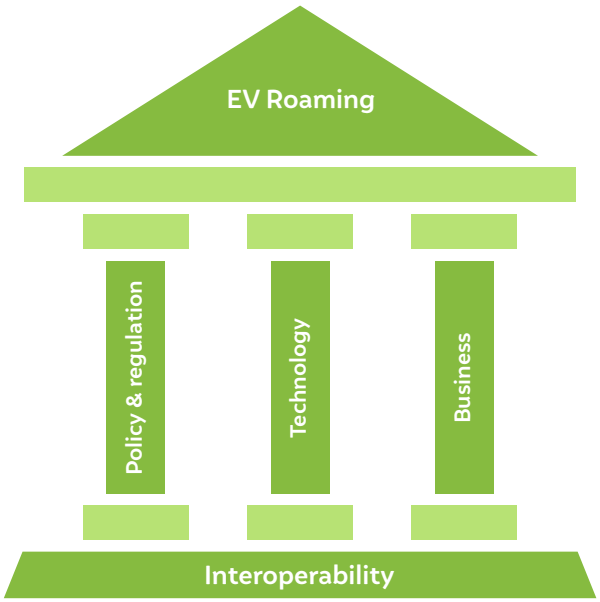
Interoperability is the means and EV roaming is the desired end result. Before operationalising EV roaming, we must first examine the current supporting architecture. This section scrutinises the three pillars enabling EV roaming – policy and regulation, technology, and business.

The fundamental pillar necessary to support EV roaming is policy and regulation. Government laws set the boundary conditions for EV roaming to exist. Various laws, policies, and regulations need to be examined to make way for EV roaming.

Technical considerations come next – the selection of an appropriate roaming protocol. EV roaming works best when implemented with a standardised and interoperable protocol. Selecting the appropriate technology requires consensus and buy-in from multiple stakeholders in order to make it a standard.

Lastly, the business of EV roaming involves devising a means to add roaming to existing charging infrastructure. For EV roaming to be a viable business opportunity, it requires demand among consumers for a better charging experience and willingness among market participants to supply appropriate solutions. The business of roaming is a direct consequence of the existing state and maturity of the charging market.

Figure 7 The three pillars of interoperability



Source: CEEW-CEF analysis

8.1 Policy and regulation

EV charging is heavily regulated in India. Some of these regulations are mandatory for PCS set up with the government's assistance while others are universally applicable. Except for certain components of the tariff, most regulations and policy pertaining to EV roaming are defined at the national level. It is crucial to take stock of current regulations to evaluate the scope for introducing EV roaming in India.

EV roaming transactions involve exchanging three elements: electrons for charging, money for payments, and information to operate. Table 3 describes each element's exchange:

As EV roaming operates at the intersection of multiple sectors such as software, electricity, fintech, and automobiles, it is not surprising that numerous stakeholders are involved in the process of formulating regulations. Let's deep dive into each element.

The essential functions for EV roaming to take place and regulation of their data are:

Table 4 Current status of Indian regulation of EV roaming functions

Activity	Currently regulated for EV charging	Regulation required for EV roaming
Authentication	✗	✗
Authorisation	✗	✗
Information recording and exchange	✓	✓
Billing	✗	✗
Data security and privacy	Partially	✓

Source: CEEW-CEF analysis

1. **Electrons**

   The physical act of charging is the same, whether or not EV roaming is involved. As Annexure 1 outlines, electricity use for EV charging is heavily regulated, in line with the overall power sector. As the current regulatory norms provide sufficient technical clarity, and electricity usage under roaming is no different from standard charging, no changes are needed in electricity regulations to permit EV roaming.

Table 3 EV roaming involves exchange of electrons, money and data

Element	Parties	Components	Flow	Jurisdiction	Transactions involved
Electrons	CPO, user	EVSE, EV	One way	Central and state governments	Charging
Money	User, inbound party, outbound party	Mobile application, payment gateway	One way	Central government	Payment, settlement
Data	User, inbound party, outbound party	Mobile application, CMS, EVSE	Two way	Central and state governments	Search, authentication, authorisation, tariff display, charging status, billing, charging data record

Source: CEEW-CEF analysis

2. Money

Two kinds of payment exchanges occur under EV roaming:

1. Payment from the user to an inbound party
2. A settlement between the inbound and outbound parties

The Reserve Bank of India tightly controls the exchange of money, both physical and digital. As payments and settlements for EV roaming are conceptually identical to monetary transactions concerning EV charging, existing banking regulations are sufficient to support EV roaming.

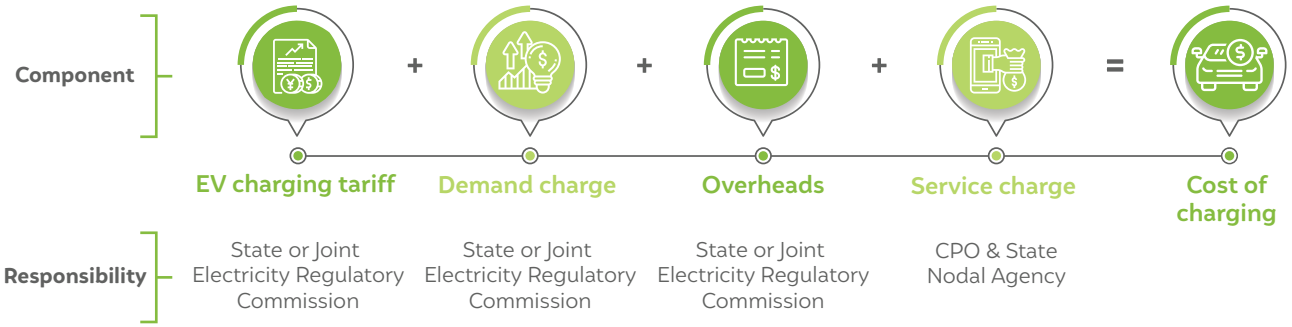
The price of charging is another important item that is regulated. The cost of charging includes several components, each with separate jurisdictions. Regardless of individual cost components, the CPO may implement a variety of pricing schemes for the user. Per electricity unit pricing (Rs/KWh) remains the most popular, and per-time and per-session pricing are also prevalent.

Table 5 Components of EV charging cost

Component	Notes
EV charging tariff (Rs/kWh)	• Definition: Cost of energy supplied by the utility to PCS • Scope: Tariff > 115% of the average cost of supply to the utility, unless a separate EV tariff is notified • Implementation: 23 states and union territories have announced EV tariffs as of January 2020, often at a concessional rate
Demand charge (INR/kVA/month)	• Definition: Charges on peak electricity demand for a time interval • Scope: Fixed value under commercial and industrial tariff categories • Implementation: 15 states and union territories as of January 2020
Overheads	• Definition: Taxes, cess, surcharges, duties, power purchase adjustment charges (PPAC), and rebate • Scope: A variety of overheads each state is expected to apply to EV tariffs. Goods and Services Tax (GST) may apply for non-electricity costs. • Implementation: Difficult to verify from info in the public domain
Service charge	• Definition: CPO's margin for providing charging services • Scope: State nodal agencies are empowered to implement a cap for charging stations using government assistance to ensure concessions are passed on to users • Implementation: Difficult to verify from info in the public domain

Source: CEEW-CEF analysis based on Das, Shyamasis, and Bhawna Tyagi. 2020. "EV- A New Entrant to India's Electricity Consumer-Basket." New Delhi.

Figure 8 Break-up of EV charging costs and the associated regulatory purview



Source: CEEW-CEF analysis

In the case of EV roaming, a roaming fee is typically added by the inbound party to the user's charging cost. This fee pays for setting up and maintaining the roaming arrangement. In the Indian context, adding a roaming fee to one of the existing cost components may be easier than regulating it as a standalone component. As roaming is a form of service provided by a CPO, it can be subsumed under the service charge. However, the challenges to its inclusion include:

- A low price ceiling on this fee may make roaming economically unviable to implement for a CPO. The caps themselves are unavailable in the public domain, making it difficult to understand the margin currently available to CPOs.
- As a standard methodology does not exist for calculating this cap, each state may develop its own calculation for this component. This may be a function of the location of chargers, the time of day, or the network's own decision. Fragmentation may hinder the addition of roaming fees to service charges in select states.

3. Data

Data is essential for EV charging, and even more so for EV roaming. Information permeates each step of EV roaming, making it the most vital, complicated, and preeminent element. Each regulatory body has a say in the exchange of data used in EV charging.

The Information Technology Act, 2000, and its subsequent amendments provide the overarching regulatory framework governing digital information in India. Additionally, a Personal Data Protection Bill, 2019, is currently under discussion, which has strong data protection, data privacy, and data localisation measures, and if implemented, will go a long way in regulating how personal data is used in the case of EV charging (and in future EV roaming) (GOI 2019).

Any EV roaming transaction starts with finding a suitable charging station. Charging station information can be shared in a centralised or decentralised manner. India is pursuing a centralised approach by creating a government database that aggregates data from CPOs. The Central Electrical Authority (CEA) maintains a national list of PCSs by collecting monthly information from discoms, which issue connections at EV tariffs (Central Electricity Authority 2020). Additionally, the Department of Heavy Industries, and states such as Delhi, plan to create super-apps for public charging stations nationally and in the state (Department of Heavy Industries 2019; Sabir 2020).

CEA's data collection is manual, offline, periodic, and static. Aggregation works best when information is collected automatically, online, in real-time, and includes dynamic information, e.g., live charger availability and slot reservation. Such data collection is usually done through application programming interfaces (APIs), or in the case of EV roaming, fit-for-purpose protocols. Implementing protocols in India is easier as PCSs are required to be connected to a CMS.

Another aspect that requires regulation is user information, especially personal data and financial data. All CPOs require prior registration to access charging – a user name, phone number, email address, vehicle registration, and vehicle identification number (VIN) are mandatory. There's considerable variance in the data privacy and protection practices followed by companies. This inconsistency needs to be solved for consumers to be confident about EV roaming. In the case of financial data, the RBI sets exacting standards for encryption, storage, and exchange. These regulations apply to all digital transactions and provide sufficient safeguards for financial data shared in the case of EV roaming.

The standards and rules for communication between an electric vehicle and EVSE are set under the regulations notified by the Bureau of Indian Standards, Automotive Research Association of India, Department of Heavy Industries and Central Electricity Authority, as outlined in Annexure 1, and provide sufficient clarity.

In summary, none of the current laws or regulations prevent the introduction of EV roaming in India. However, the government may consider issuing clarifications and amendments to existing policies to provide certainty and direction. While regulation of payments and electricity use is fairly advanced, data exchange regulations require greater thought. The government has regulated EV charging, and the same approach should carry over to EV roaming as well. By proactively adopting the principles of interoperability, India can future-proof its charging ecosystem.

In the case of EV roaming, a roaming fee is typically added by the inbound party to the user's charging cost. This fee pays for setting up and maintaining the roaming arrangement.

8.2 Technology

The fundamental challenge on the technology front is not its development, but rather selecting the appropriate protocol. India has to decide on a roaming protocol to ensure interoperability. The choice is between adopting an existing EV roaming protocol, waiting for a new 'ideal' protocol, or creating one from scratch. The protocols available today vary by functionality, adoption, market penetration, ownership, openness, and maturity (Paulraj 2020). Prominent examples include Open Charge Point Interface (OCPI), Open Clearing House Protocol (OCHP), Open Intercharge Protocol (OICP), e-Mobility Interoperation Protocol (eMIP) and International Electrotechnical Commission (IEC) 63119. In terms of functionality, however, each of the protocols exhibits near similar features with respect to data fields such as location, availability, CPO name, connector type, etc.

Very little information is available in the public domain about the IEC 63119 protocol, which is under development. Discussions with Indian stakeholders indicate that waiting until 2022 might be counterproductive. Though the IEC's sponsorship might result in a technically superior and globally representative protocol, it does not guarantee market dominance. Past instances show that standards can convert their first-mover advantage, sponsor strength, outreach strategy, and widespread commercialisation into the de facto status, e.g., OCPP over IEC 63110 (Mültin 2018). Thus, IEC 63119 protocol is not considered here.

Countries introducing EV roaming can also choose to create a new protocol tailored to their requirements. Developing a protocol from scratch is a complicated, time-consuming, and capital-intensive process, and good reasons are needed to justify the effort. Discussions with ETD 51 programme participants highlighted a clear preference for adopting existing, mature, and open standards rather than creating ones afresh.

A standards battle is ongoing between OCPI, OCHP, OICP and eMIP, with no clear winners or losers (Kam and Bekkers 2020). All four existing protocols are available for free and share many of the basic functionalities required for interoperability. According to a recent study by Eindhoven University of Technology (Kam and Rudi Bekkers 2020), the ideal protocol should adhere to certain design principles such as openness, scalability, quality control, and business model flexibility. No current protocol perfectly matches these requirements.

However, OCPI scores over the rest for multiple reasons summarised in Table 6. OCPI offers the greatest business model flexibility, has a non-profit sponsor over which no one participant has undue influence, and has matured greatly over the years (ChargeUp Europe 2020). Given that the choice of protocol may not limit the business topology thus selected, conversations with European market participants suggest that even hubs like GIREVE have embraced OCPI as their choice of protocol. Multiple Indian CPOs, network service providers and OEMs, and foreign experts on EV roaming have seconded the

Table 6 Comparison of major EV protocols

	OCPI	OCHP	OICP	eMIP	IEC 63119
Governing body	EVRoaming Foundation	Open Charge Alliance	Hubject	GIREVE	IEC
Type of governing body	Independent board	Non-commercial roaming hub	Commercial roaming hub	Commercial roaming hub	International standards organisation
Business structure	P2P + hub + mixed	P2P + hub	Hub	Hub	Not available
Supported business models	Any network	Any network	Hubject only	GIREVE only	Any network (expected)
Launch	2014	2013	2013	2015	2022 (expected)
Last release	2019	2016	2017	2015	Not applicable
Geographic presence	USA, pan-Europe	pan-Europe	pan-Europe, USA, China	France	Global (expected)
Openness	High	Medium to high	Medium	Medium to low	High (expected)

Source: CEEW-CEF analysis based on Kam, Mart van der, and Rudi Bekkers. 2020. "Comparative Analysis of Standardized Protocols for EV Roaming."

selection of OCPI for the Indian market. EV roaming protocols are not part of ETD 51's formal agenda, but participants mentioned informal conversations on roaming standards (Bureau of Indian Standards n.d.). Some Indian participants stated the potential need to customise OCPI for the Indian context (e.g., adding data fields for VIN and vehicle registration number) to address India's unique business and technical requirements. This analysis of protocols may change in the medium term with the release of new versions of protocols.

> **OCPI offers the greatest business model flexibility, has a non-profit sponsor over which no one participant has undue influence, and has matured greatly over the years**

India should proactively build consensus around a single roaming standard rather than taking a wait and watch approach. Letting the market decide would lead to a repetition of the mistake made in the case of connector standardisation, where approval of five types of plugs has led to more – not less – confusion. The early nature of the Indian charging market is an unforeseen advantage here. The absence of turf wars puts market participants on an equal footing and creates an environment for impartial deliberation on standards.

8.3 Business

At its core, EV roaming is a commercial opportunity for multiple stakeholders that market participants can realise by collaborating on charging-related services. Getting competitors to coordinate on a selective basis is a difficult ask unless there's a clear economic benefit

> **India should proactively build consensus around a single roaming standard rather than taking a wait and watch approach.**

CEEW-CEF's interaction with the Dialogue and Development Commission of Delhi

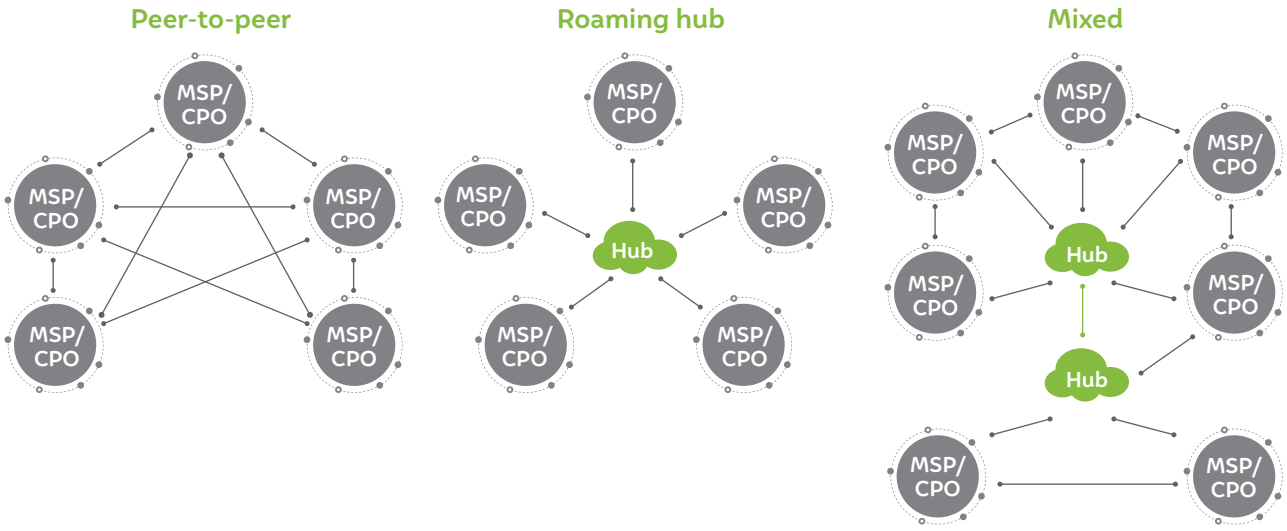
As a part of our stakeholder consultation exercise, the CEEW-CEF team interacted with officials of the DDC, to discuss various elements of Delhi's EV policy. We provided the team with inputs on their public database of charging stations and discussed the technical suitability of OCPI. In February, 2021 the Delhi Transco Limited released a notification mandating the use of OCPI 2.1 and OCHP direct 0.2 – for communication between charging stations.

for everyone involved. Therefore, it is important for the market to carefully choose a business model that suits it well. The commercial partnerships that EV roaming encourages are forged through contracts between market participants. These contracts give rise to several business models, which vary in terms of market structure, number of participants, degree of collaboration, openness, etc.

Market structure

The most common way of categorising business models is by market structure – which exists as a spectrum. Peer-to-peer and roaming hubs – as discussed below – lie on the two extreme ends of this.

Figure 9 Common market structures under EV roaming



Source: CEEW-CEF analysis

Peer-to-peer: In a peer-to-peer market structure, market participants bilaterally offer roaming on each other's charging networks. This decentralised approach helps exchange data – such as charger information, availability status, booking, and payment. These represent a business-to-customer (B2C) approach.

Roaming hub: A roaming hub is an intermediary platform that serves as a clearinghouse for information exchange. While it enables roaming, it is important to note that it is a central node but not a market participant. A hub is a business-to-business (B2B) entity, which offers a high degree of standardisation in business and technology to all those connected to it. A hub may or may not be a profit-making entity.

Table 7 Comparison of P2P and hub functionalities

Peer-to-peer	Functionalities offered to CPOs	Roaming hub
2	Number of market participants	>= 2
High	Degree of control	Low
Low	Contractual standardisation	High
Medium to high	Flexibility in protocol selection	Low
Low	Economies of scale	High
High	Barriers to entry	Low
High	Overall cost	Low
High	Operational complexity	Low-to-medium
Low	Network coverage	High

Source: CEEW-CEF analysis

A third alternative is a hybrid mix that lies at the intersection of the above-mentioned approaches. Multiple sources have shown that this market structure is highly popular in the European EV roaming market today, especially where business decisions are left to market participants themselves.

Several permutations and combinations such as peer-to-peer connections, peer-to-hub connections, and hub-to-hub connections may exist. The choice of market topology must be market-considerate.

The choice of business model depends heavily on the existing market structure. A P2P approach is suitable when there are fewer market participants. It favours market incumbents by providing them with the opportunity to consolidate their market shares. This is because such an approach requires a considerable amount of time and resources depending on the level of customisation desired. All the costs associated with implementing, maintaining, and periodically upgrading EV roaming lie with the participants involved. The American market provides an appropriate example of this. Early market consolidation helped large market participants establish even larger market shares.

Alternatively, a hub approach works best when there are many participants, most of whom are interested in furthering the boundaries of their networks through EV roaming. In addition to connecting members, hubs provide quality control, maintenance and customer support, and administrative services for a fee. They ensure uniformity through standardised contracts and service agreements. Such an approach is non-discriminatory because roaming hubs enable all market participants – big and small – to connect with each other. Low barriers to entry enable faster adoption of EV roaming. However, these are not without their challenges; hubs – owing to their size – are slower to update and adapt. Examples of these are:

The strong correlation that once existed between the choice of business model and the protocol selected may no longer hold true. With time, we see hubs adopting multiple protocols. Interactions with European

> **A market like ours may tend towards a hub approach due to the high degree of fragmentation.**

Table 8 Examples of roaming hub networks

	Hubject	GIREVE	e-clearing.net	MOBI.E
Type	Commercial entity	Public–private partnership	Commercial entity	Public institution
Business objective	For profit	For profit	For profit	Non-profit
Geographic presence	Pan-Europe, USA, China	France	Germany, the Netherlands, Belgium, Austria, Slovakia	Portugal

Source: CEEW-CEF analysis

market players suggest that hubs like GIREVE have experimented with OCPI. The emergence of specialised network service providers – such as has-to-be and Greenflux – is also a recent phenomenon. The Indian market's choice of business arrangement should be independent of its protocol selection.

A market like ours may tend towards a hub approach due to the high degree of fragmentation. Set up costs and operational costs in a P2P structure are directly proportional to the number of participants involved, unlike in a hub. This may automatically eliminate smaller players that are unable to bear these costs and expand their coverage across multiple networks. Quantifying these costs beforehand in the case of a bilateral set up may also prove to be difficult. On the other hand, a roaming hub provides a clearer and more uniform estimate for the same.

EV roaming can also be mandatorily established by the government – through a monolithic roaming hub. Countries such as Portugal have established such hubs through proactive government intervention. These ensure complete coverage of all available networks, as well as standardisation, uniformity, and equitable market access for all. On the flip-side, these may be difficult to allocate control of and cannot be customised to suit multiple needs.

It is important to note that the business topology is easier and faster to change in comparison to amending regulations and developing new protocols. Business models must evolve in tandem with the evolution of EV charging. Constant innovation in this space provides market participants with ample flexibility.

The ideal EV roaming market is one that is inclusive, user-centric, and provides market players with the flexibility they so desire. The diversity that exists in the Indian EV charging market today – with more than 30 CPOs currently operating may perhaps only be patched by giving participants the right to self-determine their business arrangements. Regulated elements of charging, have not translated into a tightly regulated commercial space – which may perhaps be the best course of action for EV roaming, too.

Openness in EV roaming

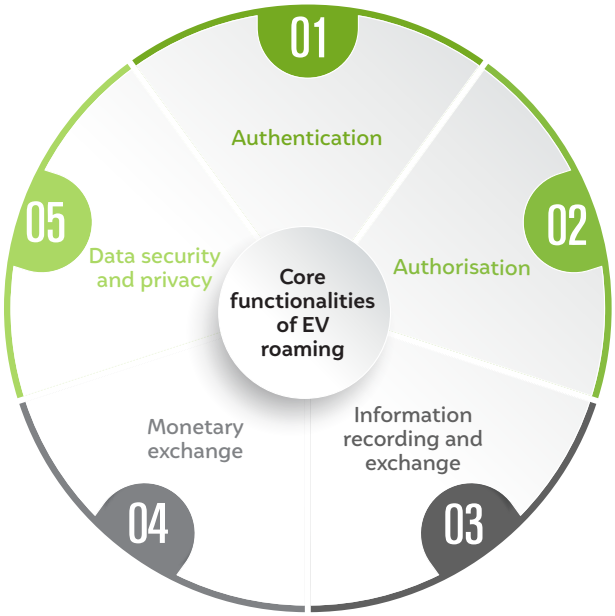
To encourage business collaboration between competitors in the EV charging space, certain practices that help build trust among market participants must be established. The World Trade Organisation mandates that all open standards should be:

- Transparent
- Non-discriminatory
- Impartial
- Effective and relevant
- Coherent
- And address the concerns of developing countries

9. Core functionalities of EV roaming

Implementing EV roaming requires integrating policy, technology, and business decisions to build a service with at least basic capabilities. All successful roaming services share some common features, which are categorised as 'core functionalities' here. These are the minimum features required to put EV roaming into practice.

Figure 10 Core functionalities of EV roaming



Source: CEEW-CEF analysis

The five core functionalities are as follows (Kam and Rudi Bekkers 2020)

Authentication: Authentication or identification is the first point of contact between an EV driver and the inbound CPO. Here, the user initiates a charge session by identifying themself through one of the multiple modes available. Mobile applications – by far the most popular mode in India, along with RFID cards and credit/debit cards – are some possible channels Considering that the user could either have a subscription to the CPO whose

charger they are using or could be availing of roaming services, accurate authentication is an important predecessor to charging and billing. With time and market maturity, these may become more sophisticated and less time-consuming, thus improving the consumer's experience. For e.g., plug-and-charge models in which CPOs automatically recognise the user when the connector is plugged into the EV.

Authorisation: Once identified, the inbound party needs to verify with the outbound party whether the EV driver is authorised to access charging. This process may be conducted online (synchronous) or offline (asynchronous) by checking the user's ID against a whitelist of approved consumers. Beyond identification, authorisation may also require roaming providers to develop common contract IDs, charger IDs, station IDs, etc. In the Indian context, most CPOs use QR codes and one-time passwords (OTP) as an added layer of security before starting a charging session.

Information recording and exchange: Information exchange between market participants to create a universally accessible network of charging stations is key to EV roaming. Market data may be static or dynamic, sensitive or public, user-generated or system-generated. It must be handled appropriately given its importance and sensitivity. Roaming providers can analyse large datasets to derive insights that can help boost user experience and improve operations (analysing peak hours for a charging station). 'Tariff transparency' is also important – clearly displaying the amount payable by the consumer before, during, and after roaming, and sharing a break-up of the amount. This information keeps tariffs and participants competitive.

Monetary exchange: Monetary exchange in roaming applies to payments made by users, billing by the outbound party, and settlements between the inbound and outbound parties. First, roaming providers must provide multiple payment channels to make ease-of-use for users. In India, digital payments are highly popular, followed by RFID cards. The outbound party should consolidate charge data records from various inbound parties and self to present a consolidated invoice to the user. Lastly, a reliable settlement mechanism is required between inbound and outbound parties to settle accounts receivable and payable at a pre-determined frequency.

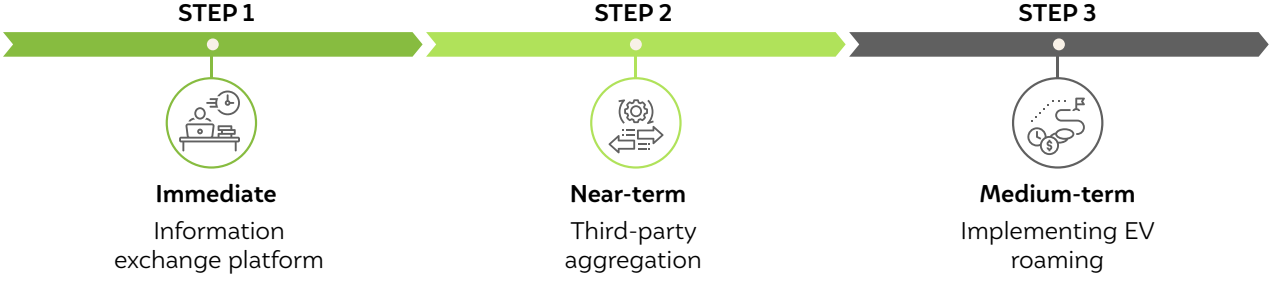
Data security and privacy: The potential for misuse grows in step with the use and exchange of data. It is critical that EV roaming participants take clear and visible steps to protect and secure information. Anonymisation, pseudonymisation, and encryption are some forms of data protection. Data security entails implementing a suite of solutions such as explicitly asking for user permissions, following the law on handling sensitive information, and communicating data safe practices to users.

The core functionalities are a critical first step in bringing a fragmented market together. In isolation, many of these features already exist for PCS in India. Implementing roaming will require harmonisation and consensus-building among market participants to bring consistency and completeness to roaming sessions.

10. Implementing interoperability

The five core functionalities we have discussed form the bedrock upon which a successful EV roaming framework can be built. But even among these, there exists a hierarchy that policymakers must take into account. With every advancement, these core functionalities should aim to become more sophisticated and add new features. However, given the existing market structure, we believe that there may be preliminaries to interoperability and roaming.

Figure 11 A three-step plan is recommended to introduce EV roaming in India



Source: CEEW-CEF analysis

Step 1 (immediate)
Information exchange platform

Aggregating point-of-interest information for users through open databases is the first step in bringing a fragmented market together. Such a database can consist of very basic and easily collected static information –the location of a charging station, the charger type, hours of operation, accepted payment methods, etc. We envision doing for multiple Indian states what the European Union (EU) does for all its members through national access points (NAP). A NAP is a register of all transport-related data to facilitate interoperable travel across the EU (European Commission n.d.). In India, this can either be a state or a national effort. The CEA has been mandated by the Ministry of Power (MoP) to create a national online database of all public chargers in the country as per the "*Charging Infrastructure for Electric Vehicles – Guidelines and Standard*s" issued in December 2020 (Ministry of Power 2019b). Under this legislation, all CPOs are expected to furnish charger details to their respective utilities who will then send this data to the CEA. As per the latest version of this database – released in June 2020 (Annexure 3) – India has a total of 934 public charging stations, with Andhra Pradesh having the largest share of these at 433 stations. For some states like Delhi, the CEA has released additional static data fields such as the location of each of the public charging stations and their associated utilities. Conversations with various market stakeholders reveal that the DHI too has expressed interest in creating a super app for PCSs across the country. However, no information regarding this is available in the public domain. Similar efforts are being pursued by the Delhi government to create a city-wide database of PCSs as part of the Delhi EV policy. Other efforts include Tata Motor's efforts to aggregate select CPOs for Tata Nexon drivers and the CEEW-CEF database on its EV dashboard.

Step 2 (near-term):
Third-party aggregation

Aggregating all CPOs under a single umbrella application makes charging more convenient for EV drivers. Instead of downloading multiple applications to locate charging stations across different networks, users can download one single app that provides them with multiple gateways. Aggregator apps like Electreefi in India provide this service. It aggregates PCSs from CPOs such as EESL, PowerGrid, and ChargeMyGaadi to not only display charging station locations from across CPOs, but also provide users with availability status and enable them to book slots. Payments however have not been enabled yet, and so the user is redirected to

Figure 12 Three phases of EV roaming

	Identification	Authorisation	User-information	Payment methods	Data-sharing
Advanced functionalities	Plug-and-charge	Synchronous and asynchronous authorisation	Dynamic information	Multiple payment methods	Comprehensive sharing of non-competitive and sensitive data
Improved functionalities	Multiple-point identification	Synchronous authorisation	Partially dynamic information	Multiple payment methods	Sharing competitive and partially sensitive data
Basic functionalities	Single-point identification	Asynchronous authorisation	Static information	Single payment method	Sharing non-competitive data

Source: CEEW-CEF analysis

payment platforms through internal gateways. While applications such as these aggregate information, they do not allow for cross-communication between different operators.

Step 3 (medium-term): Implementing EV roaming

Roaming, once introduced, can be implemented in multiple phases and within a reasonable timeframe. The final step establishes full-scale EV roaming between CPOs and MSPs. It is essential to build on its use case than to overwhelm a developing market. For the ease of the Indian market, we recommend a three-phase roadmap to interoperability. Identification, authorisation, charge session details, billing and payment, and data security and privacy remain the bedrock on which features are built and improved.

Phase I: Basic functionalities

The first of these phases focuses on the bare minimum features of EV roaming while ensuring an improved user experience. Interoperability is ensured using a single mode of identification – usually a standardised card or token – and a static whitelist to authorise the EV driver's charge session.

Phase II: Improved functionalities

The second phase provides users with multiple forms of identification – through a token, card, the user's mobile application, or in some cases their bank cards. The efficiency of identification and then real-time authorisation is improved. Partially dynamic information such as real-time availability and the hours of operation of charging stations is made available to users. They can also make payments through multiple methods – be it every month or on an ad-hoc basis using cards, wallets, etc.

Phase III: Advanced functionalities

The final phase can aim to incorporate advanced versions of each of the core functionalities such as plug-and-charge identification and authorisation as well as more accurate dynamic information. Authorisations can be made in real-time with offline back-up options available in case of emergencies. Charging networks are completely transparent and share all data between them.

11. Recommendations

General	• Prioritise interoperability in wired charging and public charging in India • Democratise access to information on PCSs using tools such as open databases and third-party aggregators • Develop a phased medium-term plan to introduce EV roaming in India, starting with improved sharing of information
Policy	• MoP to add roaming fees as part of service charges in *Guidelines and Standards for Charging Infrastructure* • BEE to provide state nodal agencies with a model framework to calculate service charges
Technical	• DST to immediately add roaming protocols to the ETD 51 agenda, prioritising the study of OCPI • BIS to publish a single, open, interoperable standard for roaming across the country
Business	• Allow flexibility to market participants to self-determine commercial arrangements under EV roaming • Explore the creation of a neutral industry forum or body on EV charging

12. Conclusion

EV charging and electric vehicles are often posed as a chicken-and-egg problem, but surveys of mature EV markets and Indian consumers show that this is not true. A sufficiently dense public charging network is correlated with the adoption of electric vehicles. While significant advances have been made to tackle the shortage of PCSs in India, it is clear that the current trajectory will be insufficient to achieve the national target of 30 per cent EVs by 2030.

In this scenario, interoperability and EV roaming seem like the obvious next steps to catalyse India's electric mobility transition. On weighing the pros and cons - there's a lot to like in interoperability and EV roaming and little to lose. Charging is a form of infrastructure, which is best seen as a public good. EV roaming offers a means to share, access, use, and pay for public charging infrastructure for the greater good of the population. By delinking the activity of charging from ownership of charging stations, EV roaming opens up charging-as-a-service and creates a pathway for future business innovations such as plug-and-charge and managed charging.

This conversation around interoperability and EV roaming has to start with the government but cannot succeed solely by its fiat. From the experience of other countries, EV roaming is not a natural outcome of a market's maturity but rather the result of an active discussion between the government and the public. In countries such as India with limited public resources, the government should embrace the principles behind interoperability to maximise the bang for its buck. EV roaming has the added benefit of unlocking private investment and nudging user demand, both of which are critical for the creation of infrastructure.

However, this is not a market structure that can be imposed overnight. India can only profit if it applies careful thought to its policy, technology, and business levers. EV roaming should add to the progress made to date and improve upon the status quo. A gradual, evidence-based evolution to full-scale EV roaming would help garner market buy-in and track the developments of the larger EV sector.

India is just one among many developing countries attempting to simultaneously improve the availability, affordability, and sustainability of transport by making a concerted push for an electric mobility ecosystem. The lessons outlined in this study are applicable to several markets either on the cusp of a transition to electric mobility or seeking a second-mover advantage to leap-frog into a more advanced charging sector.

Interoperability pilot

As a part of our project, we at CEEW-CEF and eDRV feel the need to go beyond theoretical conceptualisation of EV roaming and put research into action. The pilot project, therefore, aims to actively demonstrate the process of establishing EV roaming in India. CEEW will act as a neutral facilitator that allows competitors to selectively collaborate on features that serve their best interest, while also improving the user's charging experience. The pilot will provide CPOs with a wider consumer base and users with a wider network of charging infrastructure.

The proposed pilot is an industry collaboration between three established charge point operators in New Delhi, representing an energy service company and a state-owned electric utility company, and a leading Indian EV OEM. We expect this to be a six-week demonstration exercise, the results of which will be released as a pilot analysis at a later stage.

Annexures

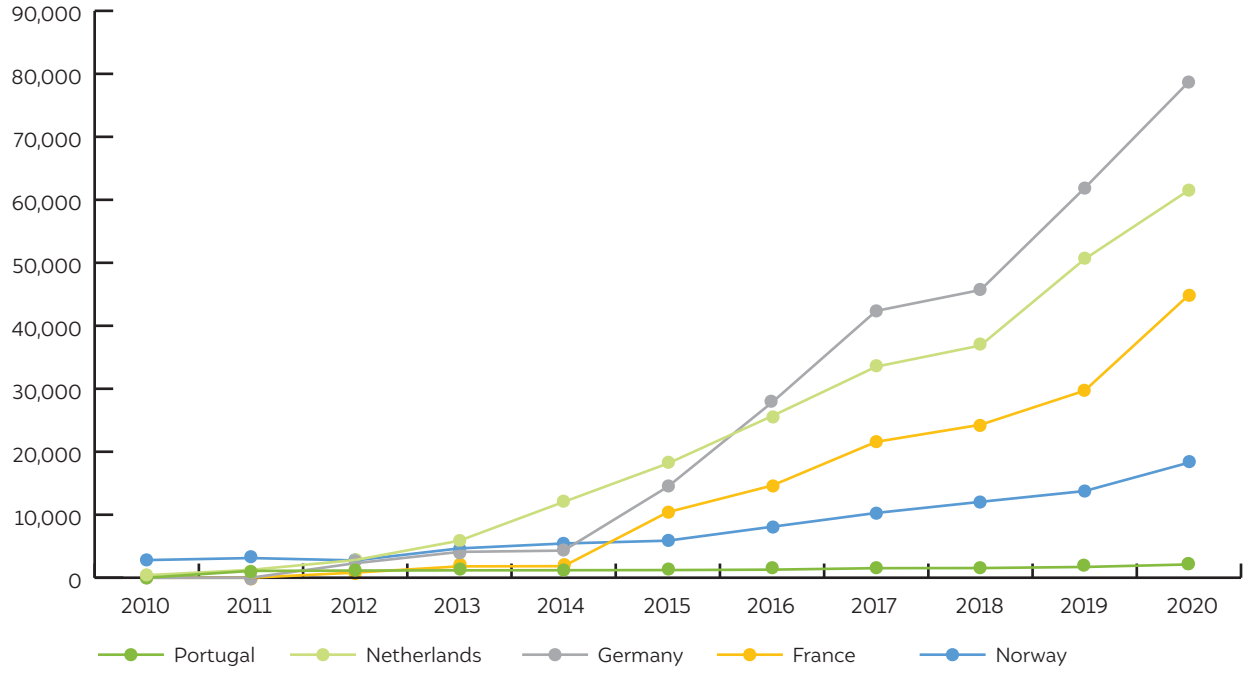
Annexure 1: Current regulatory landscape for EV charging in India

BODY	ELEMENT	RELEVANT DOCUMENTS
Ministry of Power (MoP)	Electrons, money, data	The Electricity Act, 2003 Shri RK Singh launches National E-Mobility Programme in India, 2018 Clarification on Charging Infrastructure for Electric Vehicles, 2018 Tariff Policy (2018) Draft, 2018 Guidelines & Standards for Charging of EV, 2018 Guidelines & Standards for Charging of EV, 2019 Guidelines & Standards for Charging of EV, 2020
Central Electricity Authority (CEA)	Electrons, data	Technical Standards for Connectivity of the Distributed Generation Resources Regulations, 2019 Measures relating to Safety and Electric Supply (Amendment) Regulations, 2019 Publishing of Info on Public Charging Stations, 2019
Bureau of Energy Efficiency (BEE)	Data	State Nodal Agencies, 2018
Automotive Research Association of India (ARAI)	Electrons, data	AIS 138 Part 1 for Electric Vehicle Conductive AC Charging System, 2017 AIS 138 Part 2 for Electric Vehicle Conductive DC Charging System, 2018
Department of Heavy Industries (DHI)	Electrons, data	Standardisation of Protocol for EV Charging Infra, 2017 Minutes of the Meeting of Standarisation of Protocol of AC & DC Charging, 2018 Minutes of the Second Meeting of Standarisation of Protocol of AC & DC Charging, 2018 National Electric Mobility Mission Plan, 2012 Setting up of the DHI-DST Technology Platform for Electric Mobility (TEPM) under the National Mission For Electric Mobility, 2016 National Automotive Policy (Draft), 2018 Publication of Phase-II of the FAME India scheme, 2019 Constitution of Project Implementation and Sanctioning Committee (PISC), 2019
Reserve Bank of India (RBI)	Money, data	-
State and joint electricity regulatory commissions (SERCs & JERCs)	Electrons, money, data	EV - A New Entrant to India's Electricity Consumer Basket, 2020
State nodal agencies (SNA)	Data	-
NITI Aayog	Data	NITI Aayog – National Mission on Transformative Mobility and Battery Storage, 2019 Consultation on Cutting-edge Charging Technologies, 2020
Bureau of Indian Standards (BIS)	Electrons, data	ETD 51 Standards List
Department of Science & Technology (DST)	Electrons, data	-

BODY	ELEMENT	RELEVANT DOCUMENTS
Ministry of Electronics and Information Technology (MeitY)	Data	The Information Technology Act, 2000 The Personal Data Protection Bill, 2019
National Automotive Board (NAB)	Data	Deployment of EV Charging Infrastructure in Cities, 2019 Press Release for 2636 EV Charging Stations Sanctioned under Fame – II, 2020 Press Release for Additional eBuses & Charging Stations under FAME-II, 2020 Deployment of EV Charging Infrastructure on Highways and Expressways, 2020
Ministry of Housing and Urban Affairs (MoHUA)	Data	Amendments in Model Building Bye-Laws, 2019 Amendments in Urban and Regional Development Plans Formulation and Implementation Guidelines (URDPFI, 2014), 2019
State governments	Data	All states with EV Policies

Source: CEEW-CEF analysis

Figure A13 Public charging points in Europe



Source: CEEW-CEF analysis

Annexure 2: EV Roaming in other markets

It is important to note that EV roaming is not a new phenomenon, and it has been introduced in multiple forms in over 45 countries, including China, Norway, USA, and the Netherlands. Each of these markets can be considered as an example for us. And while each EV market differs in its approach to EV roaming – some implementing it nationally and others sub-nationally – the strong correlation between roaming and the growth of EV charging is unmissable.

Netherlands

As the country with the highest public charging point density (Netherlands Enterprise Agency 2020), it is no surprise that Netherlands is the birthplace of EV roaming. Given that 7 out of 10 Dutch households rely on public parking (Netherlands Enterprise Agency 2020), a trend that makes for a high reliance on public charging, EV roaming has been possible in the Netherlands ever since 2011. This is when the Dutch government introduced the Central Interoperability Register (CIR) – allowing EV drivers to charge at stations across the country using a single card or token (Ferwerda et al. 2018). In 2012, e-Violin took over this database and ensured national roaming in the country. In November 2020, 28 per cent of all new passenger vehicle registrations in the Netherlands were electric (Netherlands Enterprise Agency 2020). A country that started with only 400 charging points in 2010 now has nearly 62,000 charging points.

One of the key lessons from the Netherlands is the need for public–private partnership in EV roaming. By giving all stakeholders a voice and stake through non-profits such as NKL and ElaadNL, the Netherlands' success shows the importance of collaboration. Another important focus in the Netherlands is price transparency to make sure users are aware of the total cost of charging before, during, and after charging.

Portugal

The first nationwide attempt at creating a fully interoperable public charging network was seen in Portugal. In 2008, MOBI.E, an electric mobility network developed by the Portuguese think tank INTELLI, aimed to establish an all-inclusive network of chargers across 21 municipalities (Energy Cities 2016). The MOBI.E model achieved full interoperability of charging infrastructure components, mobility service providers, and the electric grid management system. All charging operators in Portugal connect to the MOBI.E network, which then operates like a roaming hub. No bilateral agreements between parties are allowed. EV users can use their RFID cards or the MOBI.E mobile application to charge at any station, supplied by any retailer across the country. The payment process is relatively convenient for users. While the MOBI.E portal provides CPOs and MSPs with payment gateways, service providers are also free to use their own.

Portugal is an example of how strong government control can bake EV roaming into the design of public charging from the get go.Portugal's charging network grew by nearly 95 per cent, from 1080 charging points at the end of 2011 to more than 2,100 points in 2020. A network that started with three major CPOs now has eight along with an EV:PCS ratio of nearly 28:1.

Norway

Norway is a global leader in the EV transition, with EVs overtaking ICE vehicle sales in 2020. In 2009, the Norwegian government initiated an effort to launch a nationwide network of public chargers. Given that most passenger EVs in the country are charged at home, policymakers looked at ways to maximise the benefits of the established public network. Transnova – a Norwegian state entity – and the Norwegian EV Association created a publicly available EV charger database called NOBIL. This database contains real-time information on the availability as well as location of chargers. The websites and phone numbers of each charging station are available for users to make reservations.

As the Norwegian market is skewed towards home charging, their efforts to remove friction in accessing public charging comes as no surprise. In lieu of direct participation in EV roaming, the government has indirectly strengthened the weakest link in the EV charging space.

France

France has government-mandated interoperability and roaming. All government-supported charging stations in France >36 kVA must compulsorily connect to the GIREVE roaming hub. This platform allows users to access to information on location and availability, booking services, as well as charger features. This carrot approach has allowed France to build a sizeable roaming network for EV users, while at the same time giving private charging companies the flexibility to opt out in case public resources are used.

Germany

Germany is the birthplace for Hubject – the largest roaming hub in the world. Germany has an extremely fragmented public charging market, with hundreds of community utilities providing charging services in their limited zones of operation. Germany is also a global tour-de-force in the automotive industry, with a variety of companies entering the CPO space. A number of these companies have banded together to form Hubject, whose hub approach has overcome the downsides of market fragmentation to offer one of the most robust roaming networks in the world.

California

Within the US, California's EV market is head and shoulders above the rest of the country in terms of EV adoption. The California Air Resources Board (CARB) has proposed legislation to improve the accessibility of public charging by facilitating roaming agreements in the state. It is the first market to undertake a public–private consultation exercise to select suitable roaming protocols and has proposed OCPI and OICP for adoption (State of California Air Resources Board 2019). Additionally, a complete database of charging stations with information about their location and pricing is to be created. EV roaming will also solve inconsistent pricing formulas, make public charging accessible to everyone, and include ad-hoc payment options. Home to nearly 62,000 charging stations, California's efforts represent an attempt to bring standardisation and homogeneity to its sizeable charging sector.

Annexure 3: CEA's database of public charging stations

State	Public charging stations
Delhi	78
Haryana	1
Himachal Pradesh	12
Uttarakhand	2
Chhattisgarh	1
Gujarat	3
Madhya Pradesh	3
Maharashtra	72
Andhra Pradesh	433
Karnataka	126
Kerala	2
Telangana	160
Jharkhand	26
West Bengal	7
Assam	1
Others	7
Total	934

Source: CEEW-CEF compilation based on (Central Electricity Authority 2020)

Annexure 4: OCPI factsheet

Launched in 2015 through a collaboration between ElaadNL – an association of Dutch grid operators and eViolin – an association of Dutch CPOs and MSPs, the Open Charge Point Interface protocol is currently managed by NKL. This protocol is available to users without any registration and free of charge. OCPI has an open community based development process and considers all users' feedback. Parties are free to select specific models which they wish to incorporate. This protocol supports both synchronous and asynchronous data exchange.

Governance factors	
Transparency	High
Openness	Medium – high
Impartiality and consensus	Medium – high
Effectiveness and relevance	High
Coherence	High
Development dimension	Medium

Source: CEEW-CEF analysis based on Kam, Mart van der, and Rudi Bekkers. 2020. "Comparative Analysis of Standardized Protocols for EV Roaming."

Functionalities	
Roaming via hub	Yes
Roaming peer-to-peer	Yes
Ad-hoc payment	No
Authorisation	Yes
Reservation	Yes
Billing	Yes
Static charge point information	Yes
Real time charge point information	Yes
Smart charging	Yes
Platform monitoring	Yes
Remote start-stop	Yes

Source: CEEW-CEF analysis based on Kam, Mart van der, and Rudi Bekkers. 2020. "Comparative Analysis of Standardized Protocols for EV Roaming."

OCPI around the world

Conversations with several European market participants have confirmed that hubs such as GIREVE have implemented OCPI as their protocol of choice

The California Air Resource Board (CARB) in 2019 noted that OCPI and OICP were evaluated on market acceptance, future standardisation, open usability and on their various features. This evaluation found that OCPI had greater market acceptance domestically and highlighted its use as the communications protocol of choice. This was because it was freely available for market use and did not prevent future inclusion of other protocols.

The Delhi Transco Limited in collaboration with the Dialogue and Development Commission (DDC) of Delhi mandated the use of OCPI 2.0 for charger-to-charger communication in Delhi in 2021.

OCHP, OCPI, OICP and eMIP can be compared as follows:

	OCHP	OCPI	OICP	eMIP
Identification	High	High	High	High
Authorisation	Medium-high	High	High	High
Recording charge session information	Medium-high	High	Medium	Medium-high
Billing	High	High	High	High
Quality control	High	High	High	High
Open standard	Medium	Medium-high Expected – High	Medium	Low
Business model agnostic	High	High	Medium	Medium

Source: CEEW-CEF analysis based on Kam, Mart van der, and Rudi Bekkers. 2020. "Comparative Analysis of Standardized Protocols for EV Roaming."

References

Arora, Bhanvi. 2018. "India Says Never Targeted 100% Electric Mobility By 2030, Scales Down Aim." *Bloomberg Quint*, 2018. https://www.bloombergquint.com/business/india-says-never-targeted-100-electric-mobility-by-2030-scales-down-aim.

Bureau of Indian Standards. n.d. "ETD 51: Electrotechnology in Mobility." Accessed March 11, 2021. https://www.services.bis.gov.in:8071/php/BIS/PublishStandards/published/standards?commttid=Mzc5.

Castrol. 2020. "ACCELERATING THE EVOLUTION: The Tipping Points to Mainstream Electric Vehicle Adoption." https://www.castrol.com/content/dam/castrol/master-site/en/global/home/technology-and-innovation/electric-vehicle-adoption/accelerating_the_evolution_study.pdf.

CEEW-Centre for Energy Finance. n.d. "Electric Mobility Dashboard." Accessed March 11, 2021. https://cef.ceew.in/solutions-factory/tool/electric-mobility.

Central Electricity Authority. 2020. "Details of EVCS/ PCI as on 30th June 2020 under the Jurisdiction of Discoms/ Licensee/ PSUs." https://www.cea.nic.in/reports/monthly/ev/2020/ev-06.pdf.

ChargeUp Europe. 2020. "OCPI Enabling Electric Vehicle (EV) Roaming." 2020. https://static1.squarespace.com/static/5e4f9d80c0af800afd6a8048/t/5fbba8e8a4ebbd103bd85f65/1606133995768/Brochure_OCPI_A4_2.pdf.

Das, Shyamasis, and Bhawna Tyagi. 2020. "EV- A New Entrant to India's Electricity Consumer-Basket." New Delhi. https://shaktifoundation.in/wp-content/uploads/2020/08/Full-Report-A-New-Entrant-To-Indias-Electricity-Consumer-Basket.pdf.

Department of Heavy Industries. 2019. "Expression of Interest Inviting Proposals for Availing Incentives under Fame India Scheme Phase II For Deployment of EV Charging Infrastructure within Cities." https://dhi.nic.in/writereaddata/UploadFile/EOI for EV charging in cities 12 july.pdf.

EESL. 2020. "Setting up of Public Charging Stations for Electric Vehicles." 2020.

ElaadNL. 2017. "EV Related Protocol Study Version 1.0."

Electric Power Research Institution. 2019. "Interoperability of Public Electric Vehicle Charging Infrastructure." https://www.eei.org/issuesandpolicy/electrictransportation/Documents/Final Joint Interoperability Paper.pdf.

Energy Cities. 2016. "MOBI.E - E-Mobility Network." 2016. https://energy-cities.eu/best-practice/mobi-e-e-mobility-network/.

European Commission. n.d. "Mobility and Transport - National Access Points." Accessed March 11, 2021. https://ec.europa.eu/transport/themes/its/road/action_plan/nap_en.

EVReporter. 2019. "List of Top EV Charging Solution Providers in India." 2019. https://evreporter.com/ev-charging-solution-providers-in-india.

Ferwerda, Roland, Michel Bayings, Mart van der Kam, and Rudi Bekkers. 2018. "Advancing E-Roaming in Europe: Towards a Single 'Language' for the European Charging Infrastructure." *World Electric Vehicle Journal*.

GOI. 2019. "The Personal Data Protection Bill." http://164.100.47.4/BillsTexts/LSBillTexts/Asintroduced/373_2019_LS_Eng.pdf.

IEMF, and BSES Rajdhani Power Limited. 2020. "Consumer Insights for Electric Vehicle Charging Programs - Delhi : Consumer Perception and Behaviors Will Determine the Success of EV Charging Facilities." https://www.bsesdelhi.com/documents/55701/1364780682/BSES_EV_consumer_insights.pdf.

IHS Markit. 2019. "EV Charging Roaming Interoperability to Play a Major Role in Pushing EV Adoption." https://ihsmarkit.com/research-analysis/ev-charging-roaming-interoperability-to-play-a-major-role.html.

Invest India. n.d. "Automobile Sector in India." Accessed March 11, 2021. https://www.investindia.gov.in/sector/automobile.

Kam, Mart van der, and Rudi Bekkers. 2020. "Comparative Analysis of Standardized Protocols for EV Roaming." https://evroaming.org/app/uploads/2020/06/D6.1-Comparative-analysis-of-standardized-protocols-for-EV-roaming.pdf.

Kam, Mart van der, and Rudi Bekkers. 2020. "Design Principles for an 'Ideal' EV Roaming Protocol." https://pure.tue.nl/ws/portalfiles/portal/151710081/D6.3_Design_principles_for_an_ideal_EV_roaming_protocol.pdf.

Kumar, Parveen, and Chaitanya Kanuri. 2020. "Total Cost of Ownership of Electric Vehicles: Implications for Policy and Purchase Decisions." *WRI India*. https://wri-india.org/blog/total-cost-ownership-electric-vehicles-implications-policy-and-purchase-decisions.

Ministry of Heavy Industries and Public Enterprises. 2019. "Scheme for Faster Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME India Phase II)." https://fame2.heavyindustry.gov.in/content/english/11_1_PolicyDocument.aspx.

Ministry of Power. 2019a. "Charging Infrastructure for Electric Vehicles (EV) - Revised Guidelines & Standards - Reg." New Delhi. https://powermin.gov.in/sites/default/files/uploads/Revised_MoP_Guidelines_01_10_2019.pdf.

Ministry of Power. 2019b. "Furnishing of Information on Public Charging Station (PCS) for Electric Vehicles by DISCOMS to the Central Electricity Authority - Reg."

Mültin, Marc. 2018. "The Road to IEC 63110 and How You Can Impact the International Standard." *V2G Clarity*. https://v2g-clarity.com/blog/the-road-to-iec-63110-and-how-you-can-impact-the-international-standard/.

NDMC. n.d. "Details of AC and DC Charging Stations for Electric Vehicles at Various Locations in NDMC Area." Accessed March 11, 2021. https://www.ndmc.gov.in/Details of AC and DC Charging Stations for Electric Vehicles at various locations in NDMC Area.pdf.

Netherlands Enterprise Agency. 2019. "Electric Vehicles Charging: Definitions and Explanation."

Netherlands Enterprise Agency. 2020. "Statistics Electric Vehicles in the Netherlands."

NITI Aayog, and Rocky Mountain Institute. 2019. "India's Electric Mobility Transformation: Progress to Date and Future Opportunities." https://rmi.org/insight/indias-electric-mobility-transformation/.

Paulraj, Pon. 2020. "EV-ROAMING BASICS 102: Know about Different Roaming Protocols – OCPI, OICP, OCHP & EMIP." 2020. https://www.emobilitysimplified.com/2020/08/ev-roaming-protocol-differences-OCPI-OICP-OCHP-eMIP.html.

Sabir, Aaisha. 2020. "EV Policy: Govt Ties up with IIIT for App to Look up Charging Stations." *Millenium Post*. http://www.millenniumpost.in/delhi/ev-policy-govt-ties-up-with-iiit-for-app-to-look-up-charging-stations-427152.

Singh, Parmeet. 2020. "What Would Make Indians Buy EVs? Our Survey Has Some Answers." *TERI*. https://www.teriin.org/blog/what-would-make-indians-buy-evs-our-survey-has-some-answers.

Soman, Abhinav, Harsimran Kaur, and Karthik Ganesan. 2019. "How Urban India Moves: Sustainable Mobility and Citizen Preferences." *Council on Energy, Environment and Water*. https://www.ceew.in/sites/default/files/CEEW - How Urban India Moves Report PDF 22Oct19_compressed.pdf.

State of California Air Resources Board. 2019. "PUBLIC HEARING TO CONSIDER ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) STANDARDS." https://ww3.arb.ca.gov/regact/2019/evse2019/isor.pdf?_ga=2.18163257.1666963589.1617216568-694201987.1617216568.

WBCSD. 2020. "Advancing Electrification of Ride-Hailing in India: A BluSmart Case Study." http://www.indiaenvironmentportal.org.in/files/file/Advancing-electrification-of-ride-hailing-in-India_final.pdf.

Interoperability and EV roaming seem like the obvious next steps to catalyse India's electric mobility transition.

Image: iStock

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

Sanskrit Bhawan, A-10, Aruna Asaf Ali Marg
Qutab Institutional Area
New Delhi 110 067, India
T: +91 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia | ceewIndia

eDRV B.V.

Cannenburg 22, 1081 GZ
Amsterdam, The Netherlands
T: +31 649 055 662

hello@edrv.io | edrv.io | @eDRVio