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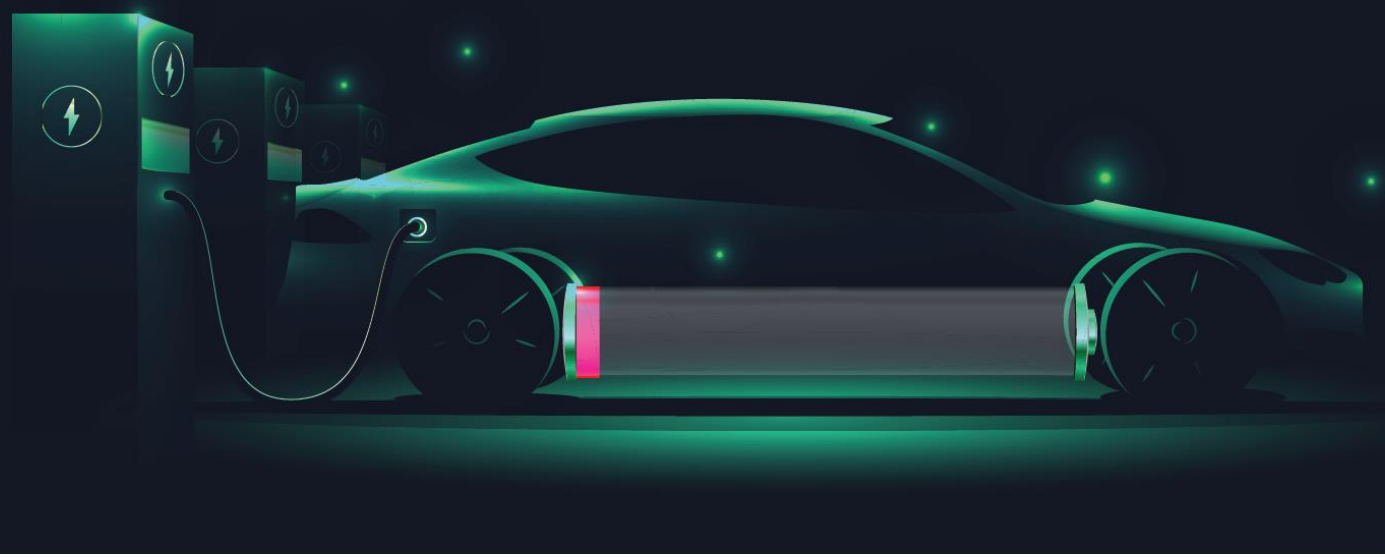
On behalf of:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

of the Federal Republic of Germany

Electric vehicle charging infrastructure and its grid integration in India

Status quo, Critical analysis and Way Forward



Prof. Zakir Rather,

IIT Bombay

FSR GLOBAL Regulatory Knowledge Hub

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International Transport Forum

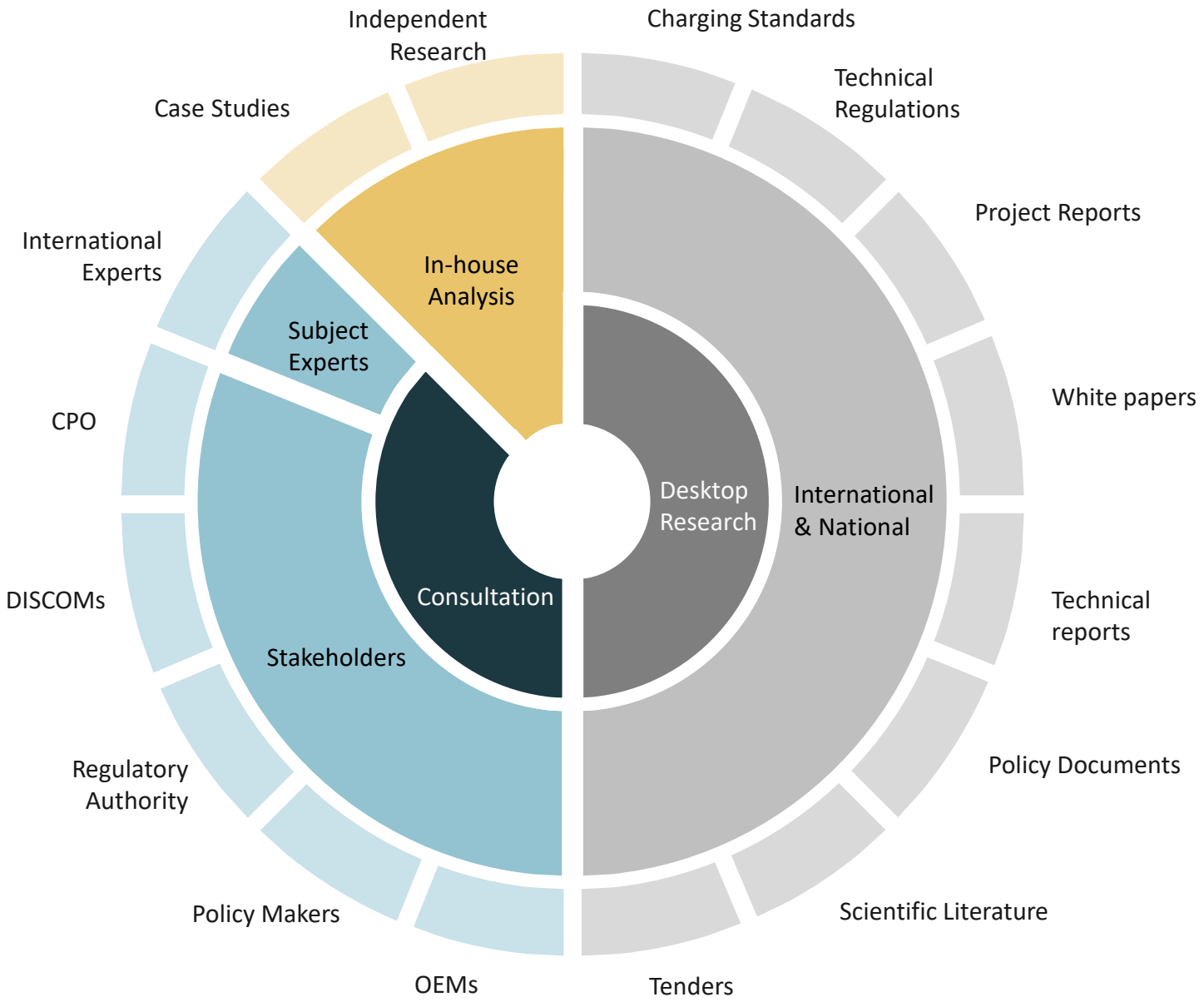
SLOCAT Partnership on Sustainable, Low Carbon Transport

Agora Verkehrswende

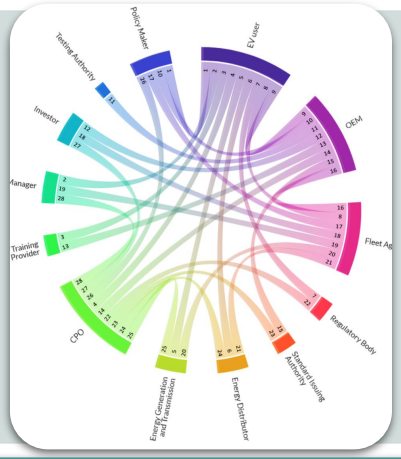
REN21

NDC TRANSPORT INITIATIVE FOR ASIA

Methodology used

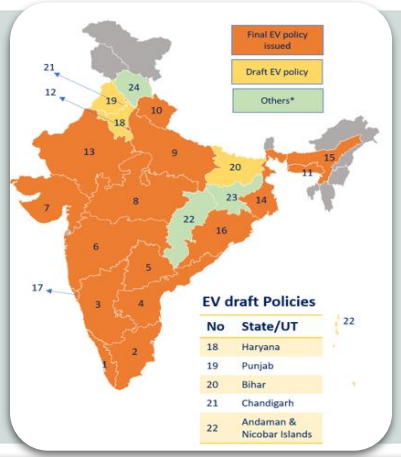


Broader Topics Covered in The Report



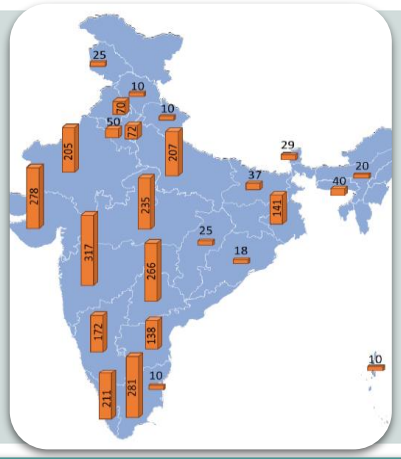
Stakeholders in Indian EV Ecosystem

- OEM
- CPO
- Fleet Aggregators
- Policy Maker
- Standard Issuing Authority
- Energy Distributor
- TSO
- EV Training Providers
- Payment Service Providers
- Investors
- Testing Authority



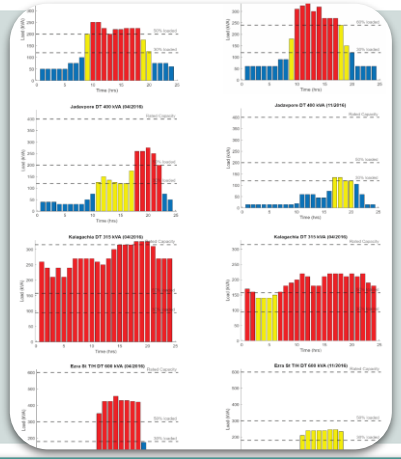
EV Policies and Regulations

- Journey of Indian Electric mobility sector
- National EV schemes and policies
- Comparative analysis of state EV policies
- EV regulations in India
- EV tariff landscape
- Building Bye-Laws



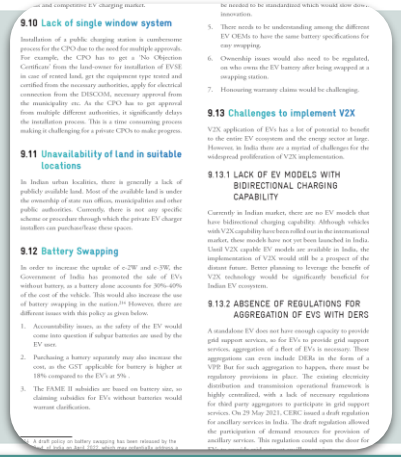
Status Quo

- National EV statistics
- State-wise EV statistics
- EV charging infrastructure status
- EV models in Indian market



Grid Integration of EV

- Status of EV integration in EV rich states
- Impacts of EV integration on the Indian distribution system
- Mitigation of EV integration impacts
- Comparative analysis between Fast Charging and Slow Charging
- Critical analysis of tenders on EV charging infrastructure in India.
- Economic analysis of EV charging infrastructure integration



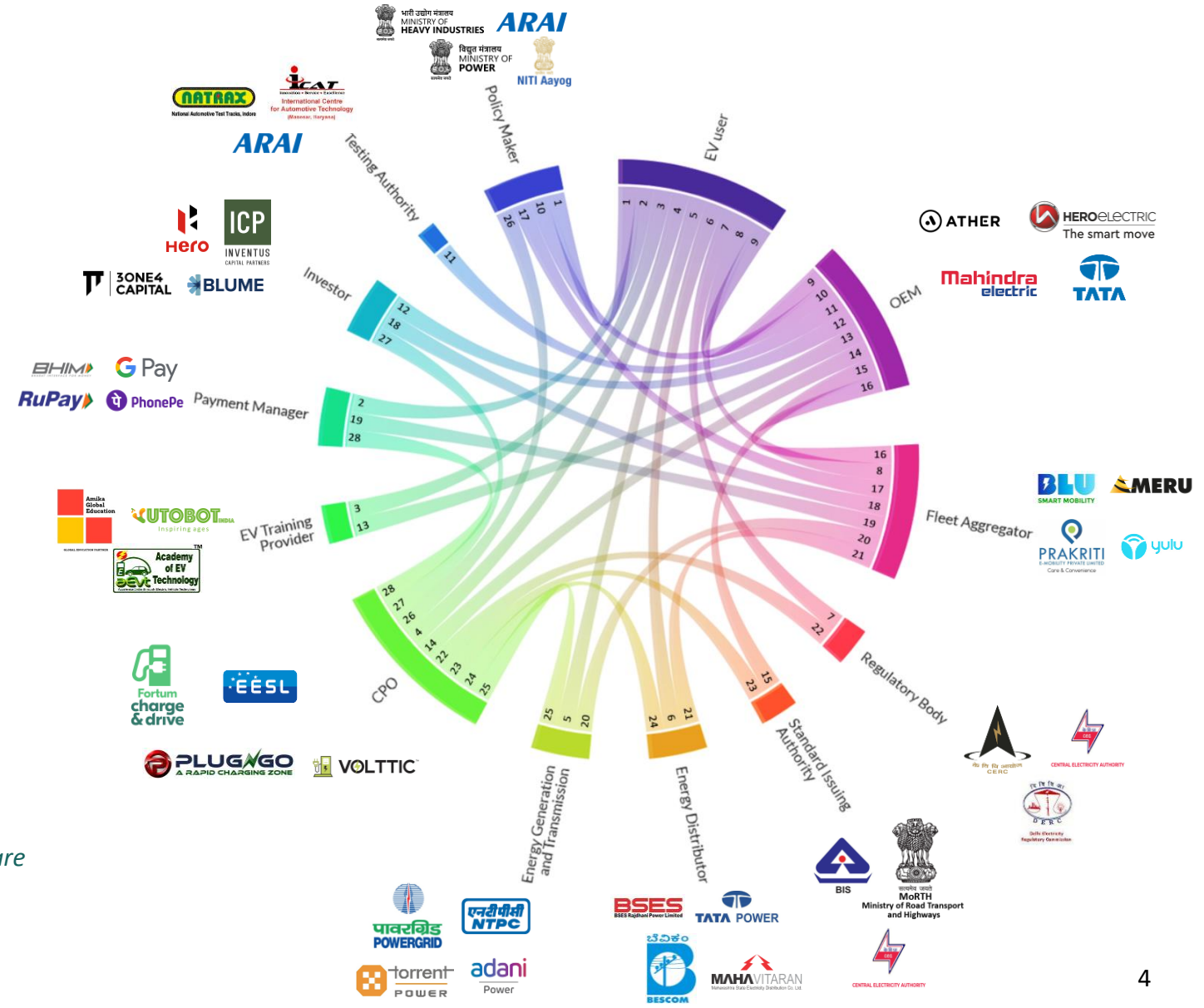
Gap Analysis in EV charging infrastructure

- Policy and regulatory gaps
- Challenges in developing charging infrastructure
- Challenges in communication infrastructure
- Challenges in smart charging
- Challenges in RE based EV charging
- Challenges in Interoperability
- V2G challenges

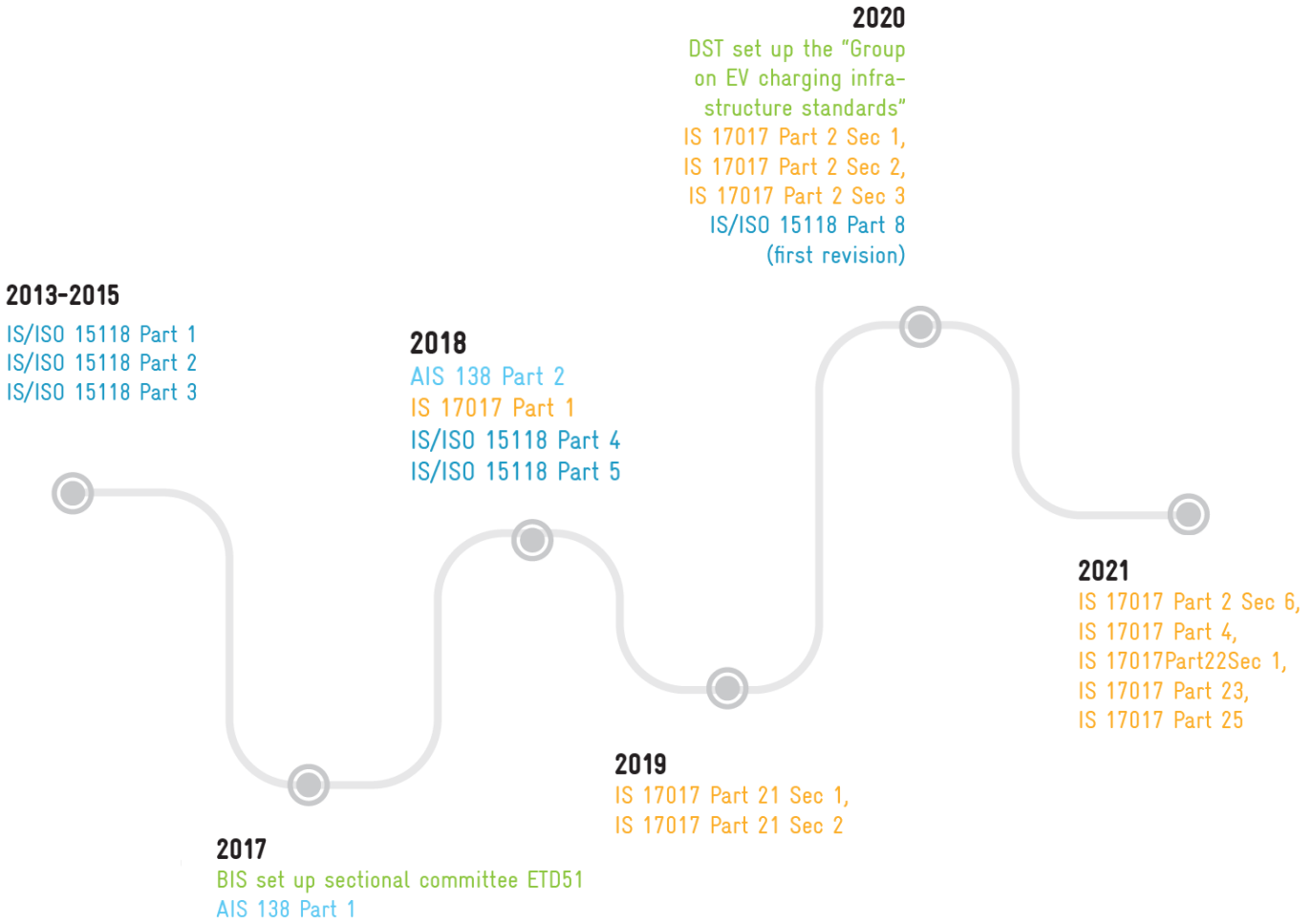
Stakeholder relationship in Indian EV ecosystem

1.	EV incentive policies
2.	Payment for EV charging at CPO
3.	Provision of EV O&M services
4.	EV public charging
5.	EV participation in grid support services
6.	EV participation in grid support services
7.	Regulation for installation of private EV charger
8.	Fleet aggregators as EV user
9.	EV and EV charger manufactured by OEMs
10.	Policies for OEMs
11.	Manufactured units tested by testing authority
12.	Investors required for setting up of new OEMs
13.	Skilled workforce required in OEMs
14.	CPOs purchase EV chargers from OEMs
15.	OEMs manufacture units as per issued standards
16.	Fleet aggregators purchase EVs from OEMs
17.	Favourable policies for fleet aggregators
18.	Investors required for creation of fleet aggregators
19.	Payment for utilization of fleet aggregator services by user
20.	Participation of fleet aggregator in grid support services
21.	Participation of fleet aggregator in grid support services
22.	Regulations for CPOs
23.	Standards for CPOs
24.	Participation of CPO in grid support services
25.	Participation of CPO in grid support services
26.	Policies for CPOs
27.	Investment needed for CPOs
28.	Payment manager utilized by CPOs

The stakeholder names are only provided as an example. Many more stakeholders are present than the ones shown here.



EV Charging standards in india



DHI under MoHIPE also introduced 2 chargers for the Indian market

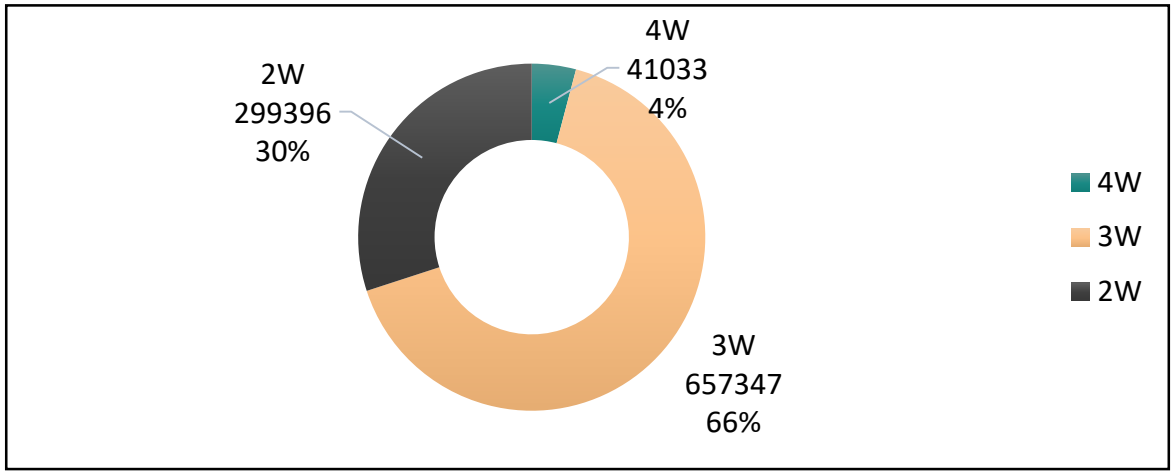
- **Bharat AC001**
- **Bharat DC001**

The Indian EV market is now moving towards the BIS standards

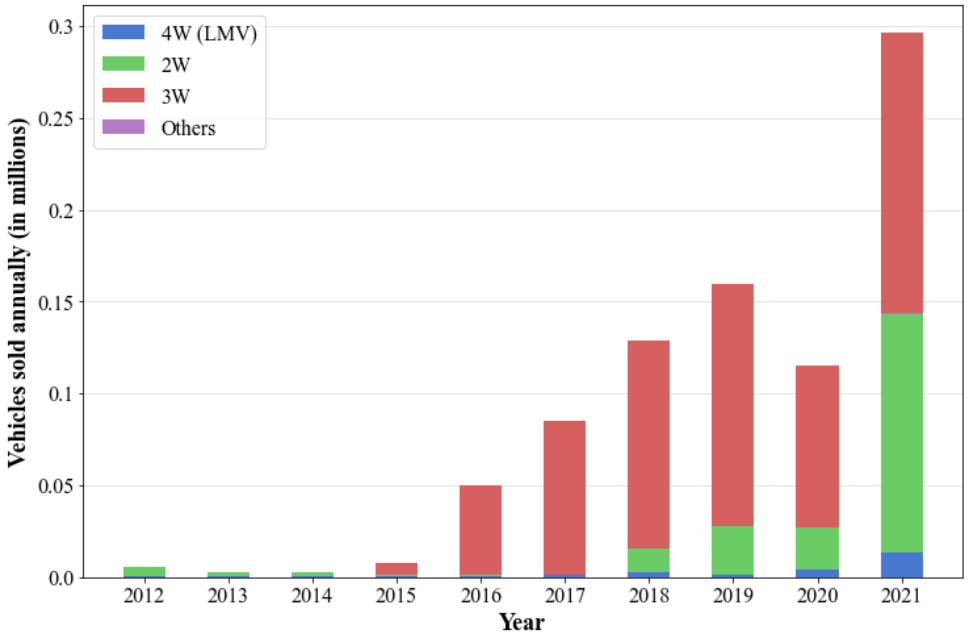
Indian EV Market Statistics

- There are **10,00,495** EVs in India by Feb 2022.
- The BEV market in India only accounts for **0.36%** of total registered vehicles
- Majority of EVs are 2W or 3W till Feb 2022.

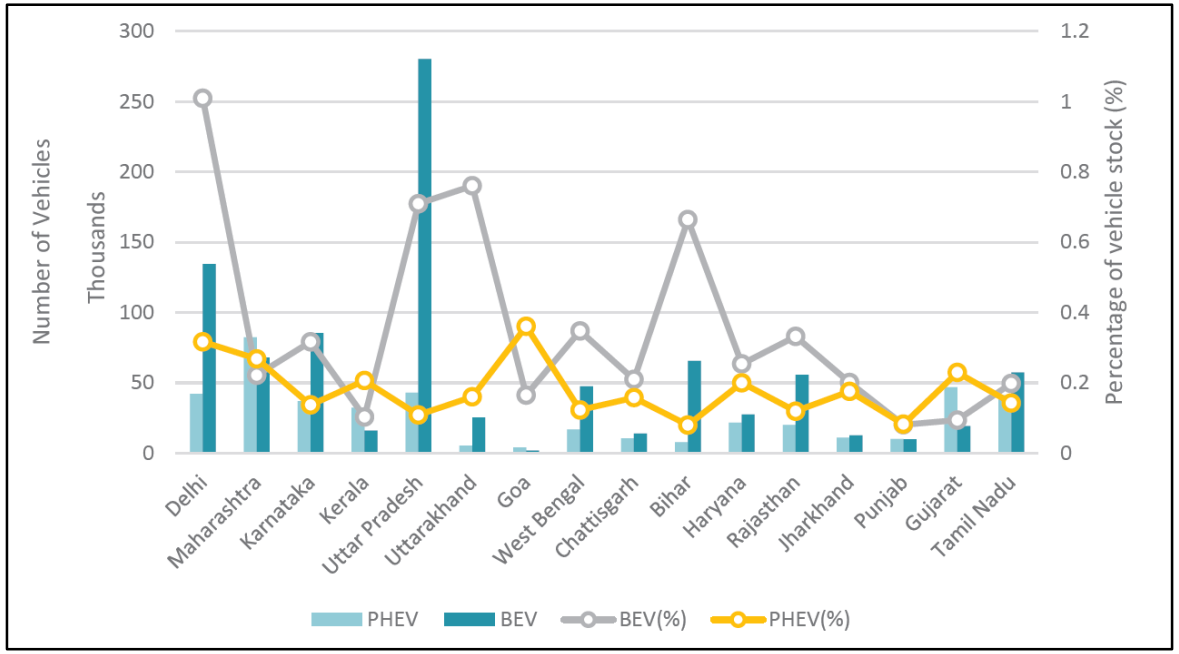
Sector wise categorization of total BEVs in India till Feb 2022



Growth of EV market in India

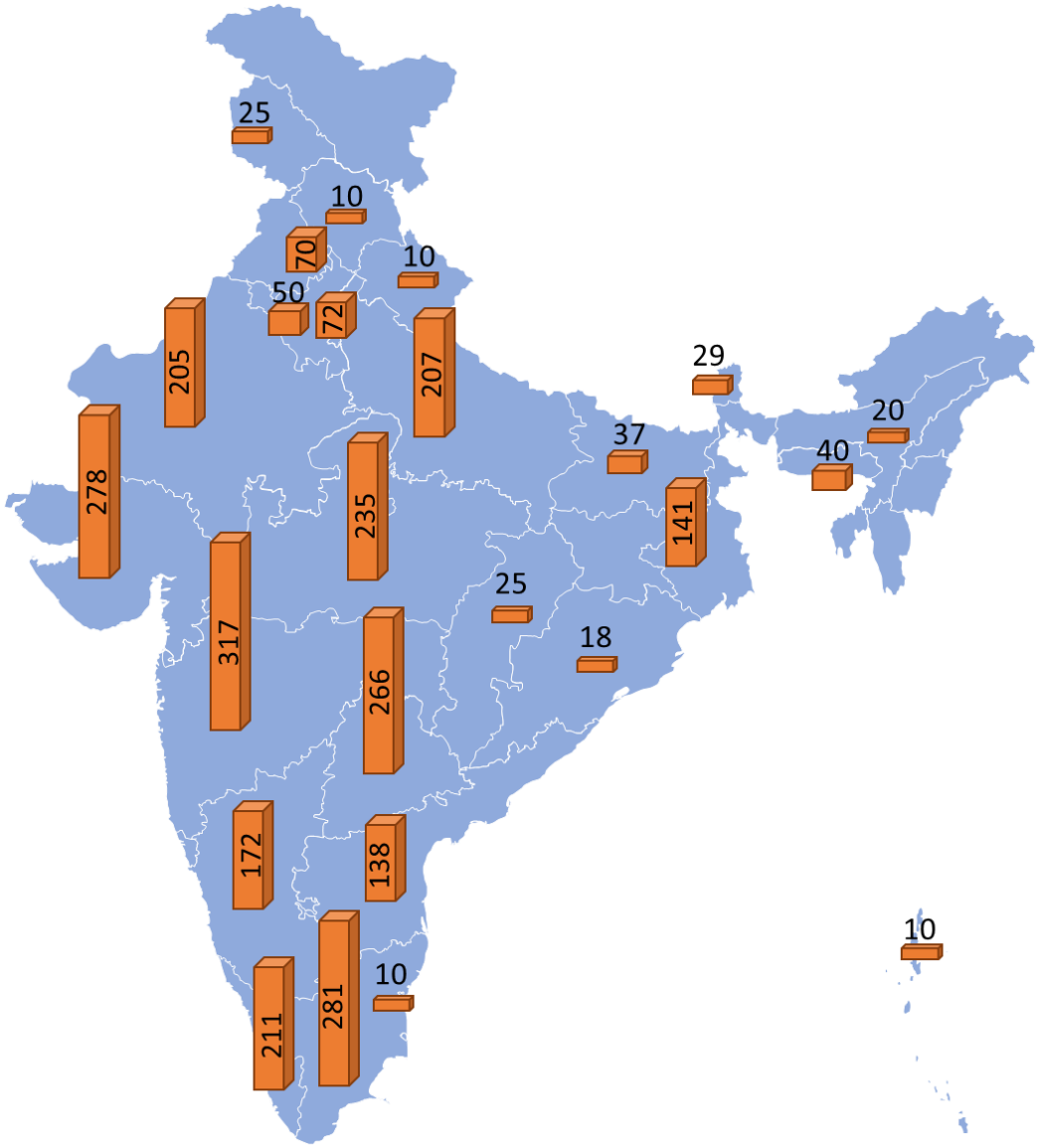


Market status of BEV and PHEV in different states in India till Feb 2022



Charging Infrastructure in India

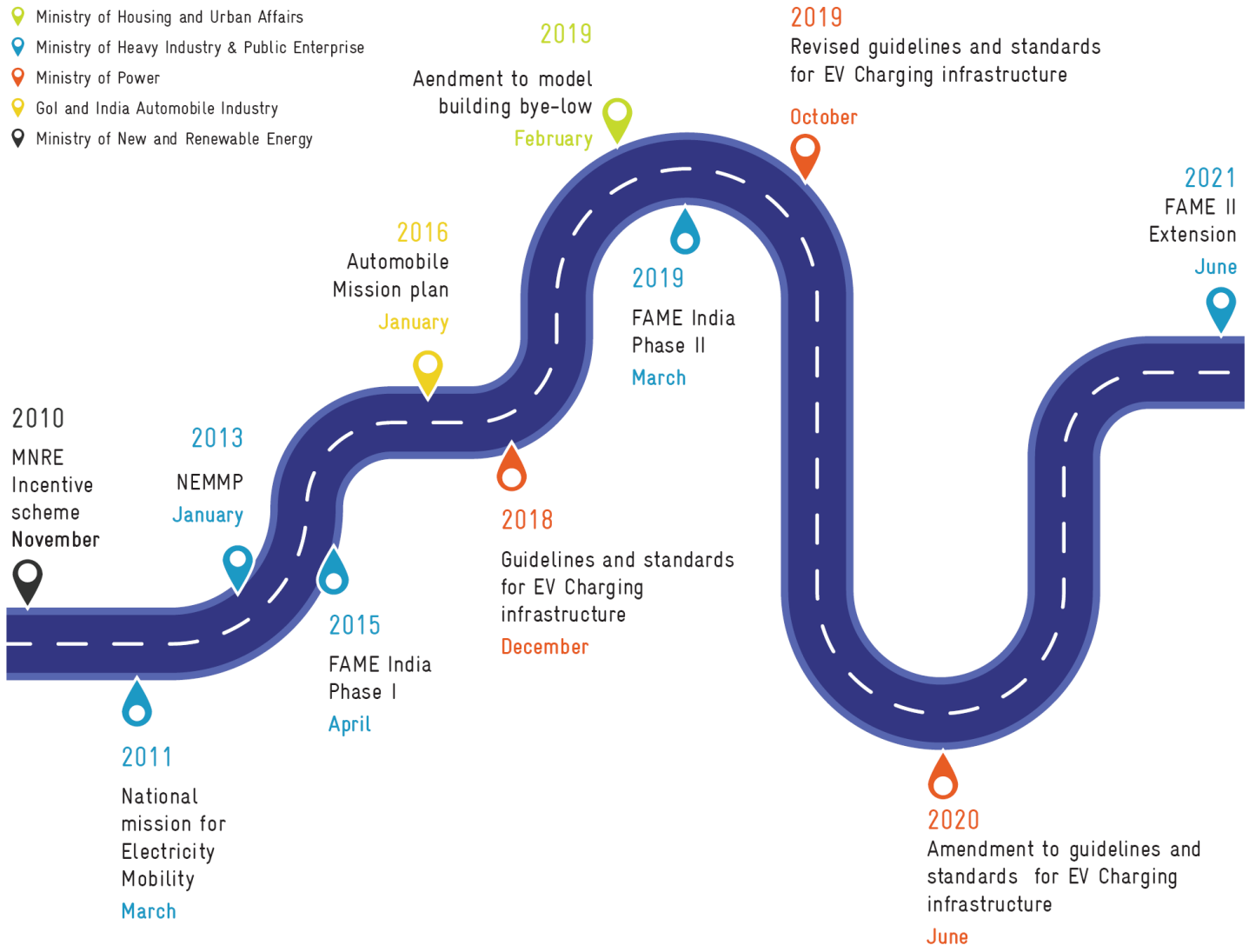
- As of May 2022, Ministry of Heavy Industries have sanctioned **4973 charging stations under FAME scheme.**
- Till Q1 2021, a total of 4305 chargers have been installed in India by different owners and charge point operators
- Few private players have also been active in the charging infrastructure space in India such as Fortum, Magenta Power, PlugNGo, TATA Power



Allotted number of charging stations under FAME II scheme

Policy Roadmap

- National Electric Mobility Mission Plan (NEMMP) 2020, first major scheme for promotion of eMobility in India.
- Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) is the flagship scheme of the central government.



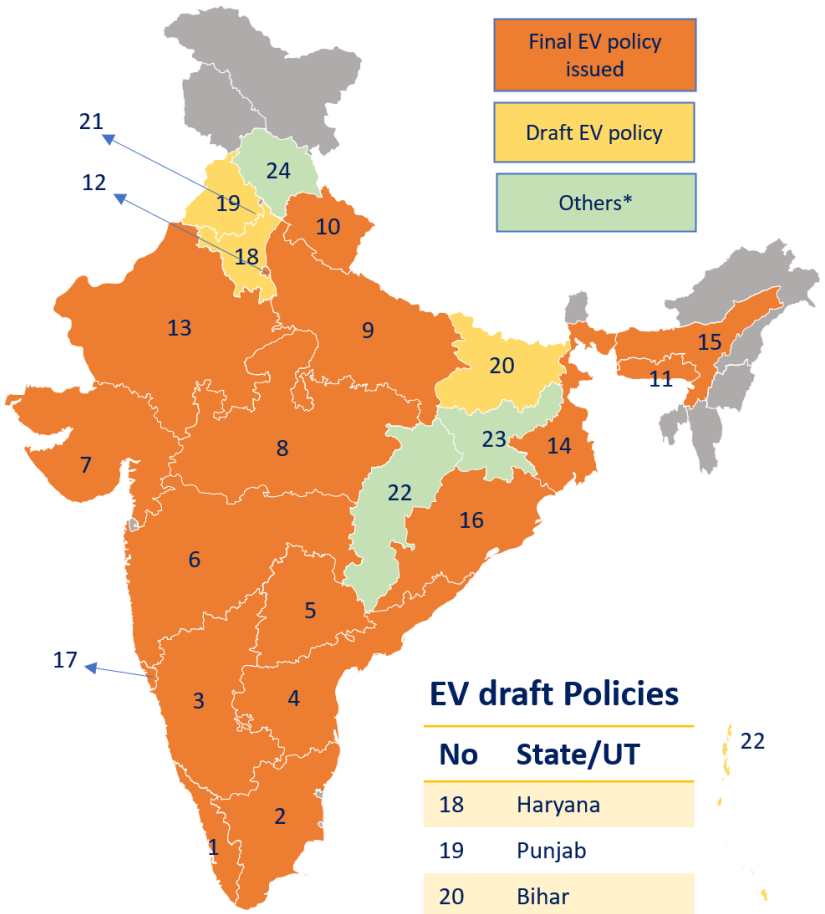
State policies

- EV state policies have been released by **17 states up to Feb 2022**.
- 5 states have released draft EV policies

Since Feb 2022,

- Haryana finalized its EV policy
- Chhattisgarh launched its EV policy
- Arunachal Pradesh released its draft EV policy

No	State/UT	Title of Policy issued and year
1	Kerala	**Kerala Electric Vehicle Policy 2019**
2	Tamil Nadu	**Tamil Nadu Electric Vehicle Policy 2019**
3	Karnataka	**Karnataka Electric Vehicle & Energy Storage Policy 2017**
4	Andhra Pradesh	**Andhra Pradesh Electric Mobility Policy 2018-23**
5	Telangana	**Telangana EV ESS Policy 2020-2030**
6	Maharashtra	**Maharashtra State Electric Vehicle Policy 2021**
7	Gujarat	**Gujarat State Electric Vehicle Policy 2021**
8	Madhya Pradesh	**Madhya Pradesh Electric Vehicle Policy 2019**
9	Uttar Pradesh	**Uttar Pradesh Electric Vehicle Policy 2019**
10	Uttarakhand	**Uttarakhand Electric Vehicle Policy 2018**
11	Meghalaya	**Meghalaya Electric Vehicle Policy 2021**
12	Delhi	**Delhi Electric Vehicle Policy 2019**
13	Rajasthan	**Rajasthan Electric Vehicle Policy ***
14	West Bengal	**West Bengal Electric Vehicle Policy 2021**
15	Assam	**Electric Vehicle Policy of Assam 2021**
16	Odisha	**Odisha Electric Vehicle Policy 2021**
17	Goa	**Goa Electric Mobility Promotion Policy 2021**

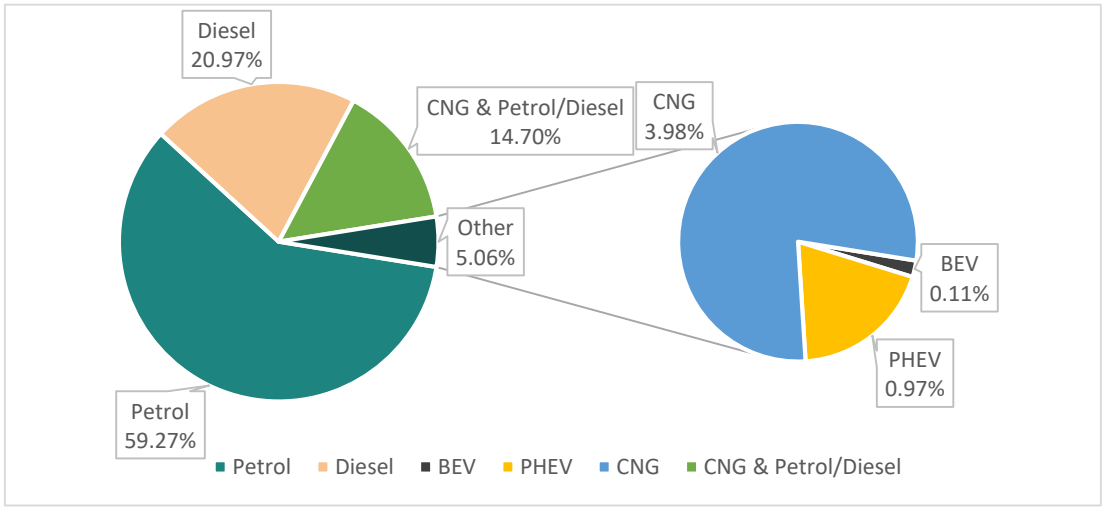


EV draft Policies

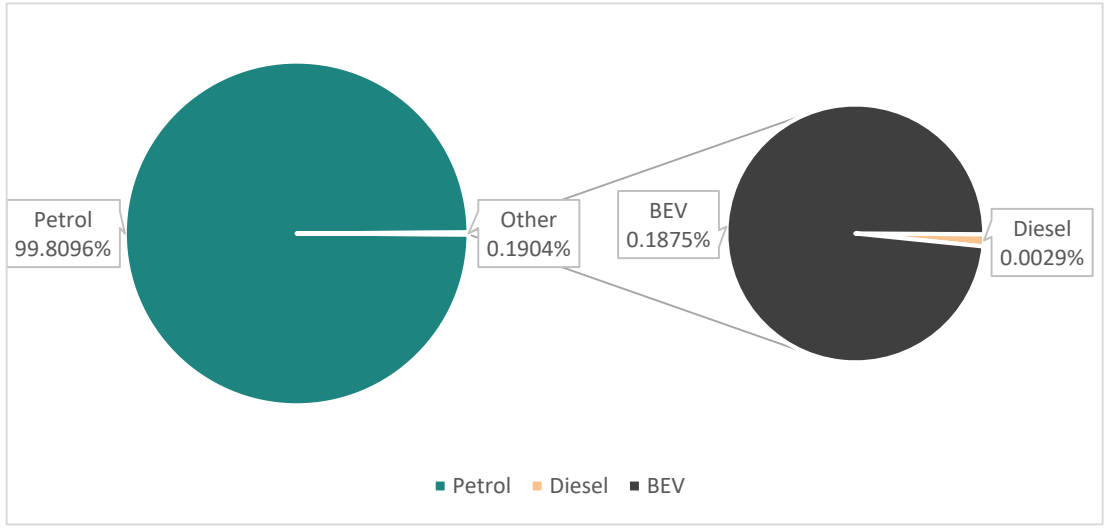
No	State/UT
18	Haryana
19	Punjab
20	Bihar
21	Chandigarh
22	Andaman & Nicobar Islands

EV statistics - Delhi

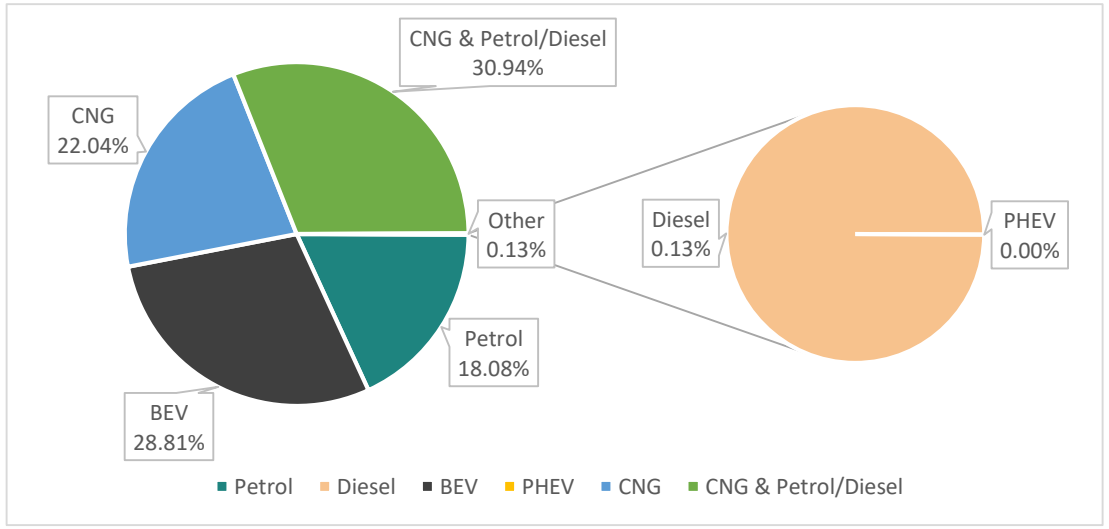
Share of total registered 4W in Delhi by fuel type (as of Feb 2022)



Share of total registered 2W in Delhi by fuel type (as of Feb 2022)



Share of total registered 3W in Delhi by fuel type (as of Feb 2022)



Detailed Analysis of state EV policy - Delhi

Key highlights in Delhi EV Policy

Limitations related to EV charging infrastructure in Delhi EV Policy

- Major focus have been to slow chargers.
- No mention of utilization of V1G or V2X capabilities and integration of RE for EV charging
- Consideration of digital platforms for database management, addressing of consumer complaints, is lacking.

Comparative Analysis of State EV Policies

	Target of Charging network (# of chargers or density)	Support for grid upgradation	Conducive market for participation of private players	Financial incentives			Facilitation of affordable and accessible land	Support for battery swapping	Focus on RE integration for EV charging	Infrastructural recommendations (modification of building bye laws/ parking spaces reserved for EV charging etc)
				Home/ workspace chargers	Public chargers	Energy operators				
Delhi	✓	×	✓	✓	#	✓	✓	✓	✓	✓
Karnataka	✓	×	✓	×	✓	✓	✓	✓	✓	✓
Maharashtra	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Andhra Pradesh	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kerala	✓	✓	✓	×	✓	✓	×	✓	✓	✓
Uttar Pradesh	✓	×	✓	×	✓	✓	✓	✓	×	✓
Gujarat	×	×	✓	×	✓	✓	×	✓	×	✓
Tamil Nadu	×	×	✓	×	✓	✓	✓	×	✓	✓
Madhya Pradesh	✓	×	✓	×	✓	✓	✓	✓	✓	✓
Uttarakhand	×	×	✓	×	×	×	✓	×	×	×
Telangana	✓	×	✓	×	×	×	✓	✓	✓	×
Meghalaya	×	×	✓	×	×	×	✓	×	×	×
West Bengal	✓	×	✓	×	✓	×	✓	✓	✓	✓
Assam	×	×	✓	×	✓	×	×	✓	×	×
Odisha	×	×	✓	✓	#	✓	✓	✓	×	✓
Goa	✓	×	✓	×	#	✓	✓	✓	✓	✓
Rajasthan	✓	×	✓	×	×	×	×	✓	✓	×

#: Subsidy on capital cost of charger installation expenses

EV Regulations in India

- Regulations on EV Charging
  - Regulations by CEA
    - Amendment to Technical Standards for connectivity of DG resources, issuing guidelines for connectivity of EV charging station below 33 kV voltage level – **February 2019**
    - Amendment to Measures relating to Safety and Electric Supply – **June 2019**
  - MoP Charging Infrastructure Guidelines
    - First Guidelines – **December 2018**
    - 1st revision – **October 2019**
    - 2nd revision – **January 2022**

Minimum control functionality requirements for EVs, Denmark

	A1	A2	B	C	D
Frequency Response (Over frequency)	✔	✔	✔	✔	✔
Frequency response (Under frequency)	-	-	-	✔	✔
Frequency control	-	-	-	✔	✔
Absolute power limit	✔	✔	✔	✔	✔
Ramp rate limit	✔	✔	✔	✔	✔
Q Control	✔	✔	✔	✔	✔
Power Factor Control	✔	✔	✔	✔	✔
Automatic Power Factor Control	✔	✔	-	-	-
Voltage Control	-	-	-	✔	✔

Category of Charging Stations

Category	Rated Power
A1	$x \leq 11\ kW$
A2	$11\ kW < x \leq 50\ kW$
B	$50\ kW < x \leq 1.5\ MW$
C	$1.5\ MW < x \leq 25\ MW$
D	$25\ MW < x$

"Technical regulation 3.3.1 for battery plants", Energinet.dk, 2017

MoP revised charging infrastructure guidelines

Key Highlights

- ❑ Owners may charge their EVs in their existing connection at residences/ workplaces/ offices
- ❑ DISCOMs to provide connection to PCS within 7 days in metro cities, 15 days in other municipalities and 30 days in rural areas, post submission of complete application.
- ❑ The tariff for supply of electricity to PCS shall be a single part tariff and not exceed the 'Average Cost of Supply' till 31st March, 2025.
- ❑ DISCOMs may leverage funding from Revamped Distribution Sector Scheme for the general upstream network upgradation requirements.

Standards specified for PCS

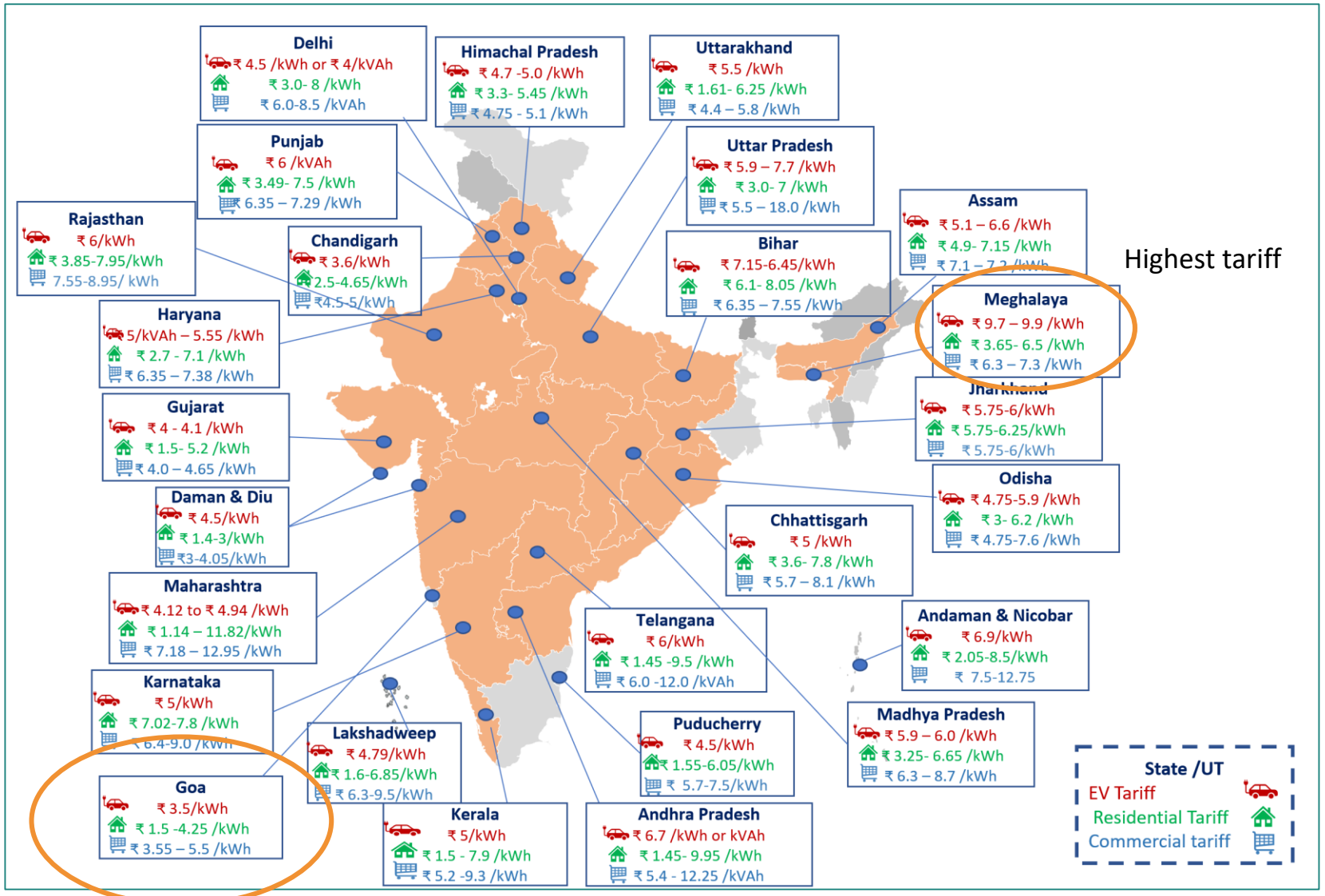
Charger Type	Charger Connectors*	Rated Voltage (V)	No. of connector Guns	Charging vehicle type (W-wheeler)
Fast	Combined Charging System (CCS) (min 50kW)	200-750 or higher	1 CG	4-W
	CHArge de Move CHAdeMO (min 50 kW)	200-500 or higher	1 CG	4-W
	Type 2 AC (min 22 kW)	380-415	1 CG	4-W, 3-W, 2-W
Slow/ moderate	Bharat DC-001 (15 kW)	48	1 CG	4-W, 3-W, 2-W
	Bharat DC-001 (15 kW)	72 or higher	1 CG	4-W
	Bharat AC-001 (10 kW)	230	3 CG of 3.3 kW each	4-W, 3-W, 2-W

- Light EV AC Charge Point (< 7 kW)
- Light EV DC Charge Point (< 7 kW)
- Parkbay AC Charge Point (11/ 22 kW)
- Parkbay DC Charge Point (50-250 kW)
- eBus Charging Station (250 – 500 kW)
- Dual Gun Charging Station
- Automated Pantograph Charging Station

EV tariffs

- As of 31st January 2022, a total of **20 states and 6 UTs** have announced EV specific tariffs

Two Part Tariff	Single Part Tariff
▪ Gujarat ▪ Haryana ▪ Karnataka ▪ Maharashtra ▪ Madhya Pradesh ▪ Kerala ▪ Rajasthan ▪ Himachal Pradesh ▪ Jharkhand ▪ Odisha ▪ Assam ▪ Meghalaya	▪ Andhra Pradesh ▪ Bihar ▪ Punjab ▪ Telangana ▪ Uttar Pradesh ▪ Chhattisgarh ▪ Uttarakhand ▪ Delhi ▪ Goa ▪ Chandigarh ▪ Andaman & Nicobar ▪ Daman & Diu ▪ Lakshadweep ▪ Puducherry



Highest tariff

Lowest tariff

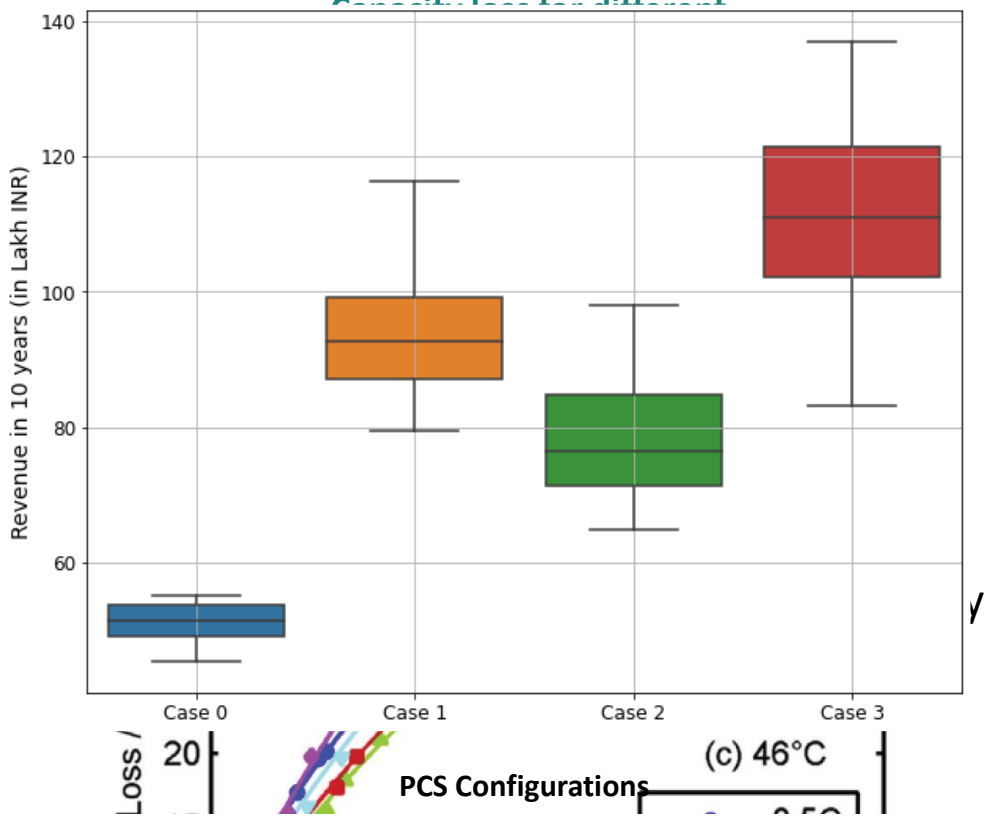
Fast vs slow charging: A Comparison

Challenges in adoption of fast charging

- ❑ Impact on battery health
- ❑ Technical impacts on electrical grid
- ❑ Economic Challenge

- The upfront cost of installation of fast chargers is significantly higher compared to slow chargers.
- Over a 10-15 year life period, the economic analysis may significantly favour the installation of fast chargers

For 25 EVs arriving on average per day at the PCS, its NPV of PCs considering 10 years of operation1



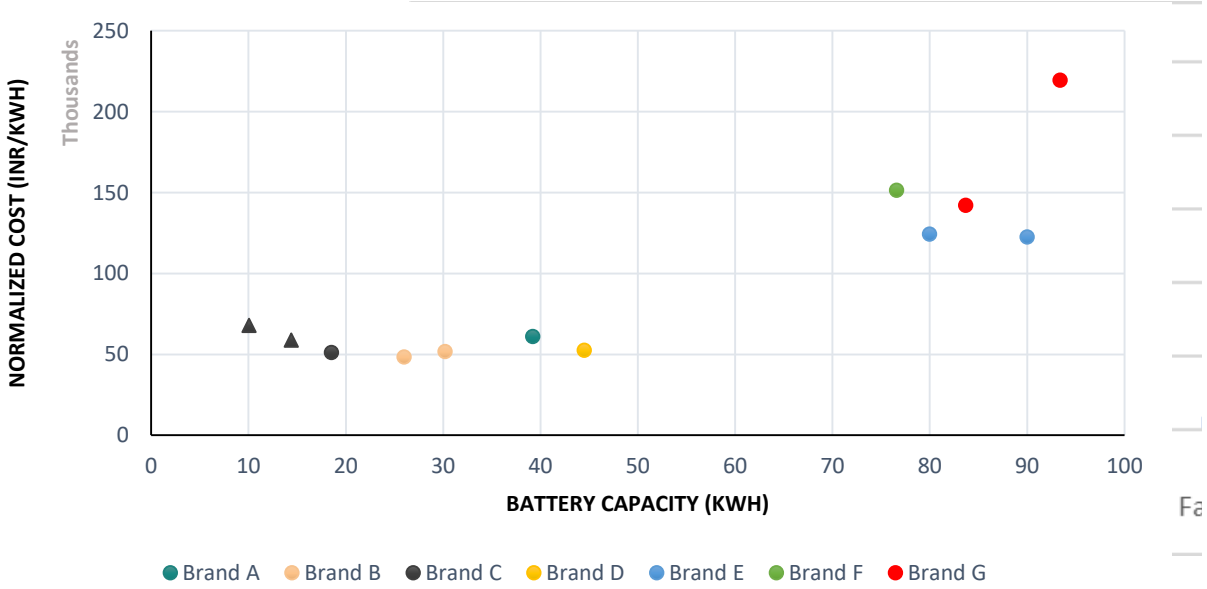
PCS Configurations

	Charger Power (kW)	Quantity	Total charger capacity (kW)	DT capacity
Case 0 (Base)	3 22	8 2	68	100
Case 1	7 50	9 1	113	120
Case 2	22 50	7 3	304	350
Case 3	50 150 200	7 2 1	850	850

John Wang et al., "Degradation of Lithium Ion Batteries Employing Graphite Negatives and Nickel–Cobalt–Manganese Oxide + Spinel Manganese Oxide Positives: Part 1, Aging Mechanisms and Life Estimation," Journal of Power Sources 269 (December 10, 2014): 937–48, https://doi.org/10.1016/j.jpowsour.2014.07.030.

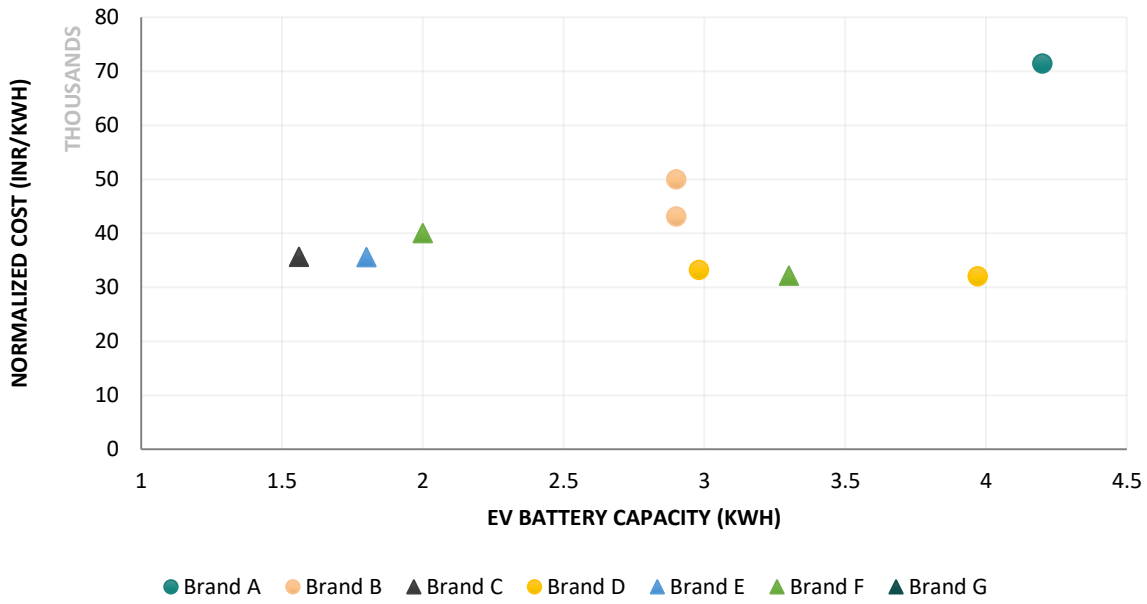
Fast vs slow charging: A Comparison (cont'd)

Normalized cost of 4W EV models available in India. The triangle markers represent EV models with slow charging capability

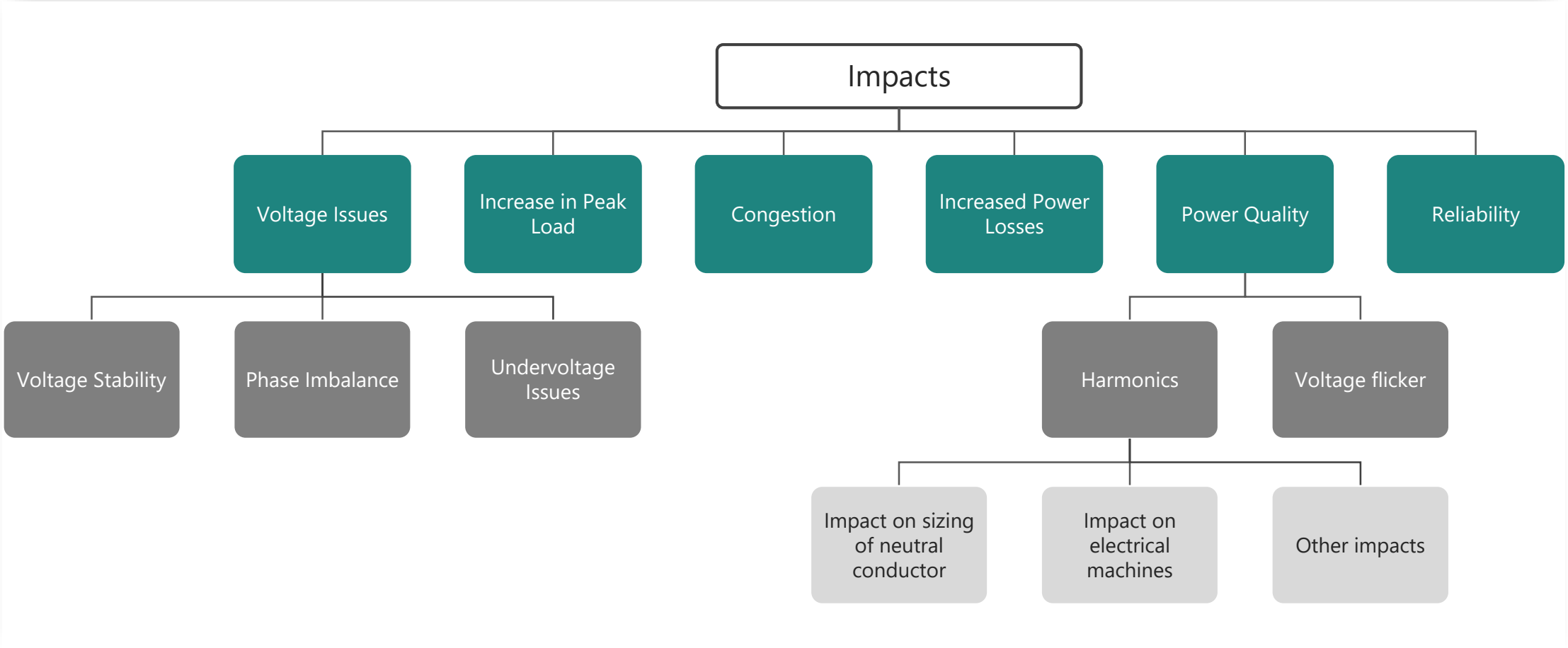


Public charging infrastructure statistics in India (Slow: < 7 kW, Fast: 7-22 kW, Rapid: > 22 kW)

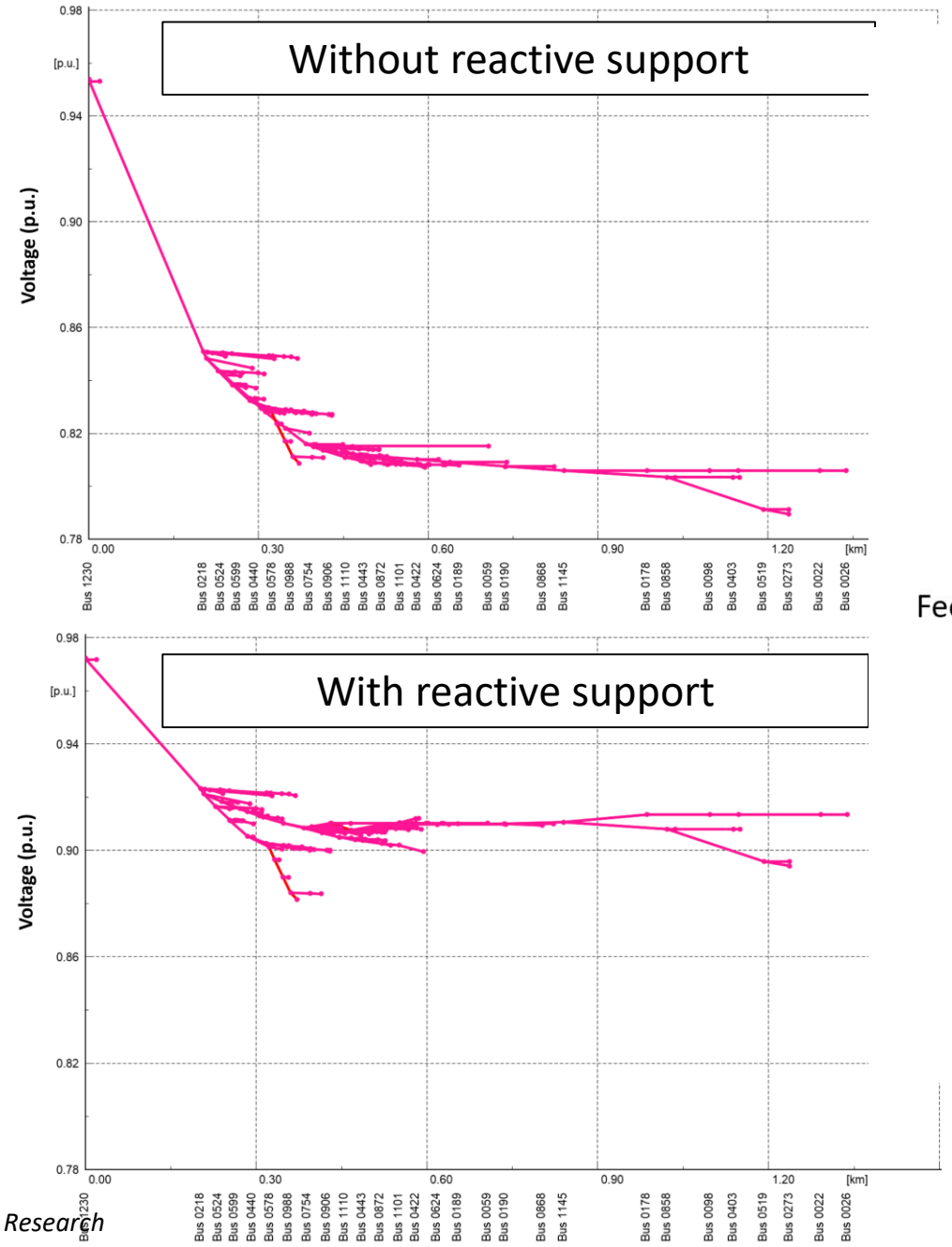
Normalized cost of 4W EV models available in India. The triangle markers represent EV models with slow charging capability

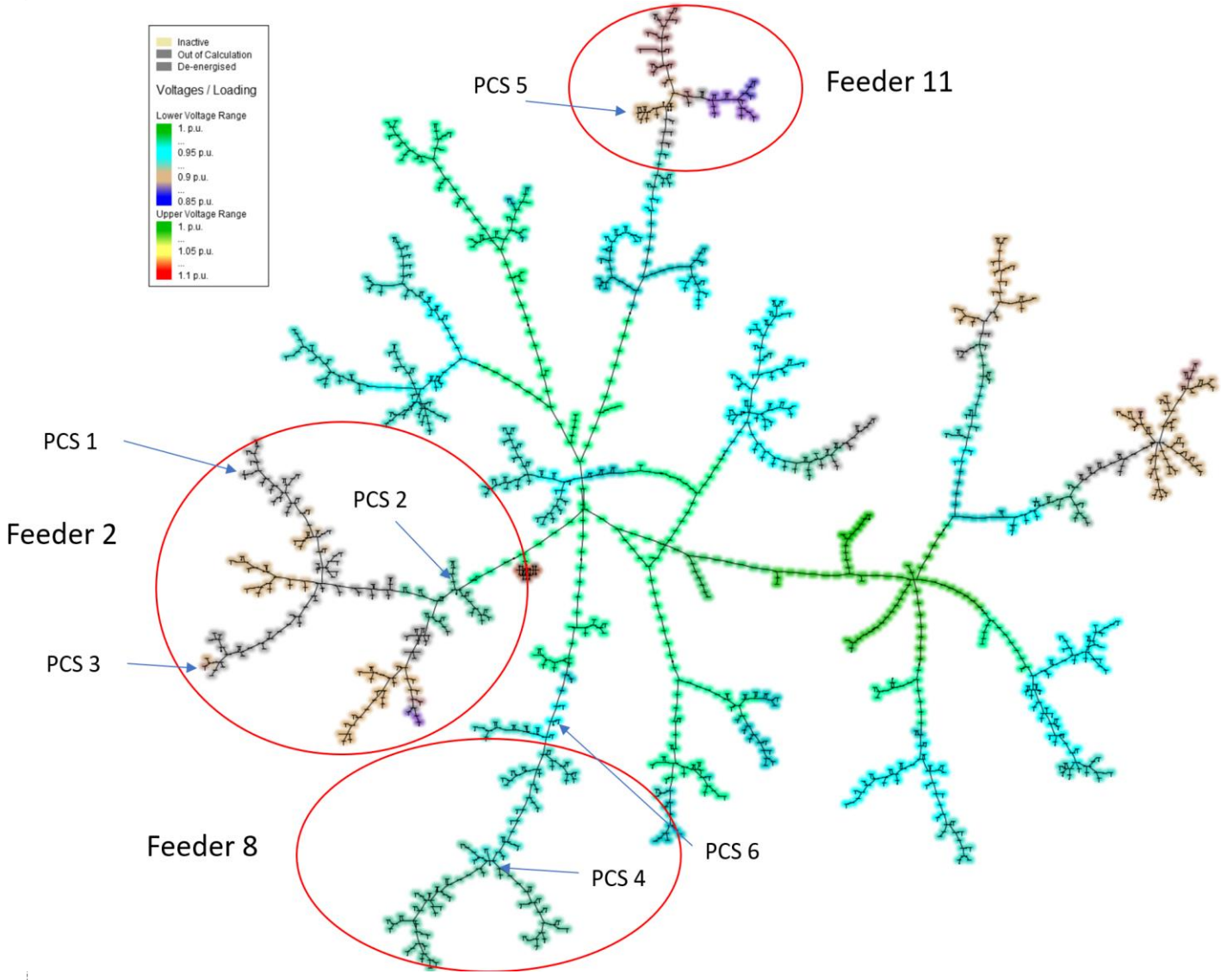


Impacts on Distribution Network

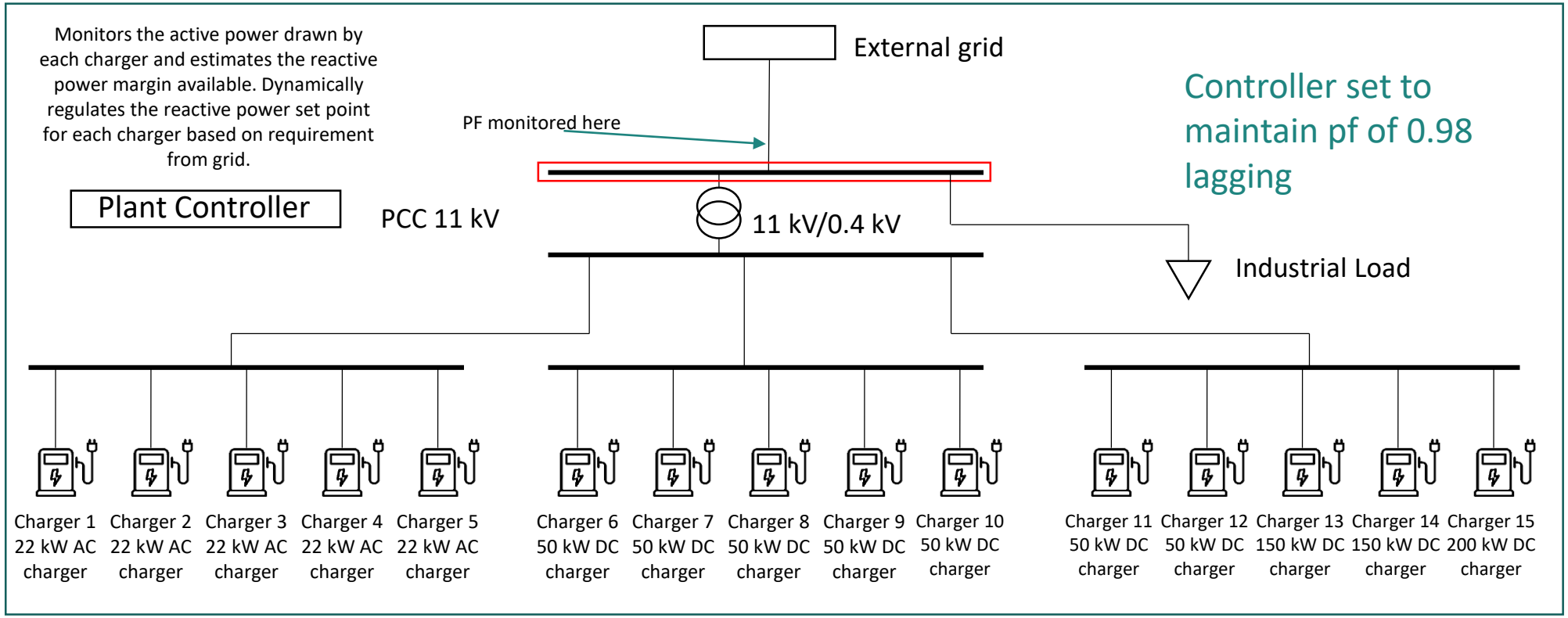


Impact of Reactive Support on Delhi Network





Economic Analysis of Reactive Power Support from EVs



Delhi Industrial tariff (2021-2022)

Demand Charge (INR/kW/Month)	Energy Charge (INR/kVAh)
250	7.75

Savings

	Demand Charge (INR/kVA/Month)	Energy Charge (INR/kVAh/day)
Without Q support	INR 3,28,687	INR 1,24,725
With Q Support	INR 3,07,596	INR 1,01,789
Savings	INR 21090 (per month)	INR 22,936 (per day)
Annual Savings	INR 2,53,087	INR 71,79,234

Mitigation of EV Integration Impacts

- **Upgradation of the distribution network**
  - Capital intensive
  - DISCOM can earn back the capital investment through
    - Financial support from government
    - Levying higher demand charges to customers with EVs and CPOs
    - Socializing the cost

- **Adoption of control based smart charging approaches**
  - Cheaper compared to system upgradation
  - Requirement of communication and IT infrastructure

Green eMotion project at European Union and Sacramento Municipal Utility at the United States on unidirectional controlled charging found that smart charging reduces the grid reinforcement cost by 50% and 70% respectively *(Source: IRENA)*.

- **Using time-based tariffs**
  - Tariff orders allowing time-based tariffs are required
  - Investment on smart meters is necessary
  - 43,56,417 smart meters have already been installed in the various states till February 2022 under the National Smart Grid Mission

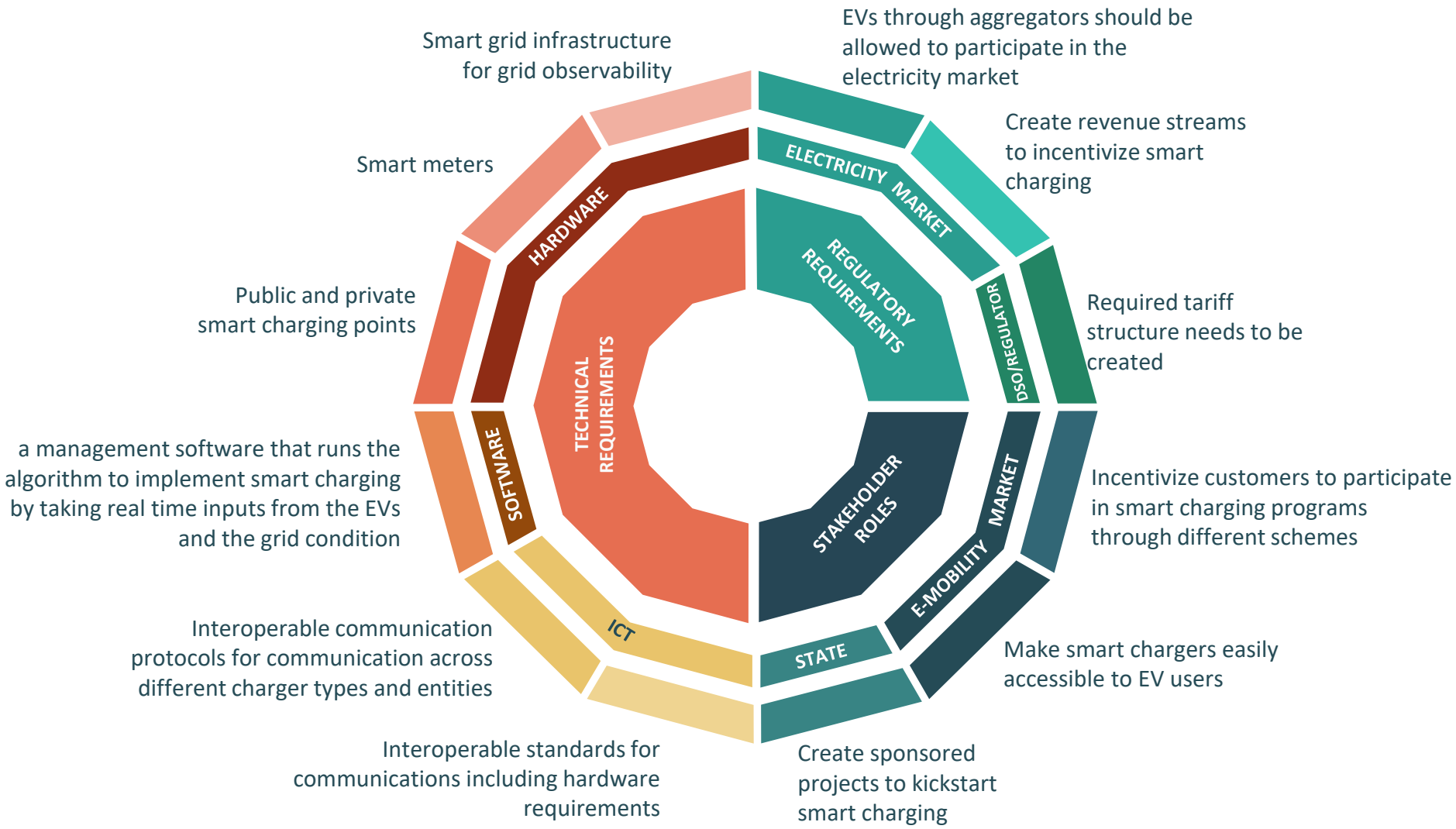
Smart charging in India

Type of Application	Control over charging power	Possible uses	Maturity
Uncontrolled but with ToU tariffs	None	• Load levelling	High
Basic Control	On/off	• Grid congestion management • Voltage Support • RE integration • Load levelling	Partial market deployment
Unidirectional controlled (V1G)	The charging current/power is dynamically changed	• Grid congestion management, • RE integration, • Voltage Support, • Load levelling, • Ancillary service	Partial market deployment
Bidirectional V2G and G2V	Bidirectional flow of power between EV and grid	• Grid congestion management, • RE integration, • Voltage Support, • Load levelling, • Ancillary service	Partial market deployment
Bidirectional V2X	Integration of bidirectional charging and home/building energy management systems	• Behind-the-meter optimization • Micro-grid optimization	Partial market deployment
Dynamic Pricing	Close to real time communication of dynamic electricity price between EVSE and grid	• Grid congestion management • Load levelling • RE integration,	Partial market deployment

Enabling Smart Charging in India

- ❑ Time based EV tariffs
  - Currently ToD/ToU tariff wherever in place in India, is largely focused on public charging stations, need domestic charging to be brought into a similar tariff.
  - Smart meter proliferation is still lacking
- ❑ Advanced communication based Smart Charging
  - Prior smart grid infrastructure is needed
  - MoP has initiated various Smart Grid Projects, which can incorporate smart charging of EV as an objective.
  - Smart charging regulations is necessary.

Requirements for Smart Charging



Ancillary Services from EV

- EVs are suited for high-power low energy services with fast response requirements (Fast frequency, primary and secondary frequency support)
- Currently, the only market procured ancillary service in India is the RRAS
- The ancillary services regulation issued on January 2022, allowed the participation of demand resources for provision of Secondary Reserve Ancillary Service (SRAS) and Tertiary Reserve Ancillary Service (TRAS). **EV can be added as a potential demand resource in this regulation**

Frequency control ancillary services envisaged in India *(Source: CERC)*

Attribute	Inertia	Primary	Secondary	Tertiary	Generation Scheduling
Time	First few seconds post disturbance	Few seconds – 5 min	30s-15min	15-60 min	>60min
Quantum	10,000 MW/Hz	4000 MW	4000 MW	8000-9000 MW	Generation-load balance
Activation	Automatic	Automatic	Automatic	Manual	Manual
Obligation	Mandated	Mandated	Road Map for paid reserves	Paid reserve	Paid
Suitable for EV	**Yes**	**Yes**	**Selective fleets**	**Selective fleets**	**Yes**

Analysis of tenders

Critical analysis of tenders catering to EV charging infrastructure

Key Observations

The main focus of the tenders are on Bharat AC001 and Bharat DC001

Low power capacity of the chargers mentioned in tenders will not be adequate for use in PCS

Compatibility of chargers may also be an issue as most current and upcoming 4W EVs in India are equipped with Type 2 or CCS chargers.

Gaps in Indian EV Charging Ecosystem

Gaps in the Indian EV Charging Ecosystem

Regulatory/Policy Gaps

- Lack of adequate support for private sector players in charging infrastructure sector
- Non-optimal Allocation of PCS under FAME scheme
- Misalignment between subsidy in charging infrastructure and vehicle subsidy
- Lack of incentives for battery swapping

Integration of EV to the distribution network

- Aging network. Need for grid upgradation requirement to cater to EV charging needs
- Poor financial status of most state run DISCOMs
- Lack of adequate IT/smart metering infrastructure
- Lack of adequate regulations in EV charging integration to grid
- Non uniform loading limits for connection at HT and LT levels
- Challenges in scheduling of EV load

Gaps

Charging Infrastructure Deployment

- Major focus on slow chargers
- Lack of standards for 2W and 3W charging connector types.
- Need for interoperability of chargers
- Challenges in metering
- Need for inclusion of charging infrastructure in building bye-laws.

Challenges for CPO

- Lack of a single window clearance system for most states
- Increased cost for installation of PCS due to added costs of grid upgradation
- Unavailability of adequate land
- Need for sustainable business models.

Gaps in the Indian EV Charging Ecosystem

Smart Charging

- Lack of dedicated communication protocols
- Lack of communication infrastructure
- Lack of smart grid infrastructure
- Lack of time-based EV tariffs for most states
- Lack of dedicated pilot case studies

Challenges in RE based charging for EV

- Lack of adequate regulations
- Metering and billing issues for Open Access
- Limited smart charging infrastructure
- Need for time-based EV tariffs
- Need for policy initiatives to encourage RE based EV charging

Gaps

Challenges for V2X implementation

- Lack of regulations for aggregation of EVs
- Metering issues
- Customer behavior and preference
- Creation of complex value chains for facilitating benefits to different stakeholders
- Lack of EV models with bidirectional charging capability

Provision of Ancillary Services

- Lack of technical regulations for EVs
- Lack of regulations for participation of EVs in energy markets
- Lack of aggregators
- Limited EV market
- Need for smart charging

Challenges for Battery Swapping in India

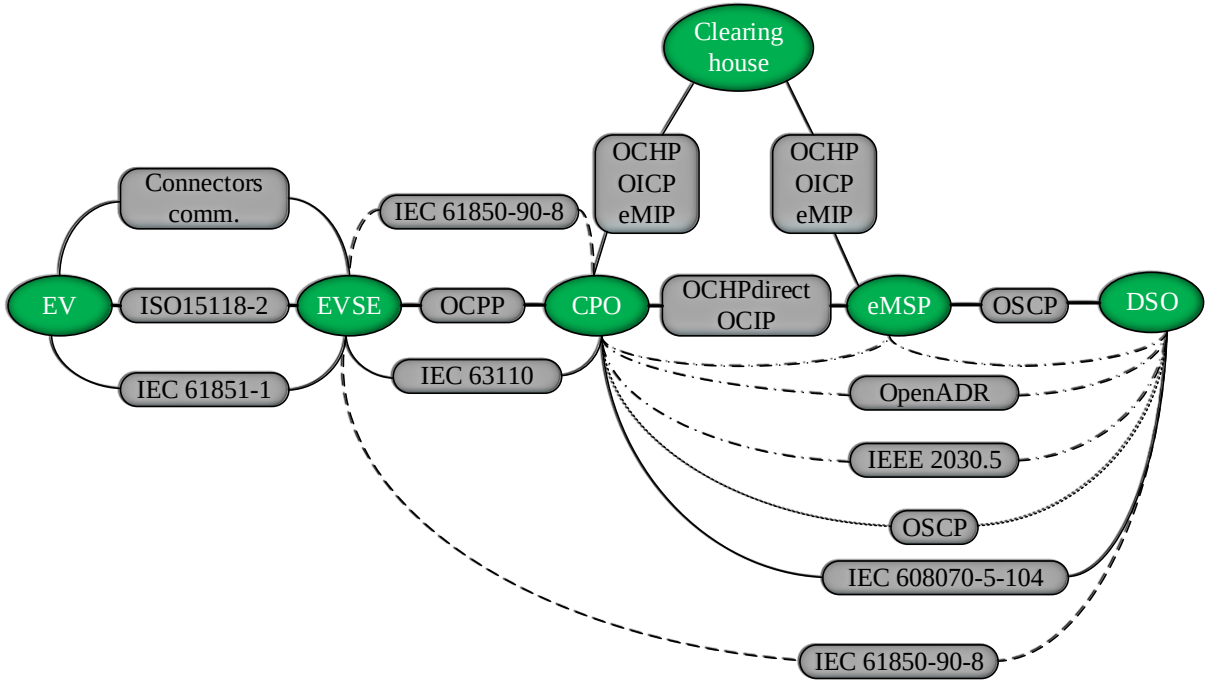
To increase uptake of e-2W and e-3W and push battery swapping, Govt. of India has permitted the sale of Evs without batteries.

- Purchasing a battery separately may increase the cost, as the GST applicable for battery is higher at 18% compared to the EV's 5%
- The FAME II subsidies are based on battery size, so claiming subsidies for EVs without batteries would warrant clarification.
- In order to increase compatibility, the batteries would be needed to be standardized which would slow down innovation.
- There would need to be understanding among the different EV OEMs to have the same battery specifications for easy swapping.
- Ownership issues would also need to be regulated, on who owns the EV battery after being swapped at a swapping station.
- Accountability issues, as the safety of the EV would come into question if subpar batteries are used by the EV user.
- Warranty claims would be difficult.

Draft policy on battery swapping has been released by NITI Aayog in April 2022

Challenges in communication infrastructure

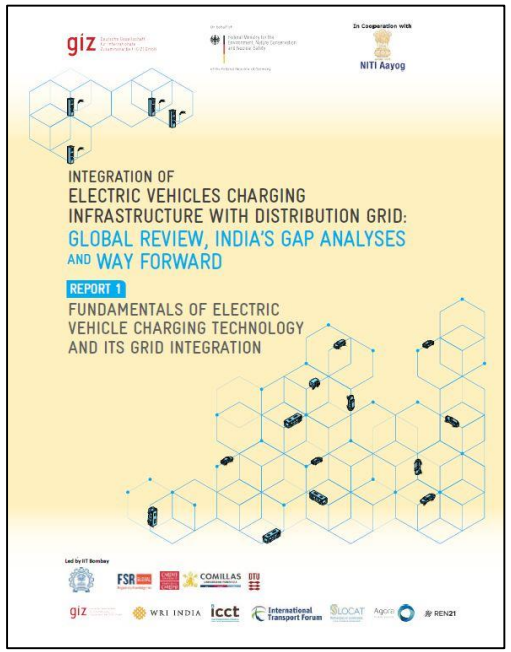
- In India, OCPP 1.5 and above has been recommended for communication between EVSE and CPO
- No mention regarding communication between the various other entities.
- Communication between DISCOM and CPO/eMSP is required for smart charging
- Provision of grid support services is largely not possible without communication
- Specification of details of data that needs to be exchanged between different entities in the EV stakeholder chain
- Specification of time resolution of data communication



Communication between different entities of the EV ecosystem

Report-1

Fundamentals of Electric Vehicle Charging Technology and its Grid Integration

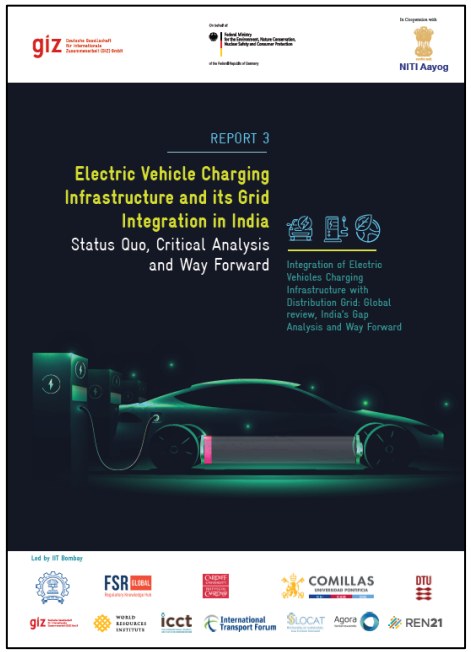


Report-2

International review of Electric Vehicle Charging Infrastructure and its Grid Integration

Report-3

Electric vehicle charging infrastructure and its grid integration in India
Status quo, Critical analysis and Way Forward



Report-4

Gap analysis and Recommendations for EV integration in India

Conclusion

- Though still in its infancy, the EV market in India has seen a sharp increase, specifically in the 2W and 3W segments.
- Critical analysis of the different state policies and regulations suggest there is a need for more focus on policy and regulatory enablers for charging infrastructure in the overall EV ecosystem
- Need to address the issue of grid infrastructure upgradation through a sustainable financial model for accommodating fast charging/large slow charging hubs
- Support for land availability (through sustainable business models) to CPOs to set up charging infrastructure
- While battery swapping can be a supplementary station, the industry standards need to be harmonized and regulated in a balanced manner
- Public charging stations are currently predominantly slow chargers (>95%). Public charging need to be predominantly fast charging.
- EV integration can have various impacts on distribution grid, there is a need for well planned adoption for EV charging
- Smart charging needs to be planned in Indian grid. It will not only unlock numerous benefits from the underlying grid scale storage in EVs, but it will also avoid/minimize/defer grid upgradation and enable higher RE integration

Thank you