USAID
FROM THE AMERICAN PEOPLE

GOVERNMENT OF INDIA
MINISTRY OF POWER

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE AND IMPACTS ON DISTRIBUTION NETWORK

GREENING THE GRID (GTG) - RENEWABLE INTEGRATION AND SUSTAINABLE ENERGY (RISE) INITIATIVE

A PARTNERSHIP BETWEEN USAID AND MINISTRY OF POWER, GOI

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE AND IMPACTS ON DISTRIBUTION NETWORK

GREENING THE GRID (GTG) – RENEWABLE INTEGRATION AND SUSTAINABLE ENERGY (RISE) INITIATIVE

A PARTNERSHIP BETWEEN USAID AND MINISTRY OF POWER, GOI

A White Paper

June 2020

Acknowledgements

USAID's Greening the Grid (GTG) is a five-year program implemented in partnership with India's Ministry of Power (MOP) under the USAID's ASIA EDGE (Enhancing Development and Growth through Energy) Initiative. The program aims to support the Government of India's (GOI) efforts to manage the large-scale integration of RE into the grid.

The central component of the GTG program is the Renewable Integration and Sustainable Energy (RISE) initiative, which involves design, implementation, and scaling of a series of prioritized innovation pilots that support RE integration. This white paper on 'Electric Vehicle Charging Infrastructure and Impacts on Distribution Network' is developed under GTG-RISE Initiative (implemented by Deloitte) in collaboration with BSES Rajdhani Power Ltd (BRPL). The white paper focusses on India's swift transition towards introducing electric vehicles into its transportation fleet and to achieve these objectives, utilities and key stakeholders need to be prepared to address the bottlenecks that are likely to arise. GTG-RISE through this white paper shares its findings on various enablers which are is important in understanding the role that a particular regulator/ government/ utility can play in encouraging the deployment of EV charging infrastructure.

The GTG-RISE would like to thank BRPL for partnering with USAID and NREL in this study. USAID and GTG-RISE team would also like to extend our sincere gratitude to Mr. Vibhu Kaushik, Director of Grid Technology & Modernization, Southern California Edison and Mr. Abhishek Ranjan, AVP, System Operation, BRPL for their valuable inputs and feedback on critical aspects of the white paper. We also thank Ministry of Power (MOP) for all their guidance and support to GTG-RISE team for this endeavour.

USAID
FROM THE AMERICAN PEOPLE

FOREWORD

The United States Agency for International Development (USAID) has a long and fruitful partnership with the Ministry of Power (MOP), Government of India (GOI) through several bilateral initiatives to modernize the energy sector. A key initiative under the U.S-India bilateral engagement is the Greening the Grid (GTG) program under the US government's Asia EDGE (Enhancing Development and Growth through Energy) initiative. This five-year program supports the GOI in its efforts to manage large-scale integration of Renewable Energy (RE) into the Indian power grid. The key component of the program, Renewable Integration and Sustainable Energy or GTG-RISE, validates technologies and solutions to support grid integration through pilots and demonstrations, while building a foundation for sound policy, capacity building in GOI agencies and incentivizing private sector engagement.

Globally, based on the available infrastructure and demand for additional electricity, renewable energy sources are offering a great opportunity to power Electric Vehicles (EVs), which can subsequently help reduce pollution, increase decarbonization and improve resource efficiency. It is exciting to see the evolving landscape for EVs. Government incentives, emerging technologies and declining prices are encouraging private sectors actors to invest in the future.

Like other countries, India aims to transition its transport system to electric vehicles to promote low carbon growth development. Transitioning to electric vehicles also allows for tackling one of the greatest environmental and public health challenges of modern India i.e. air pollution. The country has set aggressive targets for rolling out EVs and new commitments are being announced regularly, related to policy; technology; finance; or partnerships. One of the key enablers for the rapid uptake of electric vehicles is the development of a widespread charging infrastructure. While India focuses on achieving its commitments, the key stakeholders in the charging infrastructure landscape must be prepared and undertake several interventions to address the various challenges and gaps that currently exist. A White Paper "Electric Vehicle Charging Infrastructure and Impacts on Distribution Network" has been prepared under the GTG-RISE initiative, which reviews the current landscape of EV charging infrastructure in India and the key enablers and interventions required for its increased adoption, thereby accelerating electric vehicles adoption.

I would like to express my appreciation and gratitude to our bilateral partner, the Ministry of Power, for playing a key role in the effort to transform the EV market in the country. I would also like to express my gratitude to Mr. Vibhu Kaushik, Director of Grid Technology & Modernization, Southern California Edison and Mr. Abhishek Ranjan, AVP, System Operation, BSES Rajdhani Power Limited for their assistance in bringing international expertise and technical rigor to the framing of this important analytical document.

I would like to take this opportunity to acknowledge the excellent work done by the GTG-RISE team for their professional efforts in developing the white paper. And finally, I would be remiss if I didn't thank the USAID/India CLEEO Energy team, and the Senior Regional Energy Advisor and GTG-RISE Project Manager, Monali Zeya Hazra and her team for her tireless efforts in all respects. I hope the findings of the paper will be useful for all stakeholders concerned.

Thank you.

Michael Satin Digitally signed by Michael Satin
Date: 2020.07.03 17:17:37
+05'30'

Michael Satin
Director, Clean Energy & Environment Office
USAID/India

Table of Contents

List of Tables

List of Figures

Acronyms

Acronym	Description
BESS	Battery Energy Storage System
BIS	Bureau of Indian Standards
BRP	Balance Responsible Party
CAGR	Compounded Annual Growth Rate
CCS	Combined Charging Standards
CEA	Central Electricity Authority
Chademo	CHArge de MOve
DER	Distributed Energy Resources
DHI	Department of Heavy Industries
DSO	Distribution System Operator
DST	Department of Science & Technology
DT	Distribution Transformer
ETD	Electro-technical Department
EU	European Union
EVCS	Electric Vehicle Charging Station
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
GHG	Green House gases
GOI	Govt of India
GPS	Global Positioning System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	Independent System Operator

Acronym	Description
ISO	International Organization for Standardization
IT	Information Technology
kWh	Kilo-watt hour
LCV	Light Commercial Vehicle
MoHUA	Ministry of Housing and Urban Affairs
MOP	Ministry of Power
MVA	Mega Volt Amperes
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
OLTC	On-Load Tap Changer
OpenADR	Open Automated Demand Response
OVGIP	Open Vehicle-Grid Integration Platform
PCS	Public Charging Station
PM	Particulate Matter
PPP	Public Private Partnership
RE	Renewable Energy
RMI	Rocky Mountain Institute
RTO	Regional Transmission Organization
SAE	Society of Automotive Engineers
SEPA	Smart Electric Power Alliance
SOC	State Of Charge
STATCOM	Static Compensator
TOU	Time of Use
VGI	Vehicle Grid Integration

Executive Summary

India has one of the most rapidly growing automobile markets in the world and in the last one decade, it has witnessed an annual growth of 16% in the vehicle registration, resulting mainly due to high population growth rate combined with the rapid urbanization. The rapid motorization also has its consequences in terms of increased air pollution in the country. According to the World Health Organization (WHO), transportation accounts for about 11% of India's carbon emissions and is a major source of pollution in several cities nationwide. The rapidly growing automobile market is having irreversible dependency on the petroleum products, accounting for 98% and 70% of total petrol and diesel consumption respectively. India ranks third in the world for crude oil imports, both in terms of volume and value, to meet more than 80% of its oil requirements. According to PPAC, India spent USD 111.9 billion on oil imports in 2018-19, almost double since 2015-16. The high import bills, crude oil price fluctuations and other variability factors in the international market poses challenges to India's long term fuel security. The Indian government is focusing on various measures including increasing domestic production, promoting the use of alternate fuel options, energy conservation measures, technology advancement to reduce dependence on imported crude oil. India is also committed to reduce its carbon footprint and introducing Electric Vehicles (EVs) into the countries fleet is another step to meet these commitments. The transition towards EVs is one of the most promising pathways to increase energy security, reduce oil imports, improved air quality and lower the carbon emissions.

Electric Vehicle Market and Policy landscape in India

As per the Deloitte study, there is forecast of battery electric vehicles (BEVs), accounting for a substantial 70% of global sales in the EV market by 2030[1]. In India, the projected sales figures for four wheelers EV segment is likely to reach around 4.77 million by 2030 . To achieve such growth, India's policy landscape for the EV segment has evolved over the years from providing financial incentives to a more comprehensive national EV target roadmap. In 2013, the National Electric Mobility Mission Plan (NEMMP) was unveiled to develop the roadmap outlining incentives along four priority viz. demand incentives, manufacturing, charging infrastructure development and research & development for EVs. As per an assessment by the Department of Heavy Industries, INR 6000 crore of investment would be required for setting up the EV power and charging infrastructure up to 2020. NEMMP has also launched and implementation of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme. In 2017, the Indian government released its policy document on "Transformative mobility for All" with a vision for the future of India's mobility system, wherein the third phase (2024-32) envisages full scale expansion along with the introduction of regulatory mechanisms to capture full grid value of EVs. To achieve these roadmaps, challenges faced by distribution utilities in provisioning and managing access to EV charging infrastructure for the end consumers' needs to be addressed. The key challenges include the technical aspects for necessary distribution system upgrades, analyze the impact on distribution transformer loading, degradation of network components, suitable locations for

[1] *Niti Aayog, May 2017, "India Leaps Ahead: Transformative Mobility for All"*

setting charging stations and optimization of distribution network, etc. Commercial challenges which include medium to long term planning for network upgrades, modes of financing and recovery, setting up of pricing mechanisms for EV charging, and provisions of incentive mechanisms for setting up of charging stations should also be a focus area.

In order to analyze the issues that India must address to introduce Electric Vehicles (EVs) into the countries fleet, the aim of this white paper is to help remove bottlenecks related to availability and development of EV charging infrastructure by distribution utilities. A network analysis was undertaken, in partnership with a Delhi based utility, to analyse the impact of EV charging at various penetration levels, recommend a priortiziation framework for rolling out charging stations, and analyse whether managed charging could be a possible way out to decongest the network, in some scenarios. The findings and recommendations of the White Paper shall help distribution utilities in developing a plan and implementation model for EV charging infrastructure, covering aspects such as flexibility, security, integrity, and economics. The White Paper also delves into analysing successful case studies and implementations in developed markets and recommend key lessons for policymakers, regulators and technology service providers, which are essential for future roadmap of EV adoption.

Summary of recommendations and roadmap

The white paper delves into the various enablers to influence increased adoption of charging infrastructure. Understanding these enablers is important in understanding the role that a particular regulator/government/utility can play in encouraging the deployment of EV charging infrastructure. Based on international benchmarking and findings of the analysis done, phase-wise roadmap has been proposed which are classified as below

- **Near term priority (1-3 years):** The near-term priorities can be tackled immediately or over the next 1-3 years through quick policy/regulatory measures and accelerated ongoing efforts.
- **Medium term priority (4-7 years):** The medium-term priorities identified are crucial and would play a pivotal role establishing a developed EVSE ecosystem. However, these would require considerable support and substantial policy, technology and/or infrastructure changes and stakeholder buy in.
- **Long term priority (after 7 years):** These are complex initiatives requiring significant expertise to be built-up over a long period of time. Owing to the level of complexity, these long-term initiatives require transformational structural changes in policies, skill development, regulations, etc.

Recommendations and Roadmap

	Policy	Regulatory	Technological	Collaboration & partnerships
Long term priority		• Designing electricity market structures for participation of EVs	• Enabling Vehicle grid integration	
Medium term priority		• Designing TOU tariffs for EV charging • Approval for technical standards for charging equipment in the case of Managed charging	• Enabling communication system between EVCS and distribution utility • Database management and notifications to utilities	• Collaboration and partnerships amongst utilities and other stakeholders in the EV value-chain
Near term priority	• National / State level policy for incentivizing Distribution Utility investments in EV charging infrastructure • Launch of Charge ready infrastructure programme	• Approving Rate-basing of utility investments in building EV charging stations and infrastructure	• Enabling inter-operability in EV charging stations • Enabling communication between EV charging stations • Undertaking modelling and simulation studies • Smart metering	• Collaboration and partnerships amongst utilities and other stakeholders in the EV value-chain

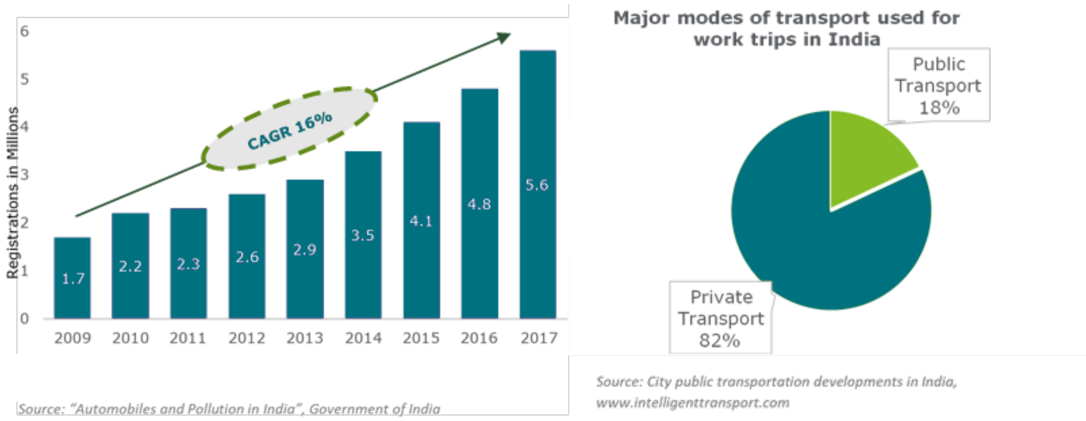
1. Introduction

1.1 Background and Context

India has one of the most rapidly growing automobile markets in the world and has witnessed an annual growth of 16% in the vehicle registration for the past decade. At current level, nearly 50,000 new motor vehicles (2-, 3-, and 4-wheelers) get registered every day. A key reason for the exponential growth in motor vehicles is high population growth rate combined with rapid urbanization. As per the World Bank, urban population accounted for 34.03% of the total population of India in 2018, an increase of 17% i.e., 69.2 million people, over 2011 levels. The slow pace of development in the public transport infrastructure has further led to heavy reliance on private transport. A recent study found that public transport has just 18.1%[2] share in work trips undertaken in the city with the rest being private.

The rapid motorization has its consequences in terms of increased air pollution in the country. Currently, fifteen of the top 20 most polluted cities in the world are in India and the transportation sector accounts for roughly approximately 20 to 30%[3] of fine Particulate matter (PM2.5) emissions in Indian cities. India is the fourth highest emitter of carbon dioxide in the world, as per a study by the Global Carbon

Figure 1: Vehicle registration in India and major transport mode



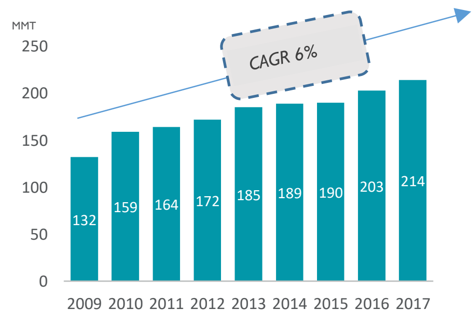
15 of the world's 20 most polluted cities are in India

-Rankings by IQAir and Greenpeace

project, which also accounted for 7% of global greenhouse gas (GHG) emissions in 2017. The transport sector contributes around 10% of these GHG emissions, while road transport accounts for 88% of transport GHGs.

Transport sector is the largest consumer of petroleum products, accounting for 98% of the total petrol consumption and 70% of total diesel consumption. India currently relies

Figure 2: India's Oil imports (FY 2009- FY 2017)



Source: MOPNG's Petroleum Planning and Analysis Cell (PPAC)

[2] *Jaspal Singh, December 2016, "City public transportation developments in India", IntelligentTransport,com, https://www.intelligenttransport.com/transport-articles/21458/city-public-transportation-india/ (Accessed: August 2019)*

[3] *http://www.urbanemissions.info/wp-content/uploads/apna/docs/2019-07-APnA30city_summary_report.pdf*

on imports to meet more than 80% of its oil needs. It ranks third in the world for crude oil imports both in terms of volume as well as value. Its oil imports account for USD 91.43 billion, constituting 27% of its total spending on imports in 2017. The fluctuations in prices of crude oil and its availability in international markets pose challenges to India's long term energy security. Reducing the dependence on imported fuel and increasing the use of alternate fuel options can reduce India's vulnerability to fluctuations in global oil prices.

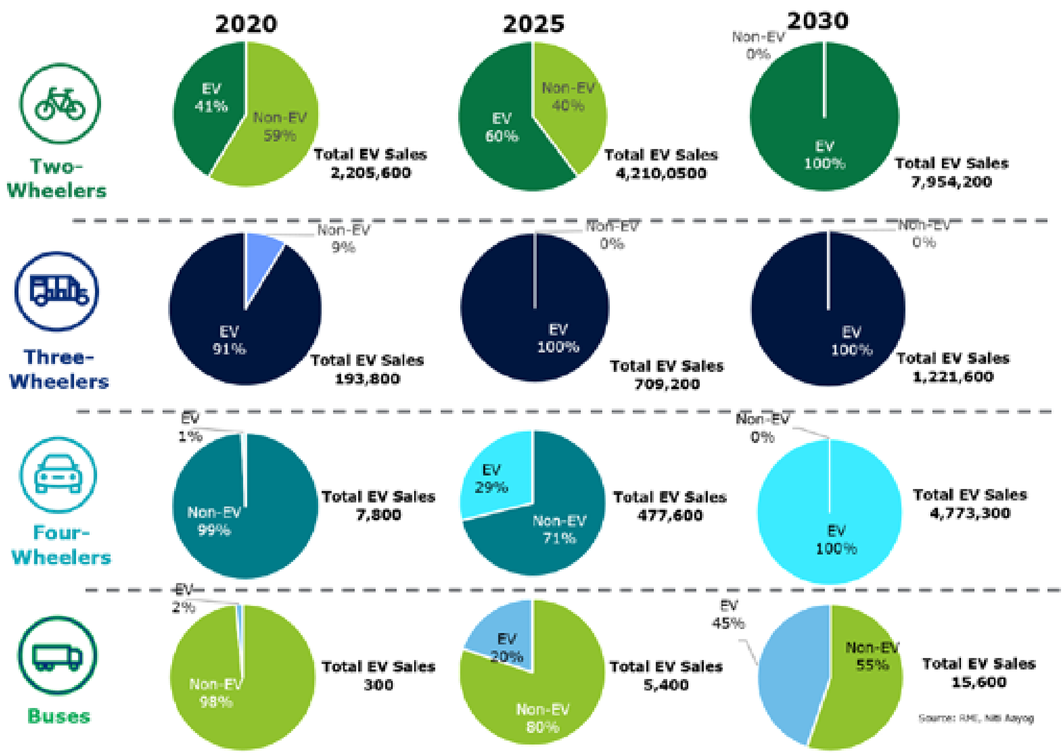
India has clearly articulated its commitment to reducing GHG emissions. At the Conference of the Parties 21 (COP21), India pledged to reduce its carbon footprint by 30-35% in 2031 from the 2005 levels. The use of electric vehicles (EVs) can be a viable option for meeting these commitments, while reducing India's dependence on imported fuel. The transition towards EVs is one of the most promising pathways to simultaneously increase energy security, reduce oil imports, lower GHG emissions, and improve air quality.

Globally, EVs have emerged as the leading option for alternative transportation in the light duty automobile sector, with China leading the pace of adoption, followed by United States.

1.2 Electric Vehicle Market in India

The Government of India has identified electric mobility as one of the key focus areas for development. Sales of EVs are projected to reach around 10.5 million for the four-wheeler segment by 2030 as per NITI Aayog and RMI. Projected sales of various EV vehicles in India for 2020, 2025 and 2030 are shown in Figure 3 below:

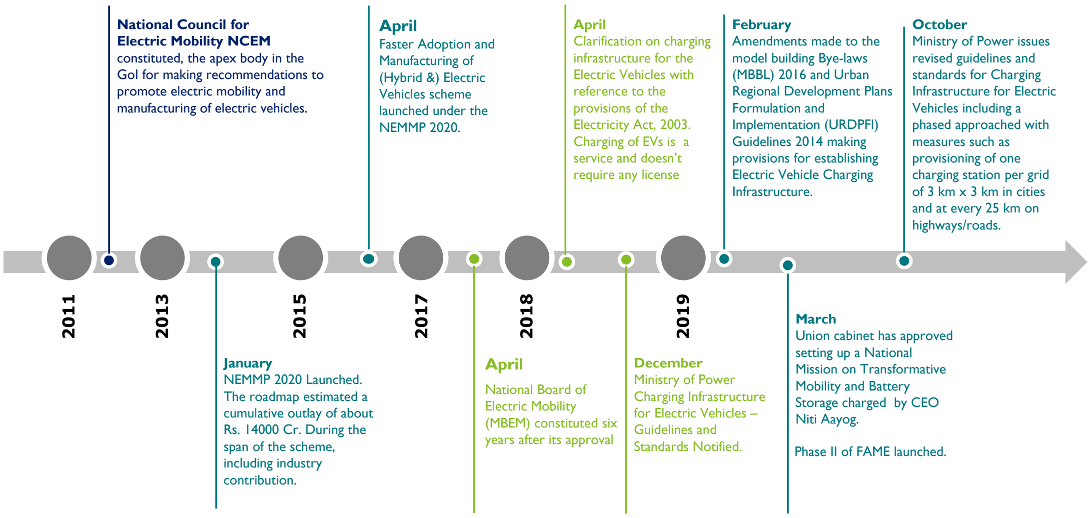
Figure 3: EV sales projections till 2030



Source: 1) Niti Aayog, April 2019, "India Electric Mobility Transformation", 2) GTG-RISE Analysis

The policy landscape for EVs in India has evolved over the years from the initial stage where the focus was on providing financial incentives for EV purchase, to a more rollout of more comprehensive policies with national level EV targets. The following figure shows the timeline of various policy and regulatory interventions:

Figure 4: Policy Roadmap for Electric Vehicles (EVs) Charging Infrastructure in India



Source: DHI, MoP, MoHUA, Niti Aayog

The National Electric Mobility Mission Plan (NEMMP) was unveiled in 2013 and provides for the development of a mission plan and roadmap for promoting electric mobility solutions in India. NEMPP outlines incentives along four priority areas for EVs: demand incentives, manufacturing of EVs, charging infrastructure development and research & development. In terms of the assessment made by the joint Government-Industry study, the total investment needed for setting up the required infrastructure up to 2020 (both power and charging infrastructure), vehicle segment wise, is summarized in following table.

Table 1: Assessment of segment wise investment requirement for EV infrastructure

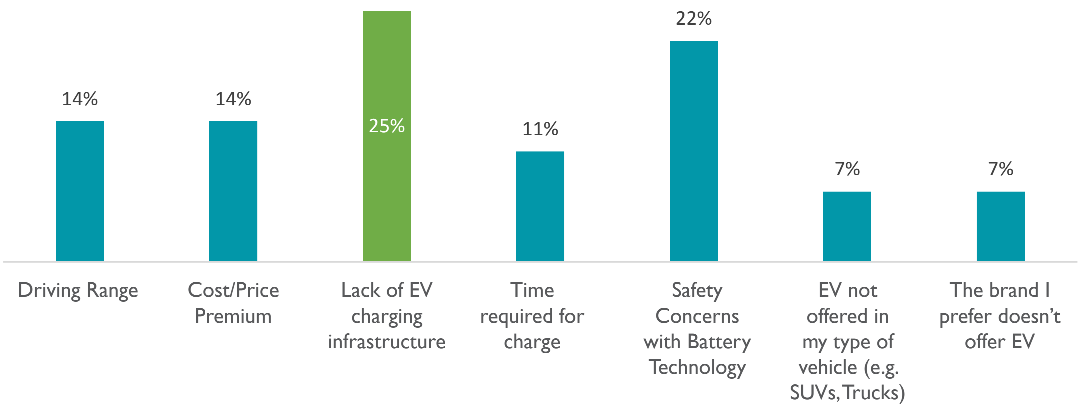
Area	4W	2W	3W	Buses	LCV	Total
Additional generation Capacity (MW)	150-225	600	10-15	<5	10-20	775-865
Power Infrastructure (Rs Crore)	1,200-1,300	3,300-3,400	75-85	20-30	90-100	4,685-4,915
Charging Infrastructure (Rs Crore)	950-1000	-	70-80	10-20	115-125	1,145-1,225

Source: Department of Heavy Industries. 2013. "National Electric Mobility Mission Plan 2020"

The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) programme was launched by DHI in 2015. It is the flagship scheme under the NEMMP 2020 mission plan of the Government of India (GOI) to enhance hybrid and electric technologies in India. The overall scheme is proposed till FY 2020 to support market development for EVs. Phase I of the scheme has been implemented over a two-year period starting from FY 2015-16. GOI has released its policy document on "Transformative mobility for All" in 2017 with a vision for the future of India's mobility system. Spread over three phases (I 2017-19, II 2020-23, III 2024-32), the plan entails taking near-term actions to build political and market confidence, followed by phase two which involves refining regulatory incentives and policy measures, and continued expansion of the charging network and scaling up domestic manufacturing. In phase three, market forces are expected to drive full scale expansion to meet e-mobility demand (electric vehicles, charging infrastructure, etc.) internationally, along with the introduction of regulatory mechanisms to capture full grid value of EVs.

As per Deloitte's Global Automotive Consumer Survey of 2018, the most common consumer concern preventing EV adoption in India is the lack of electric charging infrastructure.

Figure 5: Customer Concerns Regarding EV Ecosystem in India



Source: Deloitte. "New Market. New Entrants. New Challenges. Battery Electric Vehicles" 2018.

A well-established charging network may increase EV adoption, relieve range anxiety of consumers, and reduce the inconveniences associated with charging (which also serves to increase EV adoption). However, there are many challenges which need to be overcome and analyzed to ensure adequate EV penetration.

A fundamental question to be resolved is who will be responsible for developing the charging infrastructure. In the US, there is disagreement about the role of utilities in financing, owning and operating EV charging infrastructure[4]. In India, it is envisioned that the government will develop EV charging infrastructure, putting the distribution utilities (largely public entities) front and center in the process.

[4] *Source: The future of transportation electrification: Utility, Industry and Consumer Perspectives, Lawrence Berkeley National Laboratory, 2018.*

Distribution utilities face critical challenges in provisioning and managing access to EV charging infrastructure for consumers. A key challenge is the identification of necessary distribution system upgrades to support EV charging stations along with its associated costs and cost recovery mechanisms. Distribution utilities need to analyze the impact of EV charging on the distribution network (e.g., distribution transformer loading, increased ohmic losses and accelerated degradation of network components), and identify appropriate locations of EV charging stations to support EV charging while minimizing physical network impacts.

Commercial challenges include incorporating EVs in medium and long term network and resource planning, financing the charging infrastructure, setting up of pricing mechanisms for EV charging to ensure cost recovery, and creating incentives to encourage adoption of EVs and the use of charging infrastructure.

1.3 Structure of the Whitepaper

The whitepaper focuses on key issues related to availability and development of EV charging infrastructure by distribution utilities. Using examples from international experiences, the whitepaper also brings out key solutions to the challenges posed by development of EV charging infrastructure and its integration in the utility network. The whitepaper is intended to provide utilities with a framework for approaching the challenges associated with EV charging infrastructure.

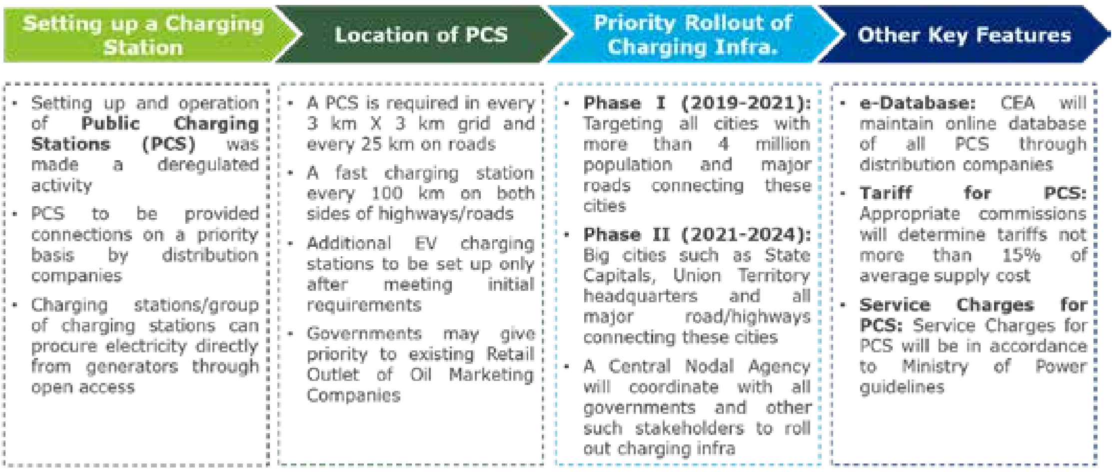
- Chapter 1 includes the context for this whitepaper.
- Chapter 2 provides the Indian context of standards and guidelines for charging infrastructure, technical and commercial aspects of EV charging and various pilots initiated across the country.
- Chapter 3 provides an extensive review of international experience in addressing challenges of EVSE integration with the help of case studies on how utilities around the world have tacked these challenges.
- Chapter 4 provides detailed analysis of the study carried out for BSES Rajdhani Power Limited (BRPL) in India. Using future scenarios, the study provides insight into the requirement of network capacity augmentation to integrate EVSE. The analysis helps understand the challenges that utilities must address going forward as they prepare for large scale adoption of EVs.
- Chapter 5 provides a gap analysis for the development of EV charging infrastructure in India and lays down key regulatory, policy and technology enablers for widespread adoption of the same. The chapter concludes with recommendations and a suggested roadmap to support integration of EV charging infrastructure.

2. EV Charging Infrastructure in India

2.1 Standards and Guidelines for Charging Infrastructure

The Ministry of Power (MOP), Government of India released the guidelines on EV charging infrastructure on December 14, 2018, which addresses the need for adequate availability of charging stations. These guidelines were subsequently revised and updated on October 1, 2019. The guidelines and standards aim to enable faster adoption of EVs in India by ensuring safe, reliable, accessible, and affordable charging infrastructure along with affordable tariffs, creating standard guidelines for EV charging businesses, and encouraging utilities and other parties to be prepared for EV adoption. Key provisions are highlighted in figure below:

Figure 6: Key provisions for development of EV charging infrastructure



Source: Ministry of Power, 2018, "Charging Infrastructure for Electric Vehicles – Guidelines and Standards"

The Ministry of Power issued a clarification on EV charging in April, 2019, namely that charging of an EV battery by a charging station is a service consisting of electricity consumption and hence should earn a revenue for this specific service. The value of the electricity is realized through a charging station operator, and hence is distinct from a typical sale of electricity. As such, EV charging does not fall under the purview of the Electricity Act of 2003 and is not subject to the other conditions of electricity retail distribution; this clarification has paved the way for participation of private players.

The minimum technical requirements for fast and slow charging stations in the guidelines are shown below.

Table 2: Guidelines for EV Charging Systems in India

Charger Type	Charger Connectors	Rated Voltage(V)	No. of charging Points/No of connector guns
Fast	CCS (min 50kW)	200-750 or higher	1 CG
	CHAdeMO (min 50kW)	200-750 or higher	1 CG
	Type-2 AC (min 22kW)	380-415	1 CG
Slow/Moderate	Bharat DC-001 (15kW)	48 72 or higher	1 CG
	Bharat AC-001(10kW)	230	3 CG of 3.3 kW each

Source: Ministry of Power, 2019, "Charging Infrastructure for Electric Vehicles – Revised Guidelines and Standards"

Other requirements are specified below:

- An exclusive transformer and related substation equipment, 33/11 kV lines, appropriate civil works, space for charging and entry / exit of vehicles, etc.
- Charging stations are required to tie up with at least one online Network Service Provider (NSP) to enable advance remote/online booking of charging slots by EV owners.
- EVSE shall be type tested by an agency/lab accredited by the National Accreditation Board for Testing and Calibration Laboratories (NABL) periodically.

The guidelines do not specify load flow studies or other forms of analysis for locating PCSs. However the guidelines provide a rule of thumb: one PCS on a grid of 3km x 3 km, one fast charging station every 100 km on highways, which can serve as a framework for discoms in identifying necessary network upgrades.

Following is a review of international charging standards as prevalent in various select countries:-

Table 3: International Charging Standards in Select Countries

	Conventional	Slow		Fast		
Level	Level 1	Level 2		Level 3		
Current	AC	AC		AC, tri-phase	DC	
Power	<= 3.7 kW	<=22 kW	<=22 kW	<=43.5 kW	< 200 kW	
US	SAE J1772	SAE J1772	Tesla	SAE J3068	CCS Combo 1 / Chademo	
China	Type 1	GB/T 20234 AC	Tesla		GB/T 20234 DC	
Germany	Type C/F/G	IEC 62196-2 Type 2 Tesla	IEC 62196-2 Type 2	CCS Combo 2 (IEC 62196-3) 62196-3)	CCS Combo 2 (IEC 62196-3) 62196-3)	Tesla and CHAdeMO (IEC 62196-3 Type 4)

The Ministry of Housing and Urban Affairs introduced the Model Building Bye-Laws for EV charging infrastructure in February, 2019. Key provisions are highlighted below:

Table 4: Amendments to Model Building Bye-Laws , MoHUA

Particulars	Details
Parking bays for EV charging	Residential and commercial buildings to allot about 20% of their parking space for EV charging infrastructure.
Power load for EV charging	Building premises should have additional power load equivalent to the power required for all charging points to be operated simultaneously with a safety factor of 1.25.

Particulars	Details			
	4W	3W	2W	PV (Buses)
No of slow and fast chargers	One slow charger for 3 EVs One fast charger for 10 EVs	One slow charger for 2 EVs	One slow charger for 2 EVs	One fast charger for 10 EVs

Source: Ministry of Housing and Urban Development(MoHUA), February 2019, "Amendments in Building Bye-Laws (MBBL-2016) for Electric Vehicle Charging Infrastructure"

Separate and independent consultative committees have been formed under the Automotive Research Association of India (ARAI), Central Electricity Authority (CEA) and ETD-51 (under BIS) which are evaluating charging and EV testing standards. The objective of these multiple committees is to help establish India's own EV charging standards. Key highlights of the report published by the Bureau of Energy Efficiency (BEE) are:

The Bureau of Indian Standards (BIS) and the Department of Science and Technology (DST) have been working on an indigenous charging standard for India. BIS has published BIS:17017[5] (derived from IEC 61851) which covers general requirements and safety for EVSE.. The standards recognize DHI supported Bharat Chargers (AC-001 and DC-001) for low voltage EVs (less than 120V). For higher voltage levels, the standard supports CCS-2 and CHAdeMO. Recent amendments in the charging guidelines allow any AC or DC charger that complies with Standards AIS 138 – 1, and AIS 138 – 2 respectively. So, it is expected that CHAdeMO, CCS-2, Type 2 AC and the Bharat Chargers will all co-exist in India.

There are additional two different working groups in BIS to decide on connectors and communication protocols, which will be important from an interoperability perspective. Until working groups have identified these protocols, the existing charging standards (Bharat Chargers, CCS-2 and CHAdeMO) and their references to connectors and communication protocols will be followed.

Based on stakeholder consultations conducted by BEE, the following specifications for charging options were identified:

Table 5: Charging options

Type	Standard	Power level (kW)	Typical charging time			
			2W	3W	4W	Bus
			1.25 kWh	3 kWh	15 kWh	100 kWh
Slow AC	Bharat Charger AC-001	3.3	1-5 hour	1-5 hour	5-8 hour	NA
Fast AC	Type-2 AC	Min 22	NA	NA	~35 min	NA

[5] https://www.standardsbis.in/Gemini/search/Browse.action?saleModeName=SOFT_COPY&subDivisionId=406#

Type	Standard	Power level (kW)	Typical charging time			
			2W	3W	4W	Bus
			1.25 kWh	3 kWh	15 kWh	100 kWh
Fast AC	Type-2 AC	Min 22	NA	NA	~35 min	NA
Slow DC	Bharat Charger DC-001	15	0,5-1 hour	~45 mins	~50 min	NA
Fast DC	CCS-2/ CHAdeMO	Min 50	NA	NA	~15 min	
High Power Fast DC	CCS-2/ CHAdeMO	Min 100	NA	NA	NA	

Source: Bureau of Energy Efficiency

2.2 Technical and Commercial aspects of EV Charging

Figure 7: Charging connector used in e-rickshaws

To cater to the large demand of electric 2-wheeler and 3-wheelers (EV2W and EV3W), which form the majority of EVs currently on the road, India has adopted the Bharat EV Charger AC-001 and Bharat EV Charger DC-001 standards. Both charger types cater to the low voltage requirements for EV2Ws and EV3Ws (battery voltage less than 100 V). Bharat Charger AC-001 can charge three different vehicles simultaneously and provides an output of single-phase AC at 230 V and 15 Amps (A). The charge rate for the vehicle is limited to 3.3 kW at each of the three connections. Bharat DC-001has an output of 72-200 V with a maximum current of 200 A (i.e., 15 kW). MOP has set the following minimum requirements for PCSs in India:

Table 6: Guidelines for EV Charging Systems in India

Charger Type	Charger Connectors	Rated Voltage(V)	No. of charging Points/No of connector guns
Fast	CCS (min 50kW)	200-1000	1/1 CG
	CHAdeMO (min 50kW)	200-1000	1/1 CG
	Type-2 AC (min 22kW)	380-480	1/1 CG
Slow/ Moderate	Bharat DC-001 (15kW)	72-200	1/1 CG
	Bharat AC-001(10kW)	230	3/3 CG of 3.3 kW each

Source: Ministry of Power, 2018, "Charging Infrastructure for Electric Vehicles – Guidelines and Standards"

The following table provides the charger specifications for Bharat EV AC (AC-001) and DC (DC-001) standards:

Table 7: Bharat EV AC and DC charger specifications

Charger Type	Charger Connectors	Rated Voltage(V)
Input requirement		
AC supply system	Three phase, 5 wire AC system	Three phase, 5 wire AC system
Nominal Input voltage	415 V (range of +6% to -10%) as per IS 12360	3 phase, 415 V (range of +6% to -10%) as per IS 12360
Input frequency	50 Hz (tolerance of 1.5 Hz)	50 Hz (tolerance of 1.5 Hz)
Environmental requirements		
Ambient temperature range	0-55 degrees C	0-55 degrees C
Ambient humidity	5-95%	5-95%
Ambient pressure	86-106 kpa	86-106 kpa
Output requirement		
No of outputs	3	2
Type of each output	230 V (+6% to -10%) single phase, 15 A as per IS 12360A.C	Type 2: Single vehicle charging at 48 V with a maximum of 10 kW power of 60 V / 72 V with a maximum power of 15 kW or a 2W vehicle charging at 48 V with maximum 3.3 kW
Output current	Three vehicles charging simultaneously, each at 15 A	200 A Max
Limiting output current	16A	16 A
Converter efficiency	-	>92% at nominal output power.

Source: 1) Ministry of Power, 2018, "Charging Infrastructure for Electric Vehicles – Guidelines and Standards", 2) EESL

These standards have been included in the MOP guidelines released in December 2018 for charging infrastructure standards. While the Bharat standards cater to the EV2W and EV3W segment for slow charging, the MOP guidelines have also been specified for fast charging, which apply to CCS and CHAdeMO, and Type-2 AC chargers. This has been specified by keeping in mind the growth of E4W and international car brands being launched in India. It has also been clarified that any forthcoming new BIS standards will be applicable, whenever they are notified.

2.3 EV charging infrastructure pilots in India

Over the past few years, public and private entities have taken up pilot projects in installing EV charging stations. While large scale EV charging infrastructure pilot projects are still under the planning and implementation stages, there has been a steady increase in standalone charging station pilots. Some of these examples are shown below:

Table 8: Select EV charging station pilots across India (non-exhaustive list)

S No	City/ State	Implementing Agency	Detail
1	**Nagpur (Maharashtra)**	Nagpur Municipal Corporation	200 electric cars, buses, e-rickshaws, and four public charging stations launched as part of the 'Multi-Model Electric Vehicle Project' in 2017.
2	**Delhi**	Niti Ayog	55 locations shortlisted across Gurgaon-IGI-South Delhi-Noida Corridor for installing 135 EV charging stations (46 – DC Fast, 89 – AC Slow). Project is still under planning and implementation stage
3	**Mumbai (Maharashtra)**	Magenta Power	Installed DC Fast charging infrastructure in 2018 in Turbhe Mumbai and also launched an APP which provides consumers with location of chargers, status, and type.
4	**Jaipur (Rajasthan)**	MNIT Jaipur	Five charging stations installed at different locations in MNIT Jaipur under the FAME scheme in 2018.
5	**Hyderabad (Telangana)**	Telangana Municipal Corporation and Urban Development	The Municipal Corporation and Urban Development Corporation launched EV smart parking and charging station on 18, March 2019
6	**Kochi (Kerala)**	Bharat Petroleum	Installed 3 charging stations in Kochi. Charging station installed at least 6 meters away from fuel vending machine due to safety reasons. Both direct charging and battery swapping facilities are available.
7	**Kolkata (West Bengal)**	New Town Kolkata Development Authority (NKDA)	New Town Kolkata Development Authority (NKDA) has installed 10 public charging stations for e-scooters and e-cars. These have been installed near the Kolkata gate, Tata medical centre, and eco parking area gates in 2018.
8	**Bengaluru (Karnataka)**	BESCOM	BESCOM has installed a total of 5 no. of charging at different locations across the city.
9	**Vishakhapatnam (Andhra Pradesh)**	NTPC	NTPC has installed a charging station at Simhadri which is capable of charging 3 numbers of EV simultaneously.
10	**Jammu & Kashmir**	J&KSRTC	J&K Road Transport Corporation is planning to commission six charging stations for supporting its fleet of 30 electric buses provided by TATA Motors.
11	**Guwahati (Assam)**	Assam Power Distribution Company Limited (APDCL)	APDCL has set up charging infrastructure for 15 e-buses procured under the FAME scheme

Source: GTG-RISE analysis

EESL has set up 60 power charging stations for electric vehicles in Delhi which is one of the largest public charging station programs in India. USAID, through its Smart Power for Advancing Reliability and Connectivity (SPARC) program, supported EESL in the roll out.

Though India is still at a nascent stage in terms of EV penetration, a range of policies, guidelines, and regulatory orders have been initiated to address some of these requirements. While a supportive framework is being put in place, utilities in India will have to prepare for meeting challenges in managing EVSE integration in distribution networks.

3. Developing EV charging infrastructure – International Experiences

3.1 Key considerations for setting up EV Charging Infrastructure

There are a range of requirements which distribution utilities and other stakeholders must consider while setting up a framework for supporting an EV charging ecosystem. These include having adequate guidelines and regulations in place, technical studies to assess and choose the right locations for setting up EV charging stations, ensuring channels for cost recovery of various network upgrades, enabling smart communication infrastructure for managed charging, setting up of TOU pricing mechanisms for off peak/dynamic EV charging, making charging services more accessible to consumers, and conducting training and workshops. These basic considerations are listed in the table below:

Table 9: Key considerations for developing an EV charging ecosystem

Parameter	Key considerations to be reviewed
Regulatory interventions	Inclusion of investments in EV charging infrastructure in the retail tariff
	Identify the tariff structure for EV charging (e.g., ToD tariff, special EV charging tariffs for EV users)
	Level of adoption of open access
Commercial interventions	Framework for public private partnerships / franchisee agreements for developing EV Charging stations
	Explore innovative business models such as pay per use
Techno – economic interventions	Adoption of smart grid capabilities, such as smart metering, "smart" charging (i.e., timed charging based on wholesale prices and other factors), vehicle to grid charging, assessing plans for conducting pilot programmes
	Managed / coordinated charging to mitigate distribution network impacts and facilitate RE integration (such as through load shifting to absorb excess RE generation): Provision for remotely controlling the charging speeds / duration of charging and modulating the same to enable optimal load on distribution system. Utilities can use managed charging to optimize the utilization of existing infrastructure and maintain grid reliability
	Explore how to lower the carbon and pollution footprint of EV charging (such as through solar coupled with storage)
	Charging stations need an adequate communication facility so that they can provide live information regarding their status, demand, energy charging pattern etc. Smart communication is key to the enablement of managed charging.
	Requirement for upgradation of network components such as transformers and substations for power supply, placement of static compensators, OLTC and other devices for voltage / frequency control
	Charging locations must be selected based on parameters such as availability of space, impact on traffic, commute patterns, business locations, and range of EVs etc.
Other elements of an enabling framework	Regulatory framework including legal aspects, licensing requirements, tariff etc.
	Specifying connectivity standards
	Specification of equipment standards
	Scientific planning and simulation models for EVSE siting

3.2 Key issues for setting up EV Charging Infrastructure

A detailed summary of the key issues with EVSE integration in distribution network is tabulated below:

Table 10: Key issues with EVSE integration in distribution network

S No	Parameter	Issue	Impact on network
1	**Voltage Stability and Harmonics**	• Non-linear load of EVs, sudden onset of charging load etc. may cause voltage unbalance, harmonics, voltage dips and may lead to voltage crossing acceptable limits at various nodes.	• Reduced Reliability • Voltage profile degradation makes system unstable • Affects equipment life
2	**Choosing appropriate locations for placement of EVSE**	• Identification of nodes that have a capability to handle external load is a key challenge. • Utilities shall be required to identify strong buses in the system for connecting EVSE, in order to maintain system stability. • Optimizing siting of charging stations such that congestion related to EV charging demand does not occur and the station is optimally utilized	• Hampers smooth operation of system if location is not optimal. • Voltage instability • Increase in Power loss if EVSE connected at weak electrical nodes • Congestion increase • Low utilization in case of sub-optimal traffic flow
3	**Tendency for uncontrolled charging in peak hours to result in** • **Requirement of Infrastructure Upgrade of T&D network** • **Procuring Costly generation sources for meeting peak demand**	• Uncontrolled charging would lead to increase in peak load demand, transformer overloading, line losses, and power losses shall become more relevant as EV penetration increases. • Due to overloading, transformer life may get impacted • EV charging at times of peak load would necessitate costlier sources of generation sources to be dispatched increasing the system costs	• Degradation of network components. • Increases network losses • Degradation in life of components Increase in Cost of operation
4	**Lack of clarity on potential impact of EVs**	• EVs in India have not seen heavy penetration and hence there is a lack of experience on the potential impacts of this load on distribution networks	• Technological unawareness

S No	Parameter	Issue	Impact on network
5	**Regulatory uncertainty**	• Uncertainty around regulatory approval of utility-owned charging infrastructure in the asset base. • No scientific method to determine actual cost-of-supply and associated tariffs	• Lack of transparent pricing scheme • Unforeseeable returns to investors
6	**Cost Recovery**	• Utilities will need to undertake investments for network upgrades required to facilitate EVSE integration.	• Lack of adequate cost recovery mechanism for investments shall put additional financial burden on utilities and may also impact the growth of EV

3.2.1 Voltage stability issues

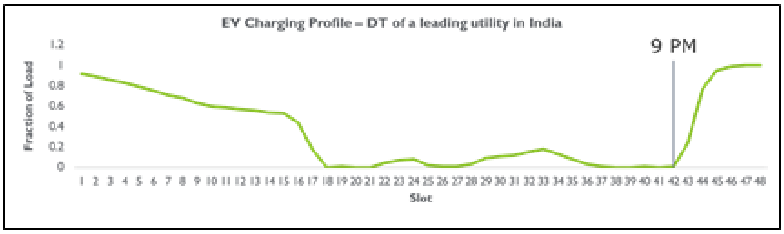
In the distribution network, due to typically high Resistance to Inductance (R/X) ratio of the distribution lines as well as non-linear load of EV, there may occur situations wherein heavy drawl of the power might lead to a significant dip in the voltage, which may cross acceptable technical limits. As EVs represent a large load in comparison to other household loads, they will increase overall power demand in low-voltage grids.

In addition to this, EVs may contribute to coincident load since drivers are likely to plug in their cars at the same time, during evening or morning system peaks, or when low tariffs start to apply. As shown in the graph below which represents a typical EV charging profile for a Delhi based distribution utility in India, the charging of EVs at the DT spike after 9 pm and peaks during the midnight which would generally represent that users charge their vehicles after returning home at the end of a work day. This time also represents the same window in which other domestic loads (such as lights, fans, ACs) will increase. The result is a higher coincidence factor on power demand.

Higher peak loads cause (relatively short-time) congestion on distribution grids, adversely impacting the voltage and network capacity. Overloads of network equipment can reduce the life expectancy of domestic components. These can also lead to voltage fluctuations outside their designated margins causing consumers' devices to malfunction at times of severity.

The following section illustrates the detailed impact on voltage and network reliability due to charging processes:

Figure 8: Sample EV Load Profile



- Reactive current: An EV stores energy in a DC battery, hence energy needs to be converted from the AC of the grid to the

DC for the battery. A general rule for convertors is that the cos phi value is not lower than 0.95 in order to avoid inefficient reactive power flows. The lower the cos phi value, the higher the amount of reactive current. Reactive current has to be transported via the grid which causes (heat) losses and reduces equipment lifespan.

- Harmonic currents: Converting the energy from AC (energy in the network) to DC (energy in the battery) can cause harmonic currents. This type of distortion results in multiple sinusoidal waves of frequencies higher than 50 Hz being distributed upon the 50 Hz sinusoidal wave of the current, as shown alongside. The higher the frequency of these harmonics, the more energy intensive they are and the more heat they generate in components.
- Voltage dips: Depending on the level of impedance in the grid (the lower the better) a high current can bring the voltage down. In case multiple EVs charge on a specific single phase of the grid (most of the current existing EVs have usually only single-phase design), it may lead to phase imbalance.
- Harmonic distortion of the voltage: When the current harmonics are high enough, and/or the grid impedance is high enough, the harmonics in the current can have a noticeable effect on grid voltage.

Standards such as J2894 issued by the Society for Automobile Engineers (SAE) can be followed to meet power quality standards requirement. SAE J-2894 Part 1 specifies the Power Quality Requirements for Plug-In Vehicle Chargers. This recommended practice includes guidelines for:

- Total Power Factor Power Conversion Efficiency
- Total Harmonic Current Distortion
- Current Distortion at Each Harmonic Frequency
- Plug in Electric Vehicle Charger Restart After Loss of AC Power Supply
- Charger / Electric Vehicle Supply Equipment AC Input Voltage Range
- Charger / Electric Vehicle Supply Equipment AC Input Voltage Swell
- Charger / Electric Vehicle Supply Equipment AC Input Voltage Surge (Impulse)
- Charger / Electric Vehicle Supply Equipment AC Input Voltage Sag
- Charger / Electric Vehicle Supply Equipment AC Input Frequency Variations In-Rush Current
- Momentary Outage Ride-Through

SAE J2894/1 defines the power conversion efficiency as a measure of how efficiently the charging equipment processes power from its input terminals to its output terminals. It can be measured over the total charging cycle or at any point in the charging cycle. It is a function of the design of the charger and, therefore, it can be a representative parameter for the charger. It has been calculated as the ratio between the instantaneous DC power delivered to the vehicle and the instantaneous AC power supplied from the grid in order to test the performance of the charger. The inverse of the efficiency of the charging process, i.e., a kind of energy return ratio

(ERR), has been calculated as the ratio between the AC energy supplied by the grid to the electric vehicle supply equipment (EVSE) and the energy delivered to the vehicle's battery.

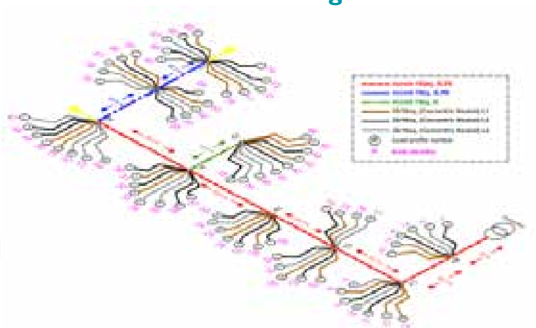
SAE J-2894 Part II specifies the testing methods for Plug-In Vehicle Chargers. It includes guidelines for testing procedures for PEV chargers. Following are some standardized test conditions prescribed by the guidelines:

- Test room: - Room must be kept at 25 degrees C with a tolerance of 5 degrees C
- Battery: Must be within 17-33 degrees C at test start.

Case study[6]- Statcom placement of Irish distribution system with high EV charging level

A modelling study was conducted by Dublin Institute of Technology (DIT) on a representative Irish (urban) distribution network with substantial EV load. The impact analysis was done to model the high EV charging rate on single phase connected distribution network and STATCOM ability to mitigate the voltage magnitude and voltage unbalance issue. Key assumptions are highlighted below:

Figure 9: Distribution System analysis for EV Loading



Source: Zaidi et. al., 2019, "Role of reactive power (STATCOM) in the planning of distribution network with higher EV charging level", IET Generation Transmission & Distribution.

- The sample distribution system analyzed is shown in the diagram below.
- EVs are removed from the consumer grid connection between 9:00 am to 5:00 pm during office hours and charged outside these hours
- Representative travelling requirements of passenger cars are considered in order to design more realistic EV battery load profiles
- A normal battery size is considered to be 20 kWh, but recent advancement in EV battery capacity suggests a 40 kWh battery is available in the market and Electrical Buses battery capacities are in the order of 200-300 kWh

Table 11: Overview of the model

Details	Particulars
Platform	DIgSILENT power factory
No of customers	74, and connected from a 10/0.4 kV transformer in a radial network topology
Voltage deviation limits	+-10% of nominal value
Residential load modelling	Household load demand profile obtained from DSO
STATCOM placement	Connected at several pillars / locations to measure voltage profile without and with STATCOM placement

[6] *https://www.researchgate.net/publication/330498865_Role_of_reactive_power_STATCOM_in_the_planning_of_distribution_network_with_higher_EV_charging_level*

Details	Particulars
EV charging load	• Typical EV charging load pattern has been considered • 7 EVs are fully charged, and the remaining (90%) of EVs retain a state of charge in the range of 0%-90%. • EVs are randomly distributed on different phases on the network • Charging rates of 3.68 kW and 11 kW (single phase) are considered
Supply	Single phase 230V (line to phase voltage) via a distribution transformer with power rating of 0.4 MVA

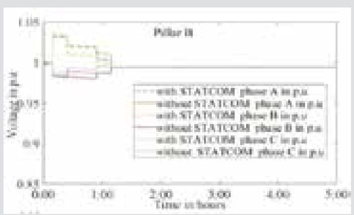
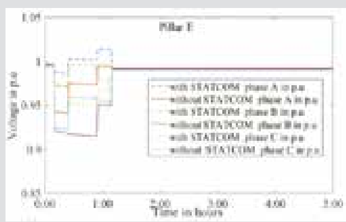
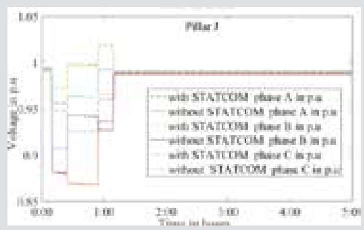
Source: Zaidi et. al., 2019, "Role of reactive power (STATCOM) in the planning of distribution network with higher EV charging level", IET Generation Transmission & Distribution.

Overview of the STATCOM deployed

- Can inject three phase sinusoidal balancing current into the grid in case of voltage deviations
- Can compensate for reactive power requirements of the grid in order to maintain voltage profiles adequately
- The compensator uses reactive power to control the voltage at given terminals
- The reactive shunt currents that can be injected by the STATCOM are based on voltage droop characteristics i.e. the slope of the droop characteristics determines the voltage regulation requirement of the system which the STATCOM would respond to
- The variation of power delivery or absorption is determined as per prevailing grid conditions

Key outputs of statcom modelling – Charging activity carried out at 11 kW

Table 12: Voltage Profile Using Statcom Modelling

Voltage profile at Pillar B - close to Supply transformer	Voltage profile at Pillar E – at centre of network	Voltage profile at Pillar J – farthest from Supply transformer
		

Source: Zaidi et. al., 2019, "Role of reactive power (STATCOM) in the planning of distribution network with higher EV charging level", IET Generation Transmission & Distribution.

The study insights are as follows:

1. The results suggest that EV penetration closest to the upstream medium-voltage (MV) grid will have less impact on voltage profile than EVs connected to the far end of the radial network
2. Under the analyzed consumer demand conditions, voltage breaches were not substantial

3. D-STATCOM, however, is able to reduce voltage drop quite effectively and as such also serves to reduce voltage fluctuations in the network.
4. The cost of such a device was ascertained to be $28000 (approximately £22000)
5. The analysis inferred that a D-STATCOM may increase the overall cost of augmentation and may not be the most cost-effective solution, but as a leverage for enhanced controllability and response time, it could be one of the optimal approaches.

Case Study: Using Storage and charging combinations for voltage stability

The high concentrations of simultaneously charging EVs could put strain on the distribution grid and cause frequency fluctuations, especially at high charging power rates. Another possible solution is to pair EV charging stations with stationary energy storage, which would allow utilities to flatten the electrical load and potentially increase renewable energy usage. Moreover, providing a decentralized/localized energy source for EV charging would reduce the congestion in the upstream LT network and arrest any voltage/frequency dips due to overload/overcharging.

Few case studies[7] of the same are mentioned below:

- Hawaii Electric Company has partnered with Greenlots to build DC fast charging stations with large battery storage to avoid upgrades in the distribution system and make use of Hawaii's substantial solar resources.
- In the United Kingdom, battery second life concept through the EVEREST system, which uses a large bank of used batteries to charge EVs and return energy to the grid to provide balancing services.
- The smart charging stations in the U.S. state of Tennessee, built by the Tennessee Valley Authority, include an on-site solar panel with batteries that supply 65% of EV charging power to minimize grid impacts and feed energy back to the grid when available
- The Energy OASIS project, developed by the British Columbia Institute of Technology, Natural Resources Canada, and BC Hydro in Burnaby, British Columbia, combines a large solar array, battery storage, and fast charging stations in order to allow fast charging with no impact to the electric grid.
- ElaadNL, working with Renault and the city of Utrecht in the Netherlands, is building 1,000 public solar-powered smart charging stations with battery storage around the Utrecht region
- BMW had, in 2016, partnered with Swedish power company Vattenfall to build a 2 MWh battery second life system designed to compensate for renewable energy fluctuations in Germany.

3.2.2 Power quality issues due to EV charging

The European Distribution System Operators in their publication titled "Smart

[7] *https://theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf*

charging: integrating a large widespread of electric cars in electricity distribution grids" have noted that:

1. The additional energy consumption from EVs (kWh) will not represent a critical factor for DSOs, as this can be handled with existing generation capacity. However, EVs can cause a significant higher peak demand, which may trigger network upgrades unless load management strategies are employed.
2. EVs across Europe do not pose significant problems in distribution grids. As their share will be rising in the coming years however, DSOs will need to improve their network operations to meet a higher instantaneous peak demand.
3. The impact on the peak load will be critically dependent on how congestion is managed: if all EVs start to charge at the same hour, the impact will be much higher

Power quality issues could be preliminarily addressed through the following:

- **Automated and controllable tap changers on DT:** The taps in the transformer alter the power transformer turns ratio in a number of predefined steps and in that way changes the secondary side voltage.
- **Capacitor banks:** Capacitors are energy storage devices. They store energy as a static charge on parallel plates. They also improve the power factor.
- **Static Compensators** (STATCOM) in case the voltage dips beyond certain threshold, which adds up to the cost of the augmentation.
- Combining **decentralized battery storage systems** coupled with charging infrastructure to act as a local source of power

These voltage fluctuations become a major threat to the load served by the DT as domestic appliances connected in the downstream network are designed to operate under prescribed voltage limits and heavy and rapid fluctuations could lead to malfunctioning and permanent damage to these appliances.

As per a study by European Distribution System Operators (EDSO), it was found that On Load Tap Changer (OLTC) transformers are able to accommodate 100% of EVs in the network at normal/slow charging rates only, however the upgrade cost of each transformer is £60,000.

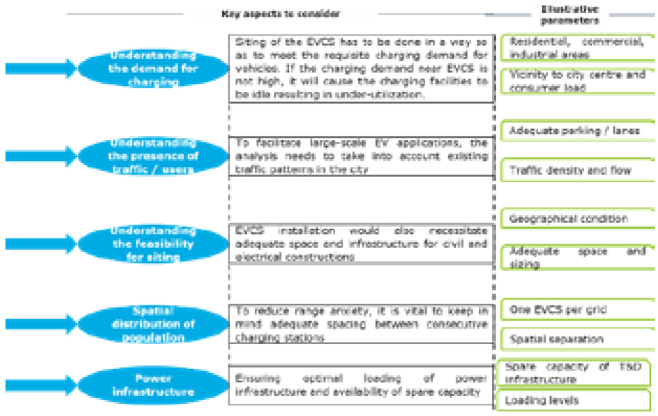
While tap changers on DTs and capacitor banks contribute to improvements in voltage profile, large scale installations of capacitor banks can cause resonance due to harmonics and switching transients. The main drawback of OLTCs are its high installation and maintenance costs. We focus on statcoms and battery-based storage systems in the following sections.

3.3 Location analysis and siting/design for EV charging infrastructure

This section discusses various factors associated with locating and designing EV charging infrastructure (EVCS). Factors such as the charging capacity required, preference of users for mode of charging (slow/fast), and the total EV load will depend on various geographical, technical and transportation parameters. Appropriate site selection and capacity determination of EVCS is a critical step to building a successful E mobility ecosystem.

A location close to the central point of a city will involve both heavy and slow traffic, and have commercial establishments; whereas locations in city outskirts will have fast moving traffic and a smaller population density. A location specific analysis is essential to identifying the needed charging capacity for a particular location. Also, prioritization of EVSE locations would depend on spare capacity in the Distribution Transformers (DTs) in the feeders connecting the EVSE stations.

Figure 10: Key parameters for siting of EV charging stations



Highlighted below are few case studies of cities where detailed locational analysis has been carried out.

Case study[8]- Siting and Design Guidelines for Electric Vehicle Supply Equipment

New York State Energy Research and Development Authority and the State of New York have published siting and design guidelines for Electric Vehicle Supply Equipment (EVSE). In these guidelines, siting and installation of EVSE depends on a number of considerations: proximity to power supply, parking space size and orientation, pedestrian traffic, lighting and visibility. Many of these considerations are not yet standardized in terms of functionality, and others fall outside the realm of the standards and codes system, such as aesthetics. Each EVSE installation will be different, so these guidelines take the important step of establishing baseline considerations that are predicated on a typology of sites.

The report suggests the following list of factors for site selection and site design:

Table 13: Location selection criteria: US Department of Energy, NYSERDA

Interfaces	Criteria for location siting / design
Network interface	• Presence of cellular network for car to parking spot communication • Consumer to charging network communication enables payment for publicly-accessible EVSE • EVSE to utility communication for enabling controlled charging • EVSE to grid connectivity for metering solutions
Urban interface	• Proximity to Traffic: Large-scale traffic patterns and counts determine viability of locations for most commercial operations, and such analytics may be used for EVSE location choice • Proximity to building entrances: Placement of the EVSE determines its visibility and accessibility, typically with respect to priority parking spaces—those that are located a short distance from building entrances. • Pedestrian traffic: EVSE and cord sets should not interfere with pedestrian routes; charging stations should not be placed in a location that would cause a cord to be a tripping hazard:

[8] *https://www.nyserda.ny.gov/Researchers-and-Policymakers/Electric-Vehicles/Resources/Best-Practice-Guides-for-Charging-Stations*

Interfaces	Criteria for location siting / design
Power interface	• Electrical capacity: Connecting EVSE to a power source will require evaluation of existing electrical capacity. This has two parts: the electrical system at the location of the EVSE installation, and the capacity of neighborhood systems to support many EVs charging at once. Electrical cabinets, panels and circuitry will need to accommodate the anticipated additional load. • Some municipalities, such as Vancouver, Canada, have used their building codes to require that new construction allow sufficient space within electrical rooms for panels and other equipment required to increase capacity in the future • Construction cost: The cost differential for EVSE installation is represented by the power interface. Considering a site's power sources and capacity will help plan for lower-cost installations that require less physical construction. • Proximity to power source: Installing the EVSE close to the required power source reduces the need for cutting, trenching and drilling to add new conduits to reach the EVSE. Additionally, the cost of installation can be reduced if the existing conduit has adequate capacity for EVSE.
Parking interface	• Parking Space Size: Availability of adequate parking space and minimal interference with adjacent traffic • Lighting: Visibility is critical for EV driver safety and helps to deter vandalism of the equipment. Most parking facilities are designed with lighting that is suitable for EVSE installations. Dim lights or cables can create tripping hazards • Accessibility: y to create spaces and routes that are safe and accessible to drivers of all physical abilities

Case study- San Pedro District of Los Angeles[9]

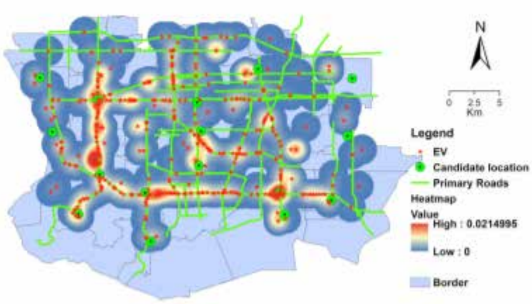
A general-purpose simulation software—The EV Virtual City 1.0 using Repast was used. The Repast based tool is a Complex adaptive system composed of interacting and autonomous variables which influence each other. With this kind of modelling, the full effects of diversity of a dependent variable can be brought forward and how they lead to overall dynamic behavior of a given system can be determined.

The simulation software is designed to construct a virtual digital city by integrating a variety of data and information, such as geographic information, demographic information, spatial infrastructure data, urban road network graph, electric power network graph, travel pattern, diurnal variation in traffic flow, seasonal fluctuation of driving activities, social interaction, etc.

Traffic related data: Data of San Pedro District of Los Angeles was used. The road network data from the U.S. Census Bureau is uploaded into the simulation software. In addition, the centroids of locations of residence, restaurants, supermarkets, shopping centers and workplaces using Google Maps is determined.

Figure 11: Snapshot of Traffic Data of Sand Pedro District

Snapshot of traffic data



Source: Lou et. al, 2015, "Placement of EV Charging Stations – Balancing Benefits Among Multiple Entities". IEEE

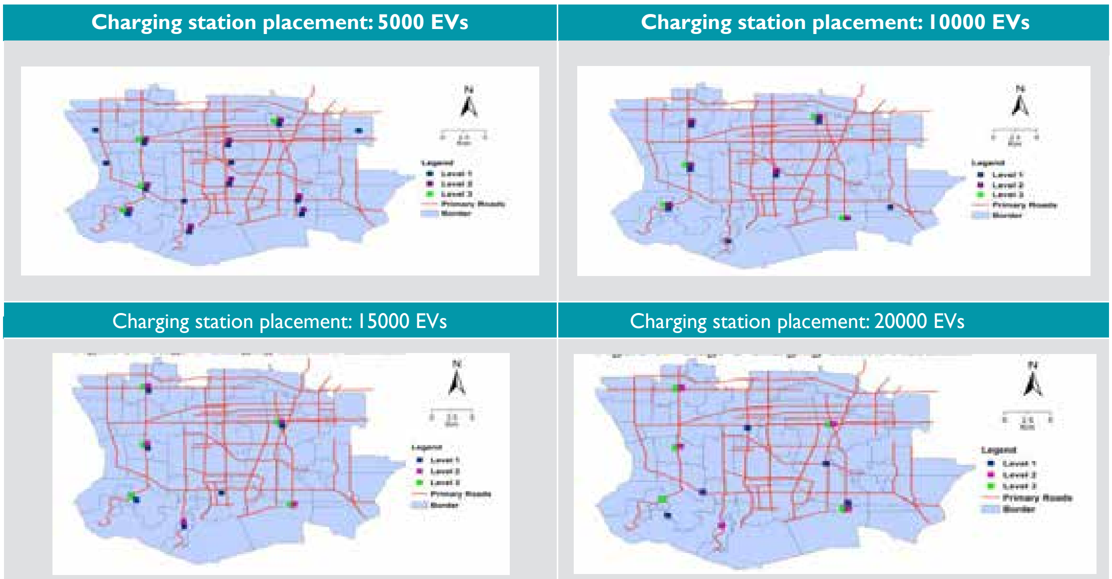
[9] *https://arxiv.org/pdf/1801.02129.pdf*

Distribution network data: From the California Energy Commission website, maps of transmission line and substations of San Pedro District were obtained and used in the simulation. This area has 107 substations in total. For each charging station placement option, the simulation used MATPOWER to calculate power flows, losses, and loading levels with and without EV charging.

The simulations were done for different EV penetration scenarios viz. 5000 EVs, 10000 EVs, 15000 EVs, and 20000 EVs.

Results of the simulation are summarized in following tables:

Figure 12: Illustration of charging station placement with varying EV penetration



Source: Lou et. al, 2015, "Placement of EV Charging Stations – Balancing Benefits Among Multiple Entities". IEEE

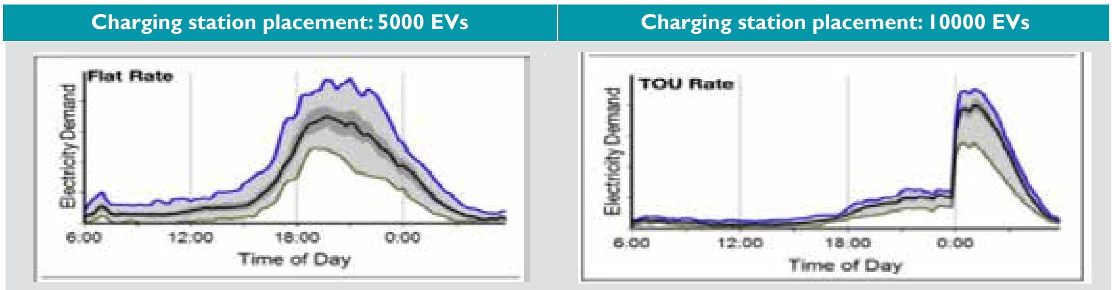
1. The optimal charging station deployment is consistent with the traffic flow heatmap
2. Level 1 charging station is predominant over Level 2 and Level 3. Level 1 service provider must place more charging stations since more of them are required to charge the EVs than the fast charging station
3. Level 1 charging stations are placed evenly across the entire area, while level 3 is more likely to be placed at high traffic locations
4. At the initial stage, Level 1 and Level 2 charging stations are placed more than the next stages. This is because of the fact that service providers must place more charging stations to meet the service coverage constraints. As the number of charging stations increases, however, the service coverage constraint is less of a concern for the service providers since gradually fast charging stations also come up.
5. A key inference of the simulation is that charging stations are clustered. This suggests that service providers prefer clustering instead of spatial separation since consumers using level 3 chargers won't use level 1 and vice versa and hence the competition risk tends to even out if clustered.

3.4 Modelling and simulation to understand the impact of EV charging

As the aggregate load of EVs increase, utilities will need to address couple of issues, primary among them are the following:

1. **Impact on distribution grid infrastructure:** Generally, EV drivers on flat electricity rates tend to plug in to charge their cars upon returning home. If a large number of drivers in a neighborhood return home and commence charging at the same time, there could be a sudden spike in demand which may exceed the capacity of the distribution transformer or other local network infrastructure. Rather than increasing the capacity of the distribution grid, shifting load to times of day when the grid is underutilized is an effective means of providing additional electricity without investing in grid upgrades. This could be carried out using workplace or business charging where EV users can charge their vehicles during low demand hours when the grid is typically underutilized, which would not only increase the utilization factor of the network but would also result in less technical losses in the distribution system. Adequate incentives and policy / regulatory provisions mandating workplace charging could lead to adoption of the same.
2. **Impact on Power procurement:** One of the benefits of EVs is increased electricity sales but with growing penetration of renewables, it is economic to procure cheaper off-peak power over expensive peak power, and shift demand to times of day when electricity rates are lower. In addition, as variable renewables increase their share of the power supply, there would be an increasing need to match flexible loads like EVs to available supply.

Figure 13: Comparison of load profile with different EV charging scenarios



Source: NRECA, US

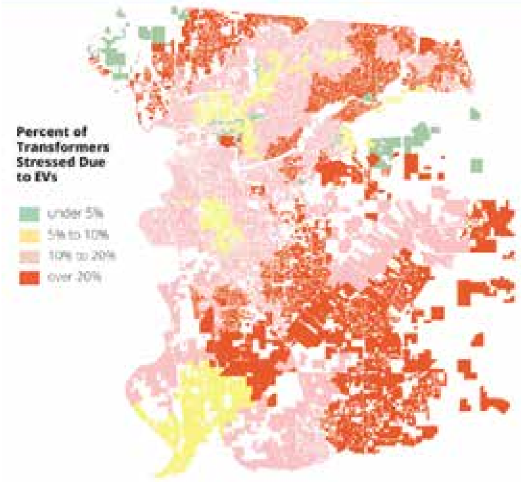
Thus, utilities will need to adopt several strategies to address these impacts, increase load factor to avoid the need for expanded infrastructure, and align EV charging load with supply. Generally, in the US, more than 70 percent of EV charging occurs at home (ERPI 2018, INL 2015). EVs are generally at home overnight and for long periods of time, allowing flexibility in when the vehicle is charged.

Case Study on EV impact on transformers (Sacramento Municipal Utility District (SMUD))

Sacramento Municipal Utility District (SMUD) has experienced significant DER growth in its service territory over the past decade. To anticipate future necessary investments required in its network and prepare itself for increased integration of EVs, the utility commissioned Black & Veatch to provide an integrated forecast of customer-side DER growth and estimate costs for any necessary distribution infrastructure upgrades. The study was conducted by SEPA and Black & Veatch, under a high-penetration DER scenario that included 240,000 EVs by 2030. It was assumed that nearly all EV owners would take advantage of SMUD's current EV rate, which encourages customers to charge between midnight and 6am, and this led to significant load increases during these night-time hours that caused the transformer overloads. It was found that:

- Up to 17 percent (12,000) of SMUD's service transformers may need to be replaced due to overloads
- Cost of replacement of service transformers would be at an average estimated cost of $7,400 per transformer.
- EVs would have considerable impact by 2030, and the transformer replacement costs translated to about $100 per EV.
- The study also brought out findings on % of transformers which would likely be stressed due to increased uptake of EV charging. The adjoining map indicates that there would be significant number of transformers stressed in the utility area due to uncontrolled charging.

Figure 14: EV Impact on Transformers in SMUD Service Territory through 2030



Source: Smart Electric Power Alliance, Black & Veatch, and SMUD, 2017

SMUD inferred that if EV charging is concentrated during a limited number of hours, managed EV charging was recognized as one potential solution to reduce transformer stress and defer upgrades (and possibly provide other grid services), as long as the cost of the communications infrastructure is low enough that managed charging can provide a net benefit. Another solution is rate-based incentives for EV owners to charge during the middle of the day to absorb excess PV generation. Moreover, The Sacramento Municipal Utility District estimates that one-way smart charging will reduce grid upgrade expense by over 70%.

Note: These results represent an EV adoption scenario that is 30-60% higher than SMUD expects in reality, and total upgrade costs could be lower if cheaper mitigation solutions are available. Today, only about 30% of EV owners in SMUD's territory take advantage of the EV rate, so charging may not be as concentrated during night-time hours as this analysis assumed. Each utility will need to conduct its own analysis to determine where EV adoption is likely to occur and how charging behavior affects utility infrastructure costs.

Managed charging can be broadly sub-divided into two main categories: **Passive** and **Active** managed charging. **Passive managed charging** relies on load control through behavioral changes in consumers. The energy service provider attempts to influence the EV charging behavior by incentivizing certain behavior patterns through predetermined time-of-use rates for charging or other such incentivizing programs.

Active Managed charging involves taking direct control of the charging process through advanced telematics sent from the Load Dispatch Centre (LDC) to the vehicle or the charging station. These signals can then be leveraged by the LDCs through aggregators for providing grid services such as emergency load reduction, regulation or absorption of excess generation of RE sources.

3.5 Uncontrolled charging and undertaking managed charging

3.5.1 Early stage adoption of EVs

A key foundational initiative by utilities in various parts of the world has been to understand the importance of EVs and aiming to raise consumer awareness. This strategy involves adoption of in-house EVs, educating customers through awareness campaigns, and demonstrating use cases and applications.

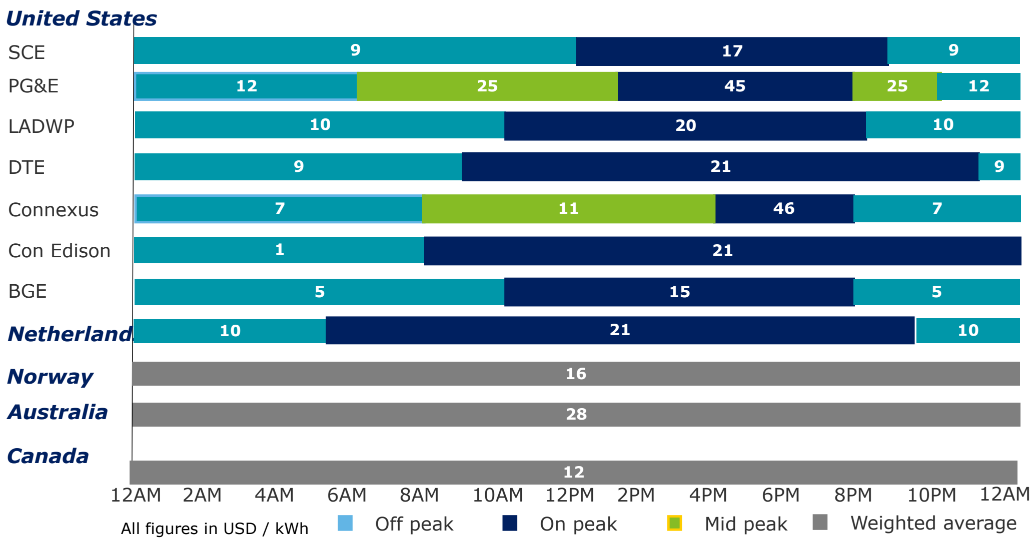
Table 14: Case studies on initiatives taken for early stage adoption of EVs

Case study	Details
Florida Power & Light, Florida	In 2006, FPL became the first energy company in the nation to place a medium-duty hybrid-electric bucket truck in service. Today, its clean vehicle fleet includes 1,849 biodiesel-powered vehicles and 493 electric and hybrid-EVs, which use up to 60% less fuel and reduce exhaust emissions up to 90%. FPL promotes the use of EVs for its company, employees, and customers. To help advance the adoption of clean driving technology in Florida, the company participates in events and offers information on its website: FPL.com/EV, where customers can learn more about EV benefits, charging requirements, workplace charging, and public charging options.
Tampa Electric Company, Florida.	Aside from a website that includes resources for types of EVs, charging options, links to U.S. Department of Energy cost calculators and a map with charging infrastructure locations, Tampa Electric is the first electric utility in the country that offers an innovative energy education program focused on EV technology.

3.5.2 Passive Management - Offering rebates and special tariffs

Indirect control refers to incentives that can be in the form of price signals, rewards programs, and other methods that incentivize EV users to undertake vehicle charging during off peak periods when the load on the distribution grid is the least. Many utilities in the United States adopt an initial EV specific time-of-use (TOU) rate to influence drivers to shift their EV loads to off-peak times of the day. This is more of a passive/indirect approach but allows customers to reduce their energy bill and encourages EV charging when the grid is under-utilized and under less stress, such as afternoon/night-time hours. Examples of various utilities offering TOU tariffs are highlighted below:

Figure 15: TOU tariffs for EV charging provided by different utilities in US



Source: Tariff schedules, 2019

On average, the weighted electricity price (i.e., time-weighted) ranges from 10-15 US cents per kWh for EVSE operators. Typically, off-peak rates occur overnight and on-peak rates in the morning and evening hours.

Table 15: Additional provisions introduced by utilities providing EV charging tariffs

Case study	Details
Braintree Electric Light Department, Massachusetts	Through its Braintree Drives Electric program, Braintree Electric Light Department encourages customers to attend EV workshops, test drive cars, and acquire EVs. The utility offers customers an $8 monthly credit, the equivalent of about 175 free miles, for charging at offpeak times. Advanced smart meters help the utility collect data on charging patterns and enable the utility to verify customers are charging during off-peak times.
Wrighthennepin Electric Cooperative, Minnesota	This utility offers residential customers two pricing options for charging EVs at home. Customers can choose between a TOU program and a Storage Charge program. The Storage Charge program lets customers charge during off-peak hours and sets the energy rate at $.054 per kWh for that time. For the TOU program, the charging circuit runs through the meter to accurately track the car's charging, and charges the customers according to the time of charging.
San Diego Gas & Electric Company (SDG&E), California	Customers in apartments, condominiums, and workplaces have access to charging stations with an EV rate structure that reflects the hourly cost of electricity. Dynamic Hourly pricing is set the day before, and customers use a phone app to enter their preferences for maximum energy price or/and amount of hours to charge

Source: GTG-RISE research

Some small electric cooperatives in the US offer whole-home and EV TOU rates as shown below:

Table 16: EV charging tariffs provided by cooperatives in US

Cooperative	Rate type	On-peak ($/kWh)	Off-peak ($/kWh)
Berkeley electric	Whole-house	0.239	0.059
Connexus energy	EV	0.455 (summer) 0.345 (winter)	0.073
Illinois	EV	0.085	0.05
Lake region	EV	0.4734	0.0707
Minnesota Valley	EV	0.397	0.065 (summer) 0.049 (otherwise)
New Hampshire	EV	0.23608	0.10468
Randolph Electric	Whole-house	0.4641	0.0546
	EV	0.3642	0.0843

Source: Tariff schedules, 2019

To summarize, indirect control strategies using TOU pricing has the following requirement, benefits and key challenges:

Table 17: Requirement, benefits and challenges of indirect EV control strategies

Particulars	Details
Requirement	If the price signal applies to the EV separately from the rest of the home, a second meter and/or a Level 2 EVSE is necessary for metering
Benefits	• Effective at shifting load to off-peak times • No losses for utility if rates are set so that they reflect the cost of power
Challenges	• Installing a separate meter and/or Level 2 EVSE adds significant cost to the implementation of this strategy. • Owners may have little / no incentive to install a Level 2 EVSE, and the utility misses out on an opportunity to install the equipment necessary for future direct control. • Utility may experience sharper peak at off-peak times if all EV owners schedule their charging sessions simultaneously during off-peak periods. This will necessitate some form of controlled charging from utility side to avoid sharp charging peaks.

3.5.3 Offering incentives for EVSE

National-level charging infrastructure programs have been essential for boosting rapid deployment of charging stations. For example, China, US, France, Japan, and Norway have developed incentive programs for the installation of EVSE. The following is a high-level overview of such programs:

Table 18: Incentives for creating EVSE in different countries

Country	Program	Budget	Mechanism of support
China	• State Grid national fast charging corridors • Regional investments by automakers • City government-funded construction in pilot cities		• State-owned utility programs • PPP • Grants to local governments
Germany	Deployment of 10,000 Level 2 and 5,000 DC fast charging stations	$285 million	Subsidies for 60% of costs for all eligible businesses
Japan	• Next Generation Vehicle Charging Infrastructure Deployment Promotion Project • Nippon Charge Service government-automaker partnership	$1 billion	• Grants to local governments and highway operators • PPP
Norway	Deployment of charging stations through grant scheme from 2009 onwards		Quarterly calls for proposals for targeted projects
UK	DC fast charging stations along major roads in England	$12 million	• Municipalities apply for grants • Grants and tenders administered by public body

Source: Deloitte research

3.5.4 Active Managed Charging for System Stability

As the level of EV penetration increases in the distribution system, impact of EV charging on distribution system load patterns can become significant. Managed charging can help utilities meet the challenge of maintaining network reliability with high EV penetration. As per Smart Electric Power Alliance, managed charging allows a utility or third-party to remotely control vehicle charging by turning it up, down, or even off to better correspond to the needs of the grid, much like traditional demand response programs.

Active managed charging—also called vehicle-to-grid integration (V1G), intelligent, adaptive, or smart charging—allows a utility or third-party to remotely control vehicle charging by any of the following means:

- Modulating the charging by delaying the start/stop of charging period
- Increasing/reducing charging rates which is also called throttling; this leads to change in amount of electricity drawn, or
- The utility can also resort to turning off the charging to better correspond to the needs of the grid at times of high stress.

<u>Accommodation for customer preferences:</u>

As the primary focus of managed charging is for charging of EVs, customers may have concerns about their EV not getting adequately charged. Any managed charging methodology must take into account customer preferences to ensure higher participation. To ensure good implementation of managed charging, customer preferences need to be put at the highest priority.

Utilities can decide which managed charging control strategy to implement based on factors such as customer preferences, level of EV penetration in network, and infrastructure available to implement passive and active controls. While passive charging management can induce customers to shift their EV charging loads, a sudden onset of EV charging loads during the off-peak period can lead to steep surge in load on the distribution transformer at the onset of the off-peak period. Ideally, this concern can be addressed by staggering charging times using an intelligent assessment of charge status of vehicles, obtaining desired departure time of vehicles, the charge rate, and other factors, thus distributing the charging across a wider time window. Overall, there are several benefits of managed charging described as follows:

Table 19: Advantages of EV managed charging

Advantages	Particulars
Improve grid economics	By modulating/varying the charging levels to reflect the grid conditions, managed charging can achieve higher utilization rates, and therefore capacity factor of generation assets (increased charging rates during off-peak period and reduced rates during peak load/overload conditions)
Reduction in emissions	Managed charging can reduce emissions by aligning charging with surplus renewable generation, thereby creating a scenario where excess renewable capacity can be absorbed in the system, such as photovoltaic (PV) production during peak solar hours and wind spikes during off-peak hours.
Reduced stress on the grid	Managed charging can reduce grid stress and maintain grid stability by minimizing charging ramp rates and reducing the strain on local distribution transformers which tend to be overloaded during peak period.
Capex deferral	Managed charging can reduce the need for new peak generation and distribution capacity resulting from EVs charging during peak hours.
Reduction in T&D losses	Modulating the amperes flowing through the charging station can also result in reduction of technical losses in the distribution system
New market opportunities	Capacity and ancillary market services such as frequency regulation and spinning reserves.
Benefits to EV consumer	Economic returns to EV owners by reducing the cost of charging through dynamic rates and potential payments for the supply of ancillary services.

1. Types of managed charging and key requirements for implementation:

One of the most common method to implement managed charging is through Automated Demand Response (ADR). In this case, the utility cuts power to the EV during peak load periods, curtailing load in order to reduce peak demand. Curtailment events may be initiated using a load control switch or a Level 2 EVSE. A standard practice by utilities is to automatically "opt-in" EV users into the demand response program (i.e., users need to contact the utility if they wish to opt out of the program). Utilities can use an ADR approach to limit charging to off-peak hours. The

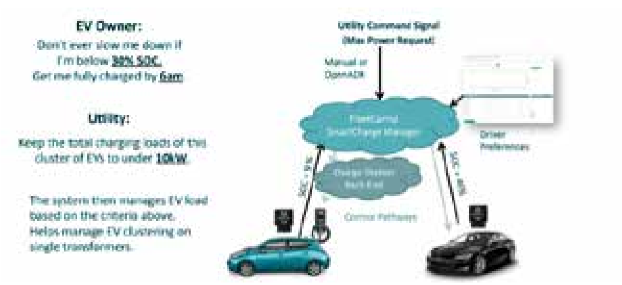
EV charging circuit, in this case, would need to be controlled separately from the rest of the house, using a load control switch or a Level 2 EVSE.

Table 20: Requirement, benefits and challenges of Automated Demand Response

Particulars	Details
Requirement	Load control switch or Level 2 EVSE installation would be required for load curtailment
Benefits	Automated demand response will yield more curtailment than voluntary DR since it is managed by the utility themselves. Presents the opportunity to incentivize installation of Level 2 EVSE for managed charging
Challenges	Load control switches do not facilitate managed charging control strategies

Under active controls, EV consumers provide rights to utilities and energy service providers to manage EV charging using a common communication and hardware protocol made available at the consumer and utility/energy service provider's end. The following are the pre-requisites for implementation of managed charging:

Figure 16: Illustration of basic requirements for managing EV clustering



Source: fleetcarma

- **Setting of User preferences:** A vital input to managed charging is driver preferences for charging. Typically key attributes which act as an input for smart/ managed charging from the user perspective are EV owners' time of next departure, minimum charging levels required for next trip, other preferences viz. fast charging till 30% SOC and slow charging thereon, etc.
- **Signaling of utility DR events:** The signals which utility would send to EVs and vehicle chargers combines messaging, or application, protocols (e.g., OpenADR 2.0, OCPP) and transport layer protocols, also known as network communication interfaces (e.g., Wi-Fi, cellular). The messaging protocol contains the instructions that would affect the charging behavior of the EVs i.e. do not charge until after midnight, or charge after 3am etc.—while the network protocol ensures a message gets from point A to point B, but does not provide any instructions or guidance as to behavior of the receiving devices.
- **Assessment of vehicle parameters:** Manage charging will work through an intelligent assessment of charge status of the vehicle, incorporating customers' desired "charge by" times, the charge rate, and other grid factors. The charging time could be distributed across a large time window
- **Determining the charging levels:** Different EV charging levels offer different potential for managed charging. Long- duration of charging with Level 1 or Level 2 provide more time for managed charging events and flexibility for deferring customer charging. Alternatively, the high power demand of DC Fast Charging (DCFC) may be less attractive

- **Communication Pathways:** Communication between the EV user- EV / EVSE, utility-/grid-operator, aggregator, EVSE provider, EVSE and the vehicle itself are critical factors for effective managed charging.

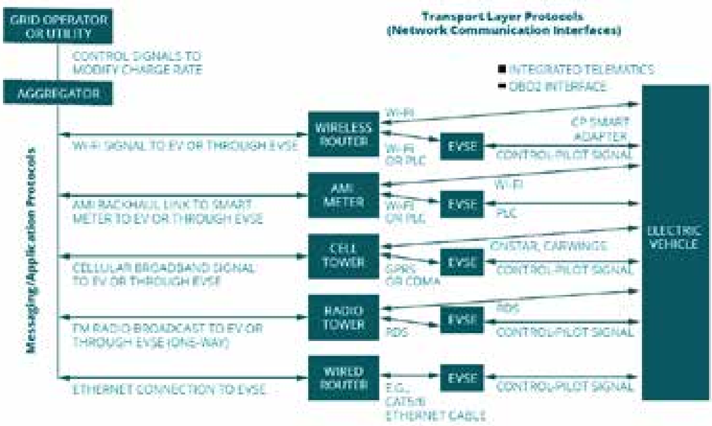
Smart charging can occur in either a centralized (via aggregators) or decentralized manner. In the centralized framework, EV load aggregators act as an intermediary between vehicle owners and grid markets and contract power demand from several EVs. In the decentralized framework, individual EVs respond to market information made available to them.

As per SEPA, various modes of transport layer are mentioned below:

Table 21: Communication requirements to implement managed charging

Medium	Details
Wi-Fi	Wi-Fi signal can be sent directly to the EVSE via Control Pilot (CP) Smart Adapter or sent directly to the car by using a telematics link or on-board diagnostic interface (OBD2).
AMI	Utility AMI backhaul link to a smart meter, using Power Line Carrier (PLC) protocols (e.g., Green PHY), and wireless networking protocols (e.g., Wi-Fi, ZigBee) which send signals directly through power lines.
Cellular network	Cellular broadband signal can be sent to the EVSE by using Global System for Mobile communications (GSM), which sends data via code division multiple access (CDMA) low bandwidth wireless connections (data speed requirements for EVSE can also vary, e.g., 2G, 3G, 4G, LTE) or general packet radio service (GPRS). Cellular signals can also be provided to the vehicle through onboard integrated communications
Radio network	FM radio broadcast through a Radio tower to embed digital information directly to the vehicle or the EVSE.
Ethernet	Ethernet also called as Local Area Network (LAN) connection to the EVSE

Figure 17: Communication protocol for managed charging



Source: Smart Electric Power Alliance, Black & Veatch, and SMUD, 2017

Telemetry and equipment interoperability are a challenging barrier for managed charging. The main roadblock is in finding a cost-effective way to send communication signals while also being reliable, and customer-friendly. Figure 12 illustrates the links in the chain of communication between the utility and the vehicle.

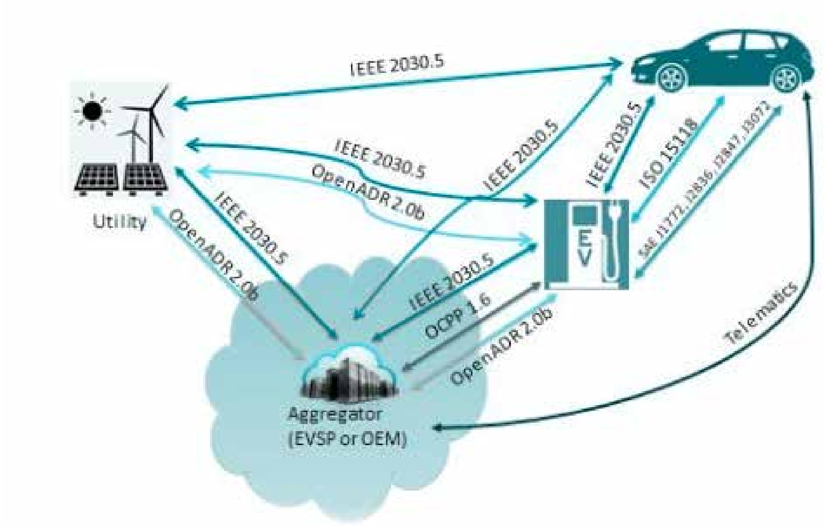
Messaging Protocol: In EV managed charging, messaging protocol signifies the rules, formats, and functions for exchanging messages between **EV, charging station, and**

charging station network. Following are **two types of messaging protocols** widely used in managed charging:

Table 22: Managed charging messaging protocols

Type of protocol	Details
Open source	• For managed charging, it is vital that uniform and non-proprietary communications / messaging protocols are used between the EVSE and EV, for e.g. ISO/IEC 15118 that enables the managed charging functionality in an EV and can give an improved EV consumer participation. • The Electric Power Research Institute (EPRI) is synchronizing a software application (Open Vehicle Grid Integration Protocol) that connects EVSE and EVs to various nodes to allow utilities to more dynamically manage charging activity that could help with a variety of grid applications. Details are given in annexure • The standards followed by the OVGIP are IEEE 2030.5,36 ISO/IEC 15118, and telematics with utility standard interface protocols (i.e., OpenADR 2.0b, IEEE 2030.5) and EV charger application program interfaces (i.e., ISO/IEC 15118, OCPP, and industry applied standard and proprietary APIs) through a common platform.
Proprietary	GPS tagging • Vehicles can be managed through an on-board diagnostic interface (OBD2) which has built-in capabilities, like GPS location software, which can be managed according to the local grid circuit Programming capabilities • Currently multiple EVs already have the ability to program their charging window that would enable the user to align charging with TOU or other EV rates. A more advanced way to strength, these vehicles would for the utility or aggregator to send price, emissions, or grid stress signals directly to the vehicle, so that the EV's charging program could use the information to modify its schedule of charging the vehicle time. • Some examples that are using Proprietary protocol are eMotorWerks JuiceNet, Siemen's VersiCharge platform, and Itron/ ClipperCreek's OpenWay network.

Figure 18: Basic schematic of managed charging



Source: CAISO, 2014, "Vehicle-to-Grid (VGI) Integration Roadmap"

Table 23: Requirement, benefits and challenges of EV managed charging

Particulars	Details
Requirement	Level 2 EVSE, EV capable of managed charging, Communication pathways, networking and messaging protocols, utility readiness, technological partners etc.
Benefits	Allows the utility to match demand and supply in real-time, avoid rebound peaks associated with off-peak structures, and provide charging-as-a-service to members. Opens the potential to aggregate EV resources for V2G services.
Challenges	Utility takes on the responsibility of providing EV charge to member expectations. Requires various user and grid inputs Currently technology is still under development and only a number of pilots have been done

2 Case studies on managed charging implemented by utilities

Case study - Maui Electric, Hawaii[10]

Maui Electric offers residential customers a discounted TOU rate from 9 a.m. to 5 p.m. when solar and other renewable energy options are readily available. This rate requires customers to install a separate meter at no cost to the customer.

TIME-OF-USE CHARGES

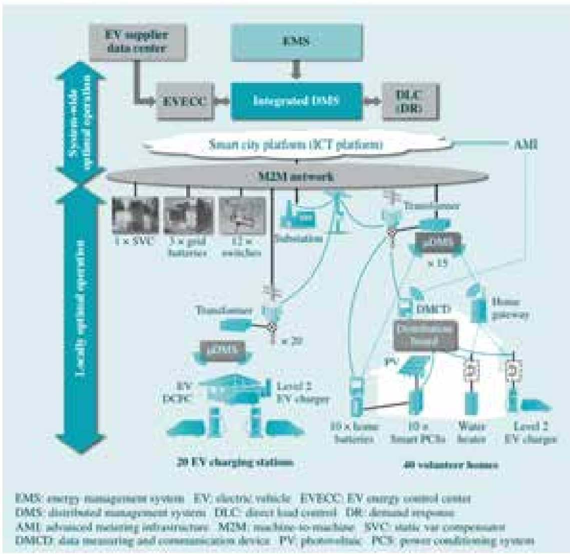
On-Peak Period – per kWh 39.2152 ¢/kWh

Mid-Day Period - per kWh 14.0098 ¢/kWh

Off-Peak Period – per kWh 38.1370 ¢/kWh

Through the JUMPSmartMaui pilot with Hitachi and Nissan Leaf owners, volunteer drivers were provided with EV-Power Conditioning Systems (EVPCS) in their homes. The purpose of this EVPCS system is to allow utility operators to manage EV charging to balance generation and power demand

Figure 19: Managed charging schematic for Maui electric



System overview

The project aims to improve the convenience of using EVs in order to encourage their adoption by installing EV direct-current fast chargers (EV DCFCs) at five sites around Maui, and subsequently at an additional 15 sites. The sites were selected based on an analysis of traffic patterns and distances from homes, offices, and tourist sites.

[10] *http://www.hitachi.com/rev/pdf/2014/r2014_08_102.pdf*

[11] *Source: https://www.mauielectric.com/products-and-services/electric-vehicles/electric-vehicle-rates-and-enrollment*

https://www.mauielectric.com/documents/billing_and_payment/rates/maui_electric_rates_maui/maui_rates_tou_ri.pdf https://www.mauielectric.com/a/5052

To provide the island with an energy infrastructure that does not depend solely on fossil fuels, it also used the EVs as batteries to absorb excess energy and to stabilize a grid that has a large installed capacity of renewable energy. In addition to installing EV DCFCs, the project also included systems for the home (standard EV chargers, water heaters, and PV power generation) and large grid batteries.

The EV Energy Control Center (EVECC) described below provides integrated energy management for the island and exchanges information with an integrated distributed management system (DMS) and energy management system (EMS) located in the control room at the Maui Electric.

Hitachi supplied:

1. variable-output EV DCFCs with direct load control (DLC) function and the ability to be coordinated with existing generation plants.
2. a charging management system that supports the EV DCFCs

Operation of charging management system

The charging management system works as per the following constraints:

1. allocates a total output capacity of 60 kW between the vehicles, with the precedence for charging being determined by the order in which they were connected. Once the charging of one vehicle is complete, the charging of the next vehicle commences.
2. Minimize excessive disconnections to maintain supply and demand balance.
3. Complete control operations within a fixed time.
4. Minimize disruption to consumers caused by restricting power demand.

The charging management system, which performs integrated management of the chargers via a machine-to-machine (M2M) network, collects information on charger operation and provides information via web screens to EV users. Users can choose an appropriate time to charge their EV by accessing the web screens to check whether sites are in use or undergoing maintenance.

The EVECC acquires information from the integrated DMS about the balance of supply and demand on the grid, and state of charge (SOC) information (how much power remains in the EV batteries) from the EV supplier's data center. It can also perform a load shifting to balance supply and demand for electric power.

1. First the integrated DMS obtains information about the supply and demand for electric power, including renewable energy, from the EMS at the power company's control center,
2. The DMS then uses this to produce a schedule of when excess energy is likely to be available.
3. Next, the integrated DMS and EVECC exchange information about the supply and demand balance and EV charging schedule so that the EVECC can revise this schedule.
4. Finally, the EVECC controls when EV charging should start and end to utilize the excess energy.

5. Micro distribution management systems (μDMSs) installed on low-voltage transformers monitors the voltage on the low-voltage grid. When a μDMS detects a fault or overload condition of distribution network, the initial response to protect the concerned DT is to issue power control commands to smart power conditioning systems or to turn off / reduce EV charging to avoid voltage deviations. In some cases, the supply and demand balance is maintained by using the DLC (Direct Load Control) function to disconnect consumer loads such as water heating or EV charging.

Source: Hiraoka et. al., 2014, "Island Smart Grid Model in Hawaii Incorporating EVs", Hitachi Reviews.

Case study - Southern California Edison

SCE utilized a workplace charging pilot[12] which included the following options:

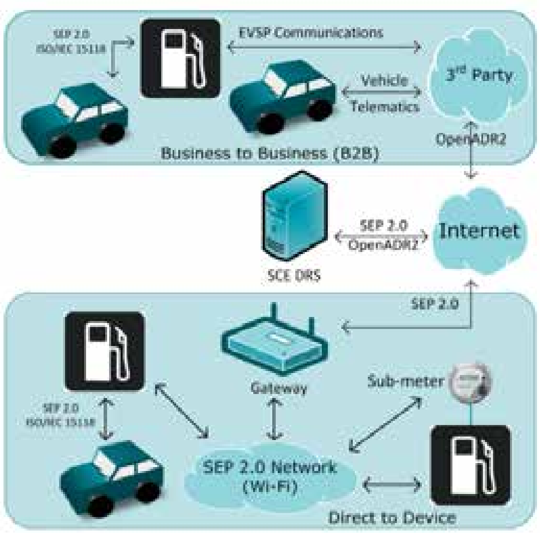
1. allowing users to have no charging disruption;
2. allowing for peak demand curtailment from a faster Level 2 to a slower Level 1 charging rate;
3. allowing drivers to be entirely curtailed during a demand event.

Even if an EV owner who has registered for load curtailment, he/she can opt out through a manual override feature which would cause the EV to charge as-usual.

SCE used OpenADR 2.0b and OCPP for the communication signals. The Pilot evaluated two possible 'paths' of over the internet communication that could be deployed for residential EV load management programs: Direct and Business to Business (B2B)

1. Demand response server: The server provided an operator portal that was common to both protocols and could be used to manage events, collect, display and provide data, provide the required customer notification (email, text, voice mail) and opt-out capabilities
2. Direct communication to devices: SCE communicated Demand Response signals directly to EVSEs via an internet gateway (GW) that was an Ethernet/SEP 2.0 client on the Wide Area Network (WAN) side and Wi-Fi access point/SEP 2.0 server on the Local Area Network (LAN) side. EVSEs and apps polled the GW server for events and the GW client in turn polled SCE's SEP 2.0 DRS

Figure 20: Managed charging schematic for SCE



[12] *http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/B2DF49B3487114808825 7FBE0073125F/$FILE/R1309011-A1410014-SCE%20PEV%20Smart%20Charging%20Pilot%20Final%20Report%20.pdf*

for DR events and other SEP 2.0 communications. Polling rates were set for 5 minutes. Similarly, meters posted data to the GW server and the GW server posted meter data to SCE's SEP 2.0 server. Posting rates were 5 seconds.

3. Integration with EVSEs and meters for Demand response: SEP 2.0/Wi-Fi was integrated into the level 2 EVSEs and meters by selecting a suitable implementation partner. This was used to communicate the signals sent by DRS to the vehicles / EVSE

   A Raspberry Pi, a programmable controller that provides a set of GPIO (general purpose input/output) pins that allow to control electronic components, with attached Wi-Fi dongle was used for the communications and DR integration. This allowed SCE to throttle / reduce the power provided by the EVSE to the EV. On other EVSE where the Pi could not be attached, a relay already integrated into the EVSE was used to curtail the charging completely.

Figure 21: Key Hardware Components of PEV Smart Charging Pilot

Throttling-through Raspberry Pi	Curtailing-through relays
	

Source: Southern California Edison, 2016, "Plug-in Electric Vehicle (PEV) Smart Charging Pilot"

4. Business to business communication: In this a 3rd party (e.g., an aggregator) enrolls in a DR program and manages loads based on SCE called events
5. Electric vehicles: EV's used in this pilot were tested for being capable of both telematics communication and load management (e.g., the ability to stop charging remotely). Some vehicles tested already had these capabilities, while others were engineering (e.g., prototype) vehicles provided by the OEMs, with either communications, controls, or both.

3.6 Regulatory interventions for enabling EV charging

There are several regulatory barriers to the deployment of EV charging infrastructure including permitting of charging infrastructure, the lack of a technical standard for charging infrastructure, policy uncertainty, regulation regarding recovery of EV-related investment by utilities. To overcome these barriers, policies are needed to create a conducive environment for private sector investment in charging infrastructure — whether it be modifying building codes, streamlining permitting, or deciding a standard in consultation with OEMs, for example.

Based on a review of international case studies, four main regulatory interventions have been identified. These are as follows:

- Cost recovery of network upgrades necessary for supporting EV charging infrastructure
- EV charging specific tariff
- Creating a managed charging framework
- Market based framework for enabling EV and other DR providers to participate in ancillary services

These regulatory interventions focus on ensuring that utilities are able to invest and recover the costs in creating a back-bone for EV charging stations to be connected to the network. Further, it ensures that consumers are able to charge EV through utility network at affordable and competitive rates. Lastly, it allows utilities to manage the charging behavior of EV consumers to ensure network reliability and enables a market framework for EVs to participate in demand response. These interventions are highlighted in detail in the following sections.

3.6.1 Cost Recovery of Network Upgradation and EVSE Infrastructure

Utilities play an important role by undertaking investments in network upgrades and adopting tariff structures for supporting EV charging ecosystem. Regulators can facilitate utility network upgrades for grid modernization through providing utilities with clear channels of cost recovery and guidance on required technologies.

Utility investments in infrastructure to support EVs, including system upgrades, dedicated meters, and workplace or public EVSE, could be funded by distributing the costs across all customers. In the US, this practice is known as "rate-basing." Rate-basing investments add only a small amount to customer electricity bills, and regulatory agencies may encourage these investments due to their potential to increase utilization of the electric grid and incentivize wider adoption of EVs and drive down rates for all ratepayers.

There are several reasons why rate-basing upgrade costs (if any) – at least for an initial period – make sense.

- Rate-basing costs is much simpler than trying to ascertain individual customer responsibility for an upgrade
- Imposing distribution facility upgrade costs on specific consumers may discourage them from purchasing an EV or "smart charging" equipment that could actually benefit the grid by facilitating off-peak load and improving grid utilization.
- Impact of EV charging on the distribution system has been minimal and hence the investments if spread across all consumers will also have minimal impact.

The state of California issued the state policy goals under Assembly Bill (AB 32) to reduce greenhouse gas emissions and the related ARB Scoping plan which includes a comprehensive strategy to reducing greenhouse gas emissions from the transportation sector. Electrification of vehicles is a critical component of the ARB's 2008 Scoping Plan. Electric Tariff Rules-Rule 15 (Distribution Line Extensions) and Rule 16 (Service Line Extensions) pertain to grid equipment used by multiple customers, for example, a transformer serving multiple homes and network equipment used by just one customer respectively.

As per California Public Utilities Commission (CPUC), the rationale for adoption of rate basing of EVSE is highlighted below:

Table 24: Rationale behind adoption of rate basing by CPUC

Particulars	Rationale
Utility expenses vs customer expenses	An upgrade to equipment which has the potential to serve multiple customers is generally considered a utility expense and the associated cost is borne by the general body of ratepayers and not just by the EV customer or just by the group of neighbors being served by the transformer.
Upgrade as a system asset and Rule 16 provisions	The cost to replace a shared distribution transformer, due to projected impact of additional loading by EVs, would be considered a total system asset and, as a result, should be included in rate base. On the other hand, the cost to replace an existing customer-specific service transformer would be at the customer's expense. A commercial or public charging station is hence considered as a system wide asset.
EV as a new and permanent load	The load profile created by EVs is similar to that created by other large residential appliances, such as large portable air conditioners and hence it cannot be considered as a temporary load created by specific customers.
Improved system utilization and reduced losses for managed charging	• Incremental EV load on a larger scale has the potential to yield improved electricity system asset utilization in the long-term. Benefits of the same would accrue to all customers of the utilities • On a large scale EV charging occurring during off-peak periods could actually reduce the price of energy for all ratepayers which would have otherwise been incurred by utilizing expensive peaker plants in on-peak periods. The benefits of the same would be realized by all customers
Residential level upgrades	Any expenses incurred over and above the standard residential allowances, if any given to EV owners, would be rate based provided that the additional expenditure pertains to only basic and necessary investments
Adherence to overall state goals	Adoption of EVs is based on California State's goal to reduce greenhouse gas emissions through the electrification of the transportation sector and hence any investments in achieving the same is as per the state goals.

Source: CPUC

The above provisions apply to utilities viz. Southern California Edison, Pacific Gas & Electric and San Diego Gas & Electric. However, the aforementioned provisions are construed as initial steps to build out charging infrastructure and help determine the best practices for long-term network growth.

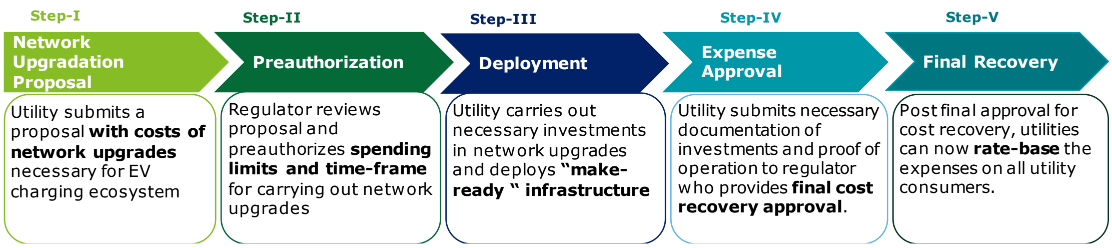
There are several U.S. utilities that have moved towards more progressive planning for electric vehicles, including deploying ratepayer – funded public charging infrastructure in order to accelerate the slow pace of growth in this sector. These programs are widely viewed as initial steps to build out charging infrastructure and help determine the best practices for long-term network growth. These programs differ in the scale, relationship with third-party EVSE provides, specific charging circumstances (e.g., home, workplace, multi-unit dwelling, etc.). However, although rate basing has been approved, regulators have only allowed a pre-determined number of charging stations, indicating that they are hesitant to let utilities fully control the market and instead let compensation be the driving force for expansion of charging stations.

3.6.2 Rate-basing of "Make-Ready" Infrastructure

Utilities are adopting a range of approaches while undertaking investments in network upgrades necessary for facilitating EV charging services. Supported by regulators, utilities in the US have taken an approach of investing in "make-ready" infrastructure where utilities set up the necessary infrastructure required for EV charging services providers to install charging stations. "Make-ready" infrastructure may include components such as necessary transformer and transformer pads, new service meter, new service panel, associated conduit and conductor necessary to connect each piece of equipment, and it can also include Smart Grid Devices.

While the "make-ready" infrastructure is owned by utilities, the EVSE is owned by charging service providers. A process chart followed by Department of Public Utility of Massachusetts for allowing cost recovery of Eversource utility's $ 45 million investment plan for development of EV charging infrastructure is as follows:

Figure 22: Process Flow for Cost Recovery



Source: Department of Public Utilities, Massachusetts

Regulators in India can explore mechanism/design to accommodate distribution utilities to recover cost associated with "make-ready" infrastructure in their Annual Revenue Requirement (ARR) filings.

Through the Charger Ready Program, SCE installs and covers the costs for make ready charging infrastructure , while participants own, operate and maintain the charging stations. The program also provides rebates towards the purchase of charging station. The Charge Ready Program will help grow the transportations electrification market by installing electric infrastructure at customer sites to support charging.

In the first phase, SCE installed approximately 1,000 EV charging points at over 60 sites in SCE's territory, including workplaces, public parking lots, hospitals, destination centres and apartment and condominium complexes were built. In Phase 2, which is yet to be approved, SCE shall support the installation of "make-ready" infrastructure at workplaces, other public locations and multi-unit dwellings, and provide rebates to cover a portion of the EV charger costs. Close to 32,000 charging ports at approximately 3,200 sits shall be built. At least 30 percent of the charging infrastructure shall be deployed in disadvantaged communities. SCE shall also be launching a number of other Charge Ready Programs and Pilots that support medium and heavy duty trucks, transit buses, port equipment and other industrial vehicles, as well as public and home-based charging for cars.

3.6.3 Tariff Framework for EV Charging.

Tariff for EV Charging at Utility Owned EVSE Infrastructure

Several regulators in US allow utilities to own charging stations in-order to avoid stifling of market competition except in particular cases where provisioning of charging service is an issue such as in disadvantaged communities. In cases where there is no restriction on utilities to own charging infrastructure, utilities have set-up charging stations along with the necessary grid facing infrastructure. In this case, utilities are allowed to recover the cost of "make-ready" infrastructure and EVSE through rate-basing.

For example, the CPUC allows "PG&E to include the EVSE it owns in its rate-base, because it will be utility property that is used and useful in rendering utility service". Similarly, SDG&E's "Power Your Drive Program" is a three-year, $45 million program to install, own, and operate 3,500 level 2 stations at workplaces and multiple unit dwelling locations. The projected increase in consumer electric bills is 0.02% per year, or about $0.18 annually.

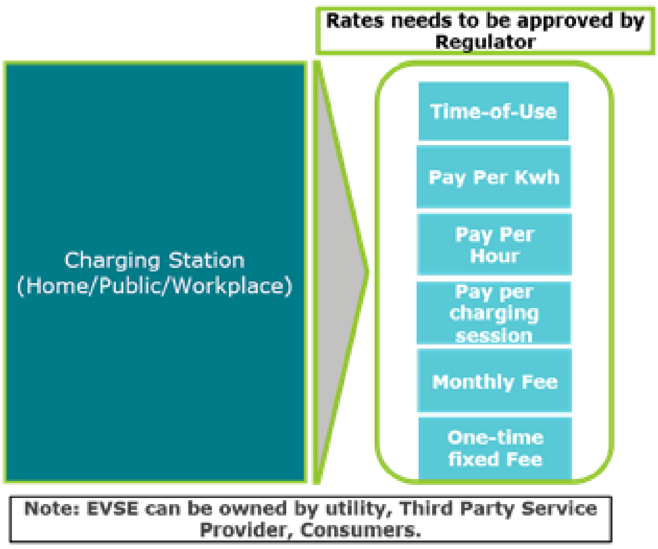
Florida Public Services Commission – Cost Recovery of EVSE

In November 2017, the Florida Public Service Commission approved a Duke Energy Florida settlement to allow the utility to own and operate an EV charging network with a minimum of 530 Level 2 and DC fast charger ports. Key details[13] of the pilot program include the following:

1. The Commission approved that DEF may incur up to $8 million plus reasonable operating expenses
2. At least 10 percent of the EVSE ports must be installed in low income communities
3. The EVSE program will be a pilot program ("Pilot") for five (5) years.
4. Electricity pricing: Where EV drivers make purchases directly from DEF when using the EVSE, said drivers will pay the appropriate Commission-approved rates/ prices for energy use at the EVSE
5. **Regulatory treatment:** DEF shall be authorized to defer the recovery of its EVSE program capital costs and operating expenses (full revenue requirements) to a regulatory asset that will earn DEF's AFUDC rate. Revenues generated through the EVSE shall offset the amount of the costs to be deferred to the regulatory asset. At the time DEF makes the filing described, but in no event sooner than the expiration of the Term, DEF will be authorized to **recover the amount of the regulatory asset over a four-year period through a uniform percent increase to the customer, demand and energy base rate charges**
6. The EVSE shall be subject to a depreciation rate of 20 percent.

Utilities can decide to recover the full cost of EVSE infrastructure through an increase in fixed charges; a mix

Figure 23: Charging Rate Structure



[12] *http://www.floridapsc.com/library/filings/2017/09951-2017/09951-2017.pdf*

of fixed and variable charges from EV charging services; or fully from EV charging services. In all cases, regulatory approval is required. A range of options can be considered for tariff rate structure design as shown in alongside.

In some states in the US, utilities have been relatively more active with EV development as a response to regulatory or policy activity. States such as Washington, Minnesota, Florida, Oregon, and California have all enacted legislation encouraging utilities to file applications for charging infrastructure with their public utility commissions. In 2015, California also enacted SB 350, which instructed the California Public Utilities Commission (CPUC) to direct the six in-state investor-owned utilities (IOUs) to submit programs that "accelerate widespread transportation electrification" to meet state goals. Similarly, the state of Minnesota required all public utilities to file an EV tariff with the commission.

Case Study – Tariff framework for EV charging in Minnesota

Under the Minnesota Statute 216B[14].1614 "ELECTRIC VEHICLE CHARGING TARIFF", by February 1, 2015, "each public utility selling electricity at retail must file with the commission a tariff that allows a customer to purchase electricity solely for the purpose of recharging an EV." It has been highlighted that the tariff must:

- contain either a time-of-day or off-peak rate, as elected by the public utility;
- offer a customer the option to purchase electricity:
  - from the utility's current mix of energy supply sources; or
  - entirely from renewable energy sources,
- be made available to the residential customer class.
- The commission shall, after notice and opportunity for public comment, approve, modify, or reject the tariff
- The commission highlighted several conditions for the tariff to be approved which include that:
- The tariff should appropriately reflect off-peak versus peak cost differences in the rate charged
- The tariff should include a mechanism to allow the recovery of costs reasonably necessary, including costs to inform and educate customers about the financial, energy conservation, and environmental benefits of EVs and to publicly advertise and promote participation in the customer-optional tariff
- provide for clear and transparent customer billing statements including, but not limited to, the amount of energy consumed under the tariff; and
- incorporate the cost of metering or sub-metering within the rate charged to the customer.
- The utility may at any time propose revisions to a tariff filed under this subdivision based on changing costs or conditions.

[14] *https://www.revisor.mn.gov/statutes/cite/216B.1614*

3.6.4 Tariff for EV Charging at Third-party Owned Infrastructure

In cases where EVSE is owned by third-party energy service providers, service providers can recover cost of charging stations through various routes. Several utilities operate on a model wherein service providers pay charges for total energy usage at the station to the utility based on TOU or flat rate tariffs. Service providers are then allowed to set their own pricing mechanisms to charge EV end consumers as shown in figure below. Regulators usually place an upper limit on charging rates that are allowed to be charged to EV end consumers by EV service providers. Examples of rate structures being currently followed in various places:

Table 25: Examples on Charging Rate structures

Type of tariff	City / utility	Details of user fees by third party providers	
		Type	**Details**
Per unit based on charging duration	ActewAGL-EVCI Provider	Basic Monthly Plan $10 Per 1 Month(s)	• FREE use of Fast Charger • 0 FREE minutes use of Rapid Charger • $3.50 per 15 minutes thereafter
		Budget Quarterly Plan $25 Per 3 Month(s)	• FREE use of Fast Charger • 30 FREE minutes use of Rapid Charger • $3.50 per 15 minutes thereafter
		Value Half Yearly Plan $45 Per 6 Month(s)	• FREE use of Fast Charger • 90 FREE minutes use of Rapid Charger • $3.50 per 15 minutes thereafter
		Freedom Casual Plan $0 Per Month(s)	• No monthly fee • $2 per use of Fast Charger • $5 per 15 minutes use of Rapid Charger
Pay per hour	Canada	Standard Charging Station: • The rate for 240-volt charging is either at a flat fee of $2,50, regardless of the length of charge or at an hourly rate of $1, billed by the minute and based on the amount of time the vehicle is plugged in. • Parking area charging costs $1 per hour, billed by the minute excluding parking fees. For example, if a vehicle is connected to a station for three hours, charging will cost $3.00, even if the vehicle was completely charged after one hour. Fast Charging Station: • The price of the 400-V fast charging station its $10 per hour, billed by the minute i.e., based on the total time connected to the station, not the duration of the charge or the total energy transfer. • Charging station in a parking facility that charges fees, parking fees must be paid as they are not included in the charging cost	

Source: Department of Public Utilities, Massachusetts

3.6.5 Defining standards for EVSE operations and managed charging

CPUC VGI recommendations for improved managed charging:

The California Public Utilities Commission (CPUC) Energy Division, California Energy Commission (CEC), California Air Resources Board (CARB), California Independent System Operator (CAISO), and Governor's Office of Business and Economic Development (GO-Biz) in 2017 led a working group to investigate whether the CPUC should require a communication protocol or protocols for the Electronic Vehicle service equipment (EVSE) and associated infrastructure that IOUs support with ratepayer funding. The study also revolved around suggesting standard specifications which would enable managed charging.

The working group evaluated the existing communication protocols utilized to enable EV management use cases in an effort to understand whether one protocol, or a specific combination of protocols, is mandatory to enable Vehicle-Grid integration (VGI) economically and at scale. The group's work included:

- Evaluating the technical requirements
- Mapping those requirements to the existing communication protocols
- Functional and non-functional requirements
- Hardware requirements
- List of recommended communication protocols for enabling VGI / managed charging

Earlier in 2017, California Energy Commission produced the VGI Roadmap which identified three tracks to direct the state's efforts: (1) Determine VGI Value and Potential; (2) Develop Enabling Policies, Regulations, and Business Practices; and (3) Support Enabling Technology Development. The VGI Roadmap identified activities intended to "increase consistency across technologies to enable interoperability and to provide guidelines for product development, while allowing for variety in VGI products and services." The Roadmap also highlighted the importance of the use of existing, internationally-adopted standards where "a common standards format ensures compatibility among multiple technologies, eases adoption by customers and increases certainty for developers about the access their products will have and about how their technologies can work with others." In particular, it notes how existing communication standards will be required to send messages between the VGI resource, aggregators, utilities etc.

The Electronic Vehicle Charging Stations Open Access Act15 (SB 454; Statutes of 2013) gives CARB (California Air Resources Board) the authority to adopt requirements to ensure public charging stations in California have interoperable billing standards, including a transparent fee structure, and allow the use of multiple payment methods. Participation in the Working Group has facilitated CARB's development of proposed requirements for publicly accessible charging stations.

CPUC highlighted the following key recommendations for managed charging:

Table 26: Key outputs and recommendations from CPUC study[15]

Key outputs	Details
Categories of use cases for EVSE	• Participation through Price Programs: These use cases influence drivers' charging habits by changing the price of electricity and differentiate between off-peak and on-peak. • Demand Mitigation: These use cases attempt to curtail peak demand use by encouraging customers to charge during off-peak times. • Vehicle Two-Way Flow: These use cases can influence charging behavior and also allow EV drivers and business owners to use electricity from a car battery. This category includes vehicle to-grid, vehicle-to-home, and vehicle-to-building use cases. • VGI Services: These use cases allow actors to access VGI services (e.g., demand response or load management programs) through the use of telematics, building management systems, network service providers and other pathways.
Identifying the entities involved	The actors involved were specified to understand the various interactions involved: • EV Driver (EVD) – who sets the charging preferences • Power Flow Entity (PFE) – An offsite entity that is requesting or mandating VGI activities from other actors downstream. • EV Battery System (EVBS) • DC Power Converter System (DCPC) – The off-vehicle power converter that controls DC energy flow to or from the EV Battery System. • EV Supply Equipment (EVSE) • Energy Meter (EM) • Building Management System (BMS) – A collection of sensors and controls intended to automate management of energy flow and use at a site location or facility • Smart charging network
Requirements needed for EVSE managed charging	• Functional (specific processes and functioning of the VGI system) • Non-functional (scalability, response time, reliability, data integrity, and interoperability etc.) • Customer requirements (controlling, opt-in, opt-out) • Other requirements (viz. manual override by customer, disconnecting EV loads by utility during emergency)
Key functional requirements stipulated for VGI / managed charging	• Information for communication back to grid viz frequency, voltage, location etc. • Pricing and tariffs • Load Control: communication of information from utility needed to respond to demand response signals for specific event • Smart Charging: communication of information needed to schedule charging sessions • Monitoring: communicating information about the charging session, including timing and electricity consumed and dispensed. • Restart: communicating information to affect the start of a charging session, including when charging is interrupted, to avoid overloading the electric system.

[15] *https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442460144*

<table>
<tr><th>Key outputs</th><th colspan="2">Details</th></tr>
<tr><td>Communication protocols for managed charging</td><td colspan="2">Following communication protocols are widely accepted whereas several others could be currently in development phase:
• Institute of Electrical and Electronic Engineers19 (IEEE) 2030.5
• Open Automated Demand Response[16] (OpenADR)20 v2.0b
• International Organization for Standardization (ISO)21 15118 v1
• CHAdeMO22 (IEEE 2030.1.1) 5. SAE23 J3072, J2847, J2931, J1772
• Open Charge Point Protocol (OCPP)24 v1.6[17]
• Telematics[18]
• Charging Network Management Protocol[19] (CNMP)26 IEEE 2690
During this mapping process, it became clear that many communication protocols could support most, but not all, of the functional requirements. Details given in annexure</td></tr>
<tr><td rowspan="7">Hardware performance functionalities</td><td colspan="2">To identify the necessary EVSE hardware functionality that will enable the high-level communication needed to achieve many of the VGI use cases, following recommendations were given by the commission:</td></tr>
<tr><td>Functionality</td><td>EVSE Hardware / Physical Layer Description</td></tr>
<tr><td>Interoperability</td><td>Interoperable with IEEE 802.11n for high bandwidth wireless networking OR Interoperable with IEEE 802.3 for Ethernet connectivity for Local Area Network and Wide Area Network applications</td></tr>
<tr><td>Mitigate need for hardware modifications and onsite software upgrades</td><td>Remote update capability should be available for updating software without need for on-site presence
Functionalities should be software based</td></tr>
<tr><td>Support real-time protocol translation/encryption/ decryption</td><td>Processor and Internet Protocol stack must accommodate multiple communication protocols</td></tr>
<tr><td>Support the use of internet protocols for management and networking of EVSE</td><td>Compliance with Transmission Control Protocol/Internet Protocol and Internet Protocol v6, or its successor version(s)</td></tr>
<tr><td>Provide the physical layer when needed to allow for high-level communications between the EVSE and the EV</td><td></td></tr>
<tr><td>Other requirements</td><td colspan="2">External protocol converter can be connected to more than one EVSE and perform any communication requirements for all the EVSEs connected to it. Each EVSE communicates to the external protocol converter, which then communicates to a third party such as an EV service provider (EVSP), aggregator, or PFE</td></tr>
</table>

[16] OpenADR is sponsored by the OpenADR Alliance, which was formed in 2010 by industry stakeholders to standardize and automate utility demand response programs using an open software platform. More information is available at http://www.openadr.org/.

[17] OCPP is sponsored by the Open Charge Alliance, and offers a uniform method of communication between a charge point and a network operator or utility system. Version 2.0 is currently being finalized. More information is available at http://www.openchargealliance.org/

[18] Each automaker has its own method of implementing telematics, either using proprietary communication protocols or IEEE 2030.5.

[19] This IEEE standard, if finalized and adopted, would define communication between Electric Vehicle Charging Systems and a device or network services system to allow for monitoring, controlling, and communicating

Key outputs	Details	
	Domain	Protocol
Recommended communication protocols	PFE to EVSE	One or a combination of the following: 1. OpenADR 2.0b 2. IEEE 2030.5 3. OCPP 1.6
	EVSE to EV	One or a combination of the following: 1. ISO 15118 v1 2. IEEE 2030.5
	Vehicle OEM to EV	Telematics (using OEM proprietary protocols or IEEE 2030.5)

Source: CPUC

A few utilities and EVSE companies in Europe, especially in the Netherlands and Germany, have advocated for communications standards to allow interoperability and "e-roaming" between charging station networks, leading to the wide adoption of the Open Charge Point Protocol (OCPP) and Open Clearing House Protocol (OCHP) in many countries. This has resulted in a number of international projects, such as Ladenetz, a collaboration between municipal utilities in Germany and the Netherlands, universities, and private EVSE operators, and Hubject, a private company supported by German power companies RWE and EnBW. The multiple international programs within Europe cannot currently work together but European Union policymakers hope to unite these efforts with common standards.

For utilities to properly plan for EV-related system upgrades and take advantage of potential grid benefits, it is imperative that utilities know which residents own EVs and how they will be charged. There is no standard protocol for alerting utilities of new EV registrations or EVSE installations in most regions (including in 46 U.S. states). The United Kingdom, however, requires notification of one's local distribution network operator in order to claim rebates for EVSE installations. The program is implemented through authorized charge point installers in order to simplify the process for customers

3.6.6 Regulations enabling EVs to participate in demand response markets

Various jurisdictions in the US and Europe have developed regulatory frameworks for participation of demand response in ancillary services. With increasing share of renewable energy sources which are intermittent and unpredictable, and changing load-generation balance scenario, resources like demand response providing ancillary services to the grid would be expected to slowly gain importance.

Table 27: Demand response and aggregators

Commission /authority orders	Definition of Demand response and aggregators
FERC Order 719	**Aggregation of retail customers-** Each Commission-approved ISO and regional transmission organization must accept bids from an aggregator of retail customers that aggregates the demand response of the customers of utilities that distributed more than 4 million megawatt-hours in the previous fiscal year, and the customers of utilities that distributed 4 million megawatt-hours or less in the previous fiscal year, where the relevant electric retail regulatory authority permits such customers' demand response to be bid into organized markets by an aggregator of retail customers
MISO provisions	"An Aggregator of Retail Customers (ARC) is an MP [market participant] sponsoring one or more DRRs [demand response resources] or LMRs [load modifying resources] provided by customers. An ARC can, but need not, be an LSE [load serving entity] sponsoring a DRR or LMR that is the retail customer of another LSE
Arkansas	Act 1078 of 2013 allowed the Arkansas General Assembly articulate a state policy authorizing the Commission to "establish the terms and conditions for the marketing, selling, or marketing and selling of demand response by electric public utilities or aggregators of retail customers [ARCs] to retail customers or by electric public utilities, aggregators of retail customers, or retail customers into wholesale electricity markets. As defined in the Act, demand response means "a reduction in the consumption of on-peak or offpeak electric energy by a retail customer served by an electric public utility ... relative to the retail customer's expected consumption in response to: (i) Changes in the price of electric energy to the retail customer over time; or (ii) Incentive payments designed to lower consumption of electric energy." The Arkansas Commission stated that it "considers DERs to include (but not be limited to) energy efficiency resources (EE), demand response (DR), smart thermostats, renewable resources and distributed generation (DG), including solar and wind technologies, storage technologies, including batteries and water heaters, and electric vehicles (EVs), all of which may be enabled, enhanced, and integrated into the grid by implementation" of advanced metering infrastructure (AMI).

Without aggregation, individual Distributed Energy Resources (DER)s can theoretically provide energy, capacity, and ancillary services at the ISO/RTO level or the distribution level, but in practice most of that potential will go unrealized due to a variety of barriers, including:

Table 28: Demand response market requirements

Key requirements for markets	Details
Minimum threshold	Load-modifying resources must be capable of shedding at least 1 MW of load in MISO suggesting that not all demand side resources can participate in ancillary services

Key requirements for markets	Details
Value proposition	The MISO markets currently have operating reserves far in excess of resource adequacy requirements. This means that load curtailments are rarely needed, and DR resources can expect very little market revenue. It also means that wholesale energy and capacity prices are consistently low, which reduces the revenue that DERs capable of injecting energy might hope to capture. As a practical matter, the transaction costs for market participation by a single customer (described above) will typically exceed any market revenues
Visibility of DERs	A utility needs to know what types of DERs have been installed, where they are, what distribution system services they can potentially provide, and their operational status. The utility will also need the ability to control the DERs or send dispatch signals to whoever controls the DERs in order to provide distribution system services when and where they are most needed

3.7 Country specific policies for enabling participation in ISO markets

3.7.1 United States

In the US, aggregation has focused pre-dominantly on obtaining demand response. Various regulatory provisions by the FERC pertaining to involvement of demand response are highlighted below:

Table 29: Regulatory provisions for demand response

Date	Particulars
2000 onwards till 2008	FERC approved proposals by several ISO/RTOs to allow wholesale and certain retail customers to bid demand response into the day-ahead and real-time energy markets, alongside generation
2008	FERC issued Order 719 requiring all ISO/RTOs to accept bids from demand response aggregators acting on behalf of retail customers
2016	Revision in Market Administration and Control Area Services Tariff (MST) to establish a framework for DER aggregations to participate in CAISO's real-time and day-ahead wholesale energy markets and ancillary services markets (the "DER program")

Source: FERC

In Nov 2016, FERC announced that each RTO/ISO will revise its tariff to define [DER] aggregators as a type of market participant that can participate in the organized wholesale electric markets under the participation model that best accommodates the physical and operational characteristics of its distributed energy resource aggregation.

[20] *https://www.cpuc.ca.gov/General.aspx?id=8314*

Case study- CAISO Demand response through aggregation

Retail electric customers in CAISO can bid on their own (if they meet all eligibility requirements) or rely on commercial entities known as "Demand Response Providers (DRPs[20]) or aggregators" who aggregate retail customers into a single bid or multiple bids. Bids that are accepted and dispatched by the CAISO will be awarded energy payments based on wholesale market prices. Customers who participate through a DRP/aggregator will be paid according to the terms and conditions of any contractual agreement between themselves and their DRP/aggregator.

A DRP/aggregator, in this case, is a commercial entity that provides demand response services such as assisting retail customers with strategies or technology to reduce their electric consumption and then providing the electric load reductions as a 'bid' in wholesale energy markets. As of Feb 2019, there are 15 registered[21] DRPs in CAISO markets.

The California Public Utilities Commission adopted Rule 24/32 in accordance with CPUC decisions D.12-11-025, D.13-12-029, and CPUC Resolution E-4630. In summary, Rule 24/32:

- specifies the roles and responsibilities of different entities involved in facilitating direct participation DR, e.g., the utilities and DRPs/aggregators,
- requires that the DRP sign a DRP service agreement with the utilities,
- specifies meter data access requirements.

Resources capable of providing demand response can participate in CAISO energy and ancillary markets as follows through aggregation[22]. Aggregation refers to a means of combining of multiple sub-resources, at single or multiple locations, into a single market resource that participates in ISO markets:

1. Proxy Demand Resource (PDR): enables third parties to bid demand response into the CAISO market independent of the load serving entity for load curtailment in wholesale energy and ancillary services markets
2. Reliability Demand Response Resource[23] (RDRR): A market participation model for reliability-based load curtailment, triggered only under emergency conditions

- RDRRs are not required to participate economically therefore day-ahead market participation is optional
- All uncommitted RDRR capacity must be offered as energy in the real-time market
- Only includes system emergencies viz. transmission emergencies on ISO controlled grid, mitigation of imminent or threatened operating reserve deficiencies, resolving local transmission and distribution system emergencies etc.

Following table provides key features of both products:

[21] *https://www.cpuc.ca.gov/General.aspx?id=6306*

[22] *http://www.caiso.com/Documents/PDR_RDRRParticipationOverviewPresentation.pdf*

[23] *http://www.caiso.com/Documents/ReliabilityDemandResponseResourceOverview.pdf*

Table 30: Key features of PDR and RDRR

Aspect[24]	Details
Requirements to be met by DRPs	Demand response providers must secure agreements for wholesale participation. They can aggregate multiple customers to provide DR to the ISO. A DRP must: • Have an agreement with the load serving entity (LSE) / distribution company who serves the demand responsive load • Execute a demand response provider agreement (DRPA) with the ISO • become a Scheduling coordinator or obtain the services of a a Scheduling Coordinator A Scheduling Coordinator is a scheduling agency which can be chosen by the market participants, that is approved by CAISO to provide the schedules on behalf of the DERs or DERPs. The SC is responsible for scheduling or maintaining the schedules of each of the participants and communicating the same with CAISO. It also handles the settlement processes.
Market participation[25] options	For PDRs, scheduling coordinator to provide: • Economic Day-Ahead & Real-Time energy bids • Economic Day-Ahead & Real-Time ancillary services (Spinning and Non-Spinning reserves) For RDRRs, scheduling coordinator to provide: • Economic Day-Ahead energy bids • Reliability real-time energy bids • RDRRs with day-ahead schedules and remaining capacity in real-time will not receive dispatch until operational conditions exist such that the resource is activated in the market.
Capacity & Aggregation Requirements	• Energy markets only: 100 kW minimum curtailment—must be sustainable for duration of bid. Ancillary Services: 500 kW minimum curtailment—must be sustainable for 60 minutes for Day-Ahead Regulation awards, 30 minutes for Real-Time Regulation awards, and 30 minutes for Spin/Non-Spin reserves. • Smaller loads may be aggregated to achieve minimum targets • Can bid load curtailment in 10kW minimum increments
Operating and bidding characteristics	Resource bids in as a supply resource; bid segments may be as granular as 0.01 MW Resource owner defines one start-up and one ramp rate
Scheduling	• CAISO will treat the **aggregation as a single resource**, regardless of the location of the individual DERs. • The **DERP has to disaggregate** CAISO's instructions to the DERs

Source: CAISO

3.7.2 Europe

EU directives have been focused on participation of aggregators through demand response. The following is an overview of various regulatory/policy provisions.

[24] *http://www.caiso.com/Documents/ParticipationComparison-ProxyDemand-DistributedEnergy-Storage.pdf*

[25] *http://www.caiso.com/participate/Pages/Load/Default.aspx*

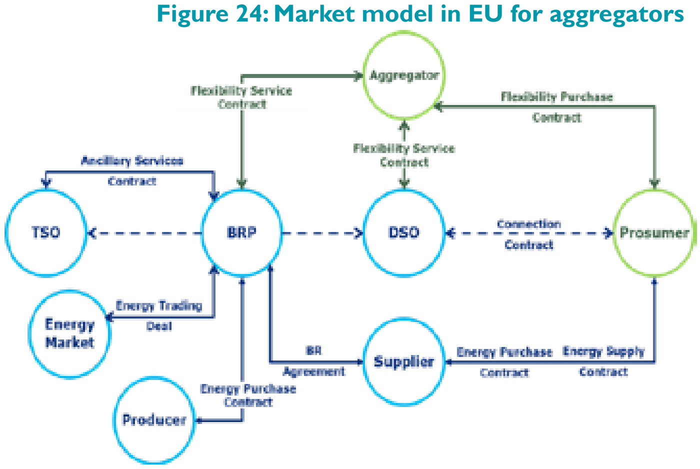
Table 31: Regulatory and policy provisions for participation of aggregators through demand response.

Particulars	Details
Energy Efficiency Directive 2012/27/EU	Energy Efficiency Directive 2012/27/EU (EED) defines the term 'aggregator' as a "demand service provider that combines multiple short-duration consumer loads for sale or auction in organized energy markets"; definition includes only consumer loads and not the generation of energy. EU Member States shall ensure that transmission system operators and distribution system operators, in meeting requirements for balancing and ancillary services, treat demand response providers, including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities. Network regulation and tariffs "shall not prevent network operators or energy retailers from making system services available for demand response measures, demand management and distributed generation on organised electricity markets, in particular: […] (b) energy savings from demand response of distributed consumers by energy aggregators." IEM directive facilitates final customers in providing balancing services to the markets
Directive on the internal energy market 2009/72/EC	Transmission system operators should facilitate participation of final customers and final customers' aggregators in reserve and balancing markets. Member States shall ensure the implementation of intelligent metering systems that shall assist the active participation of consumers in the electricity supply market. This should happen based on an economic assessment and where the roll-out of smart meters is assessed positively, at least 80 % of consumers shall be equipped with intelligent metering systems by 2020.12 IEM directive facilitates final customers in providing balancing services to the markets
Network codes	The Network Code on Electricity Balancing (NC EB) declares in Art. 10 the "facilitating [of] the participation of Demand Side Response including aggregation facilities and energy storage" to one of its general objectives of the balancing market. Furthermore, the Network Code contains that "the conditions for aggregation of Demand Side Response, the aggregation of generation units or the aggregation of both should be part of the terms and conditions for Balancing Service Providers Participation of demand side response has been identified as a primary objective of the balancing market

the basic market model prevalent in EU for aggregators is described in the illustration below:

- Aggregator is responsible for contracting with DSO to provide services, BRP for maintaining imbalances in real time

Figure 24: Market model in EU for aggregators



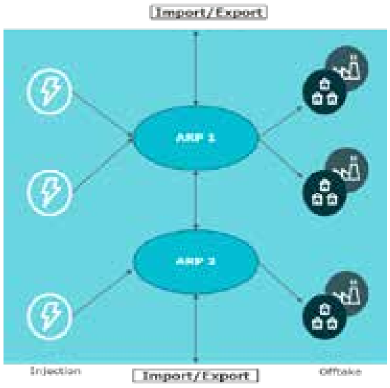
- BRP provides ancillary services in case of imbalance. It can manage its imbalances through other BRPs
- BRP can participate in energy markets to correct aggregator's portfolio in real time

Table 32: Case study – ARP in imbalance market

Case Study: Participation by ARPs in Imbalance market

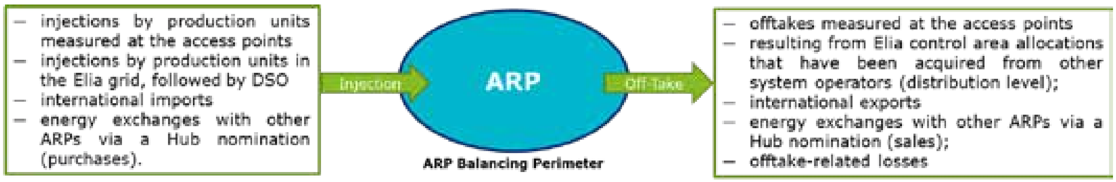
- The responsibility of maintaining instantaneous balance between the load and generation lies with the TSO.
- Belgium has only one control zone and it is overlooked by Elia.
- To help maintain the balance between generation and consumption, Elia has balance responsible parties (BRP)
- For each access point there must be a designated BRP. A balance responsible party is also called an access responsible party (ARP).
- Either the supplier takes on the role itself or else it appoints an ARP which enters into a contract with Elia.
- ARPs are authorized under an ARP contract signed with Elia.
- Elia applies imbalance tariffs if a 15-minute time block imbalance is observed.
- ARPs can avoid imbalances by:
    - exchanging energy with other ARPs on the 'intraday hub'. In this case,
    - they submit their nominations to Elia before noon the following day;
    - importing or exporting energy for the south border on an intraday basis

Figure 25 Illustration of Import and Export by Access Responsible party (ARP)



An Imbalance occurs when there is a difference for one quarter-hour between the total Injection to the Elia Grid allocated to ARP's Balancing Perimeter and the total off-take from the Elia Grid allocated to ARP's Balancing Perimeter

Figure 26 ARP Balancing Perimeter for Injection and Off-take.



ARP is responsible to balance its perimeter on an quarter hour basis
- Day-ahead nominations of ARP must be balanced
- ARP pays an imbalance tariff if the final position of its perimeter is not balanced
- ARPs react on real-time imbalance tariffs to restore their perimeter balance
- ARP which also provide ancillary services has the right to offer ancillary services to Elia

In real time, the residual imbalance of the zone is solved by the TSO
- TSO will restore residual imbalances by activation of balancing services
- Balancing actions by TSOs are reflected in imbalance tariffs

The above mechanism allows for individual ARP/BRPs to balance out their portfolios in the imbalance market through a spectrum of DER and DR response programs.

Source: EU, Energy Efficiency Directive 2012/27/EU

4. An analysis of high EV penetration in distribution systems in the Indian context

4.1 Approach to Distribution network analysis

IA distribution network analysis was conducted to explore the effectiveness of managed charging towards avoiding distribution network impacts. The analysis used a case study approach centered on the Delhi based utility, BSES Rajdhani Power Limited (BRPL). At various levels of penetration of EVs and considering a varied charging profile, the analysis performed by NREL, USA has focused on impact of integrating EVs in the BRPL network and the possible resolution options including battery storages for mitigating the challenges. The report will be separately released and can be accessed by all in their official website. The GTG-RISE/ Deloitte analysis, presented in this Chapter focuses on analyzing the impact of network loading (at select feeders and transformers), at various levels of EV penetration scenarios in the next 10 years so that a prioritization strategy of rolling out charging infrastructure can be deployed by BRPL, having looked at the available margins and constraints in the network. The analysis also provides a mitigation plan, through active managed charging, that could be adopted by the utility, to further defer the investment requirement in augmentation of the network, for optimum utilization of the network and consumer investments and builds a strong business case for representation to Delhi Electricity Regulatory Commission (DERC) in enabling managed charging framework. c

For modelling the distribution network, EPRI's freeware distribution system simulator, OpenDSS, was used, integrated with a Python based time series load flow analysis. The distribution system of BRPL was modelled with appropriate load growth assumptions to identify when overloading may occur. An instance of overloading refers to a situation whenever the loading of any DT crosses 70% of the rated DT capacity. EV growth was assumed to be in line with the GOI's target of 30% EV penetration by 2030 compared to present levels.

A preliminary analysis has been carried out in the first step to understand approximate year in the future where each of the DTs are expected to get overloaded. Once the approximate year is determined, the next step is to consider slot wise loading data of the DT and undertake a detailed time series based load flow analysis to understand total number of slots in a year where each DT becomes overloaded and whether there is a scope for managed charging in those slots.

This analysis has been carried out in a two- step process:

1. Preliminary Analysis:

- For each DT, a sample day's time series data was created by taking the maximum load for each time slot.
- Selected maximum load for each DT has been broken down into two parts: Consumer load and EV load.
- It has been assumed that the net EV load in the base year of simulation (2019) is 165 kW (Corresponding to 50 E-Rickshaws) and the EV load grows at 30% CAGR to fulfil the target of 30% EV penetration by 2030.
- The cumulative load growth (EV and Consumer) is taken as 5%.
- In the base year, the spare capacity of each of the DT is calculated as the difference of 70% of rated capacity of that DT and actual loading of the DT.

- The EV load (165 kW) is apportioned to each of the DT as per their ratio of spare capacity in the base year.
- For each year in the future, the primary loading on the DTs has been calculated considering a 5% growth of load from the base year.
- For each year, loading and spare capacities of each DT is ascertained. The years where the loading of each of the DT crosses 70% of it's rated capacity is also noted down. The detailed slot wise loading analysis is then carried out prior to and post before and after around which (± 2-3 years) the slot wise analysis (main analysis) has been carried out for the determination of the manage charging hours and slots.

2. Main Analysis

- For each data, slot-wise projected loading data has been considered for the simulation. For all the DTs where data was missing for few slots, data cleaning has been done and synthesized based on statistical approaches and the missing data was constructed.
- Slot-wise load for each DT has been broken down into two parts, viz., Consumer Load and EV Load.
- It has been assumed that the net EV load in the base year of simulation (2019) is 165 kW (Corresponding to 50 E-Rickshaws). EV load grows at 30% CAGR to fulfil the target of 30% EV penetration by 2030.
- The cumulative load (EV and Consumer) growth is taken as 5% y-o-y.
- In the base year, the spare capacity of each of the DT is calculated as the difference of 70% of rated capacity and actual loading of the DT.
- The EV load (165 kW) is apportioned to each of the DT as per their ratio of spare capacity in base year.
- Considering the year of simulation, the primary loading on the DTs has been calculated considering a 5% growth of load from the base year.
- The loading obtained for the considered year of simulation has been apportioned in the ratio of consumer load and EV load (scaled from the base year using EV load CAGR and cumulative load CAGR)
- For each of the DT, slots with overloading instances have been identified.
- Identified overloading instances have been divided into two categories, viz., manageable and Non-manageable.
- All the manageable instances, for a particular DT, are those slots where overloading can be prevented by shifting the EV load (Total loading less EV loading <= 70% of rated capacity of DT) in that particular slot whereas Non-manageable instances are those wherein DT is overloaded even after shifting the EV load on the DT chosen.
- The year of overloading for each of the DT has been calculated as the year wherein this Non-manageable slots exceed/reach 30 instances.

- Each of the manageable instances have been plotted for the decision making of contracting time (in hours for managed charging).

For the purpose of our simulation, a feeder with presence of both Domestic and Commercial loads has been considered for the analysis.

4.1.1 Input data

1. Load data

Load on each DT **for the base year** has been considered as shown below. However, this load has been increased with a CAGR of 5% year-on-year. **Load data in the base year for two sample DTs have been shown below.**

Figure 27 Load data of Sample Distribution Transformer 1

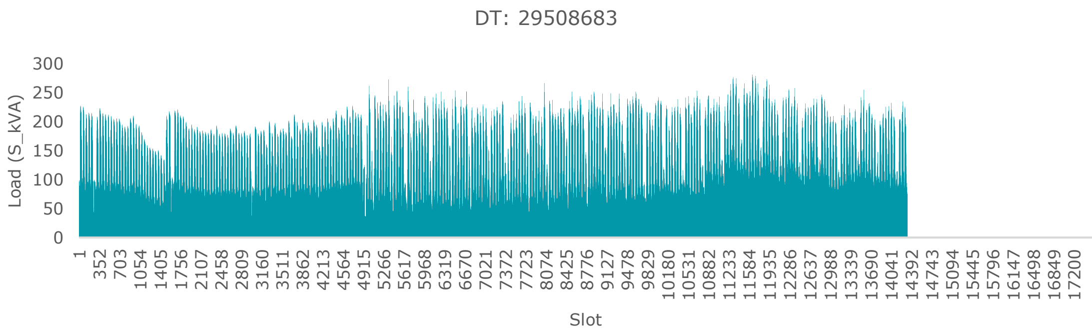
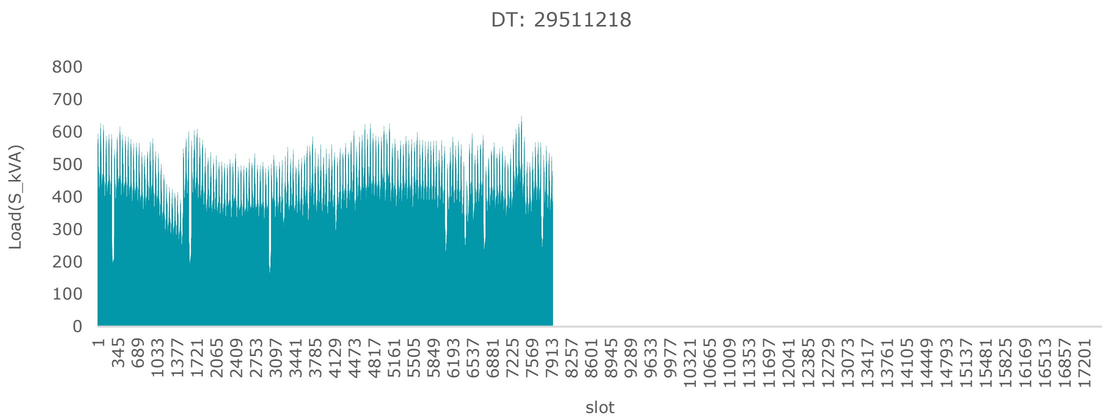


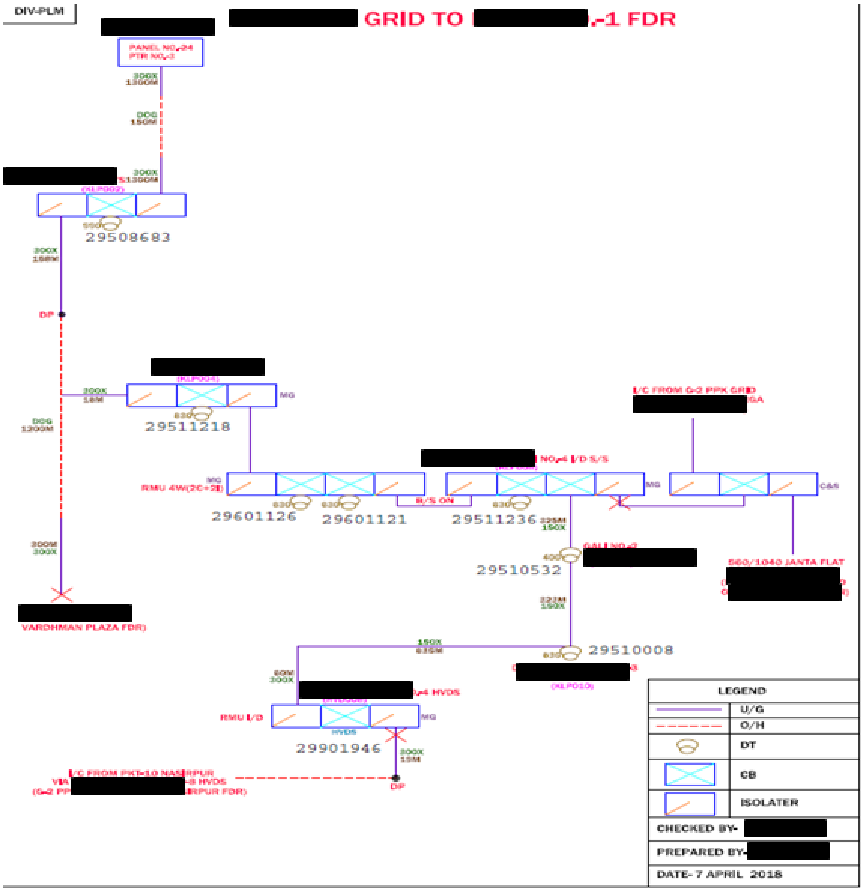
Figure 28 Load data of Sample Distribution Transformer 2



2. Single Line Diagram

The SLD of the network considered has been shown in the figure below:

Figure 29 Single Line Diagram of Dabri I feeder used for the modelling and simulation



3. Network parameters

For the load flow analysis, the line and DT parameters are highlighted below:

Table 33: DT and Line parameters

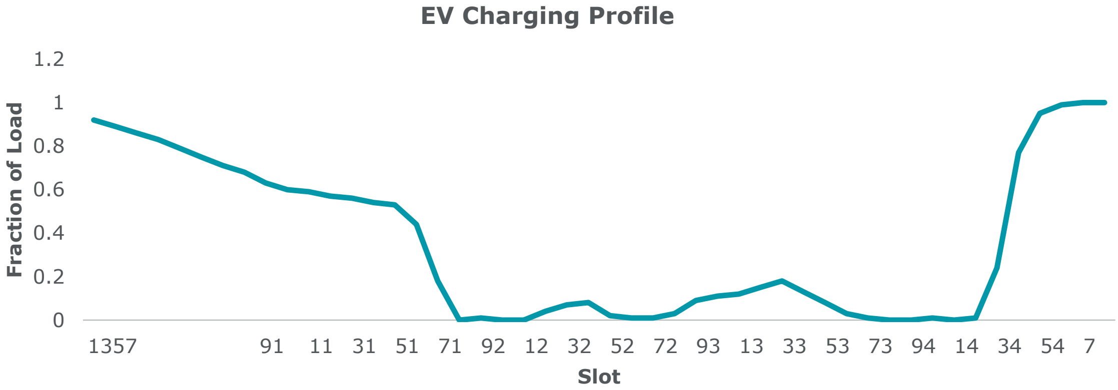
DT (Ratings)	Voltage Ratings	Z (pu)	R (pu)	X (pu)
990 kVA	11/0.4 kV	0.0484	0.01149	0.047
630 kVA	11/0.4 kV	0.0407	0.01151	0.039
400 kVA	11/0.4 kV	0.0399	0.01219	0.038

Line	kV	R (Ω/Km)	X (Ω/Km)
300x	11	0.13	0.093
150x	11	0.264	0.089
Dog	11	0.2792	0.02

4. EV charging profile

Following representative EV charging profile, as per actual observed profile at a sample node, is considered:

Figure 30: Representative profile of EV charging load



4.2. Key assumptions

- The rating for slow charging stations is 15 kW at a power factor of unity
- The rating for fast charging stations is 22.5 kW at a power factor of unity
- The spare capacity is apportioned in 1:3 ratio between fast and slow charging stations
- A DT has been considered to the overloaded when the DT is loaded >= 70% of its rated capacity for at least 30 hours/month

4.2.1 Results of the simulation

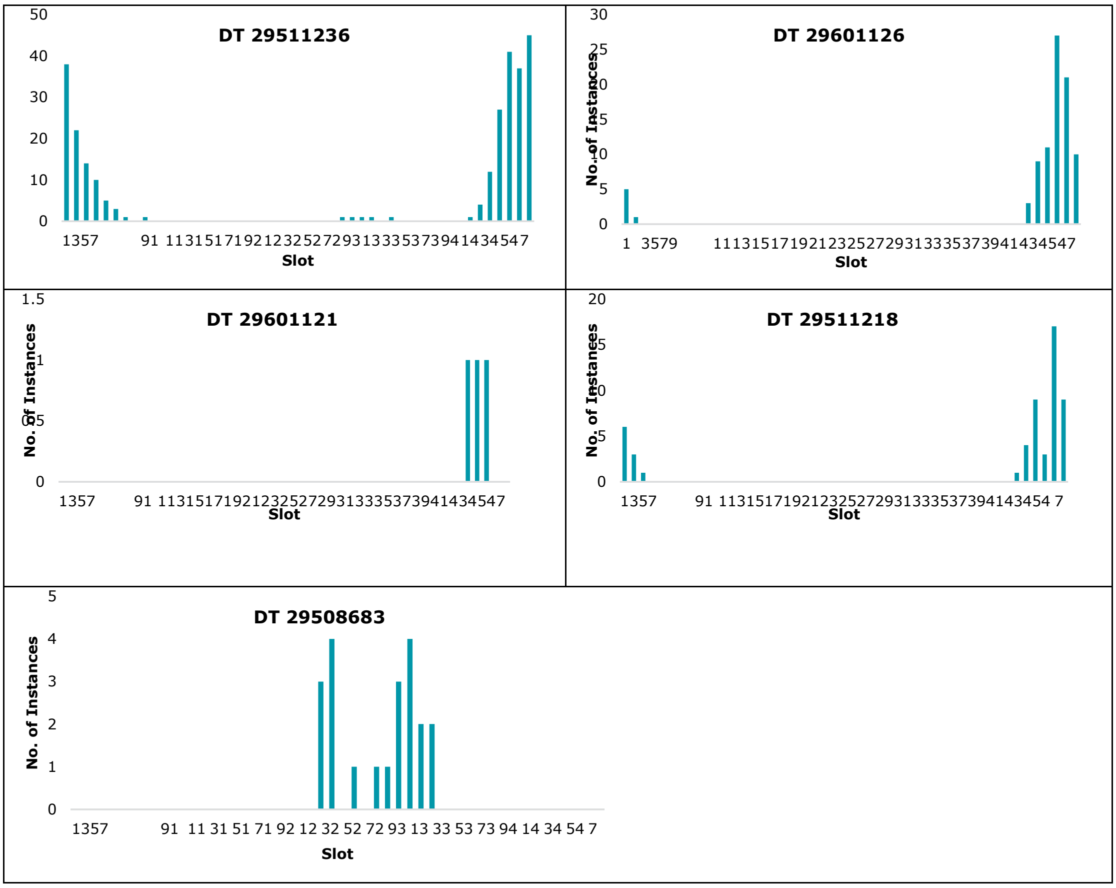
The definition of overloading considered in the analysis corresponds to the situation when at least 30 non-manageable overloading instances are observed for any given DT in a year. The years of overloading has been presented in the table alongside for each of the DTs as present in the SLD. It can be observed that one DT, 29510532 has not reached its overloading capacity until 2033, except that all the remaining DTs have reached their overloading capacity well before 2030.

Table 34: DT and Line parameters

DT number	Year of overloading
29601121	2019
29511218	2020
29510008	2021
29601126	2025
29508683	2029
29510532	>2033

In the following DT-wise graphs, all the manageable overloading instances have been plotted in a slot wise distribution prior to their respective years of overloading for the decision making of contracting hours of managed charging.

Figure 31 Slot-wise distribution of manageable overloading instances for the decision making of Managed Charging



From the graphs, manage charging hours for each DT are:

- **DT 29511236:** Slot 45 to slot 1
- **DT 29601126:** Slot 44 to slot 1
- **DT 29601121:** Overloaded in base year itself
- **DT 29511218:** Slot 45 to slot 1
- **DT 2958683:** Slot 23, 24 & slot 30 to slot 33 (Since, the overloading patterns are distributed, TOU based tariff could be considered for this DT)

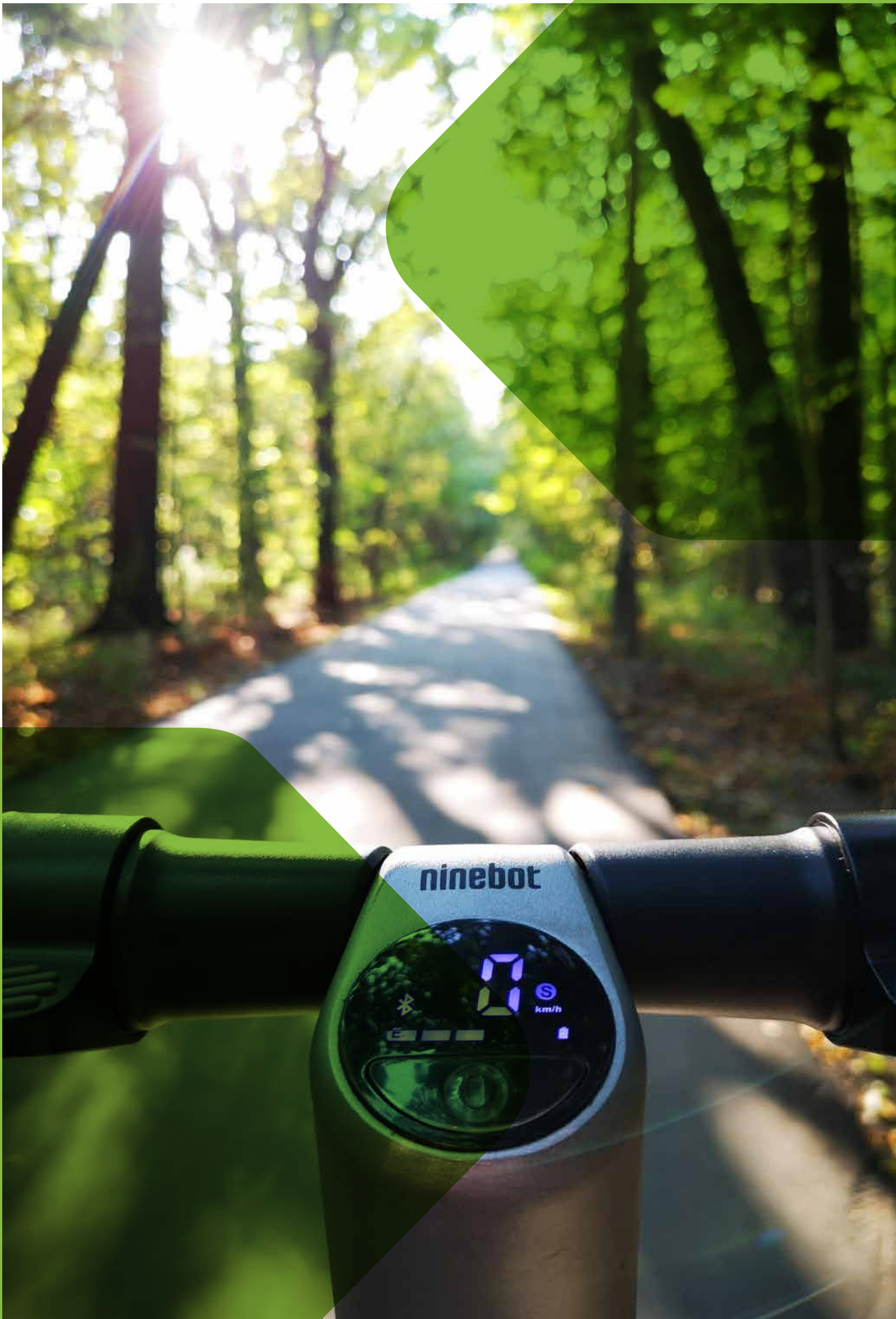
4.2. Key assumptions

- Based on the analysis, distribution system planning may benefit by considering at a 10-year planning horizon that is inclusive of consumer load growth, considering EV adoption. Capacity planning by utilities should be configured such that it addresses distribution system overloading, voltage and frequency fluctuations and any other network constraints in the future.
- It has been observed in this analysis that in the long run, the impact of EV charging could be substantial considering the gradual and steady move to EVs. Hence, distribution utilities should develop multiple system cost scenarioswith/-without storage systems and managed charging etc., to effectively design the network and address future load conditions instead of taking a 10-year time-

frame for deciding the network parameters including DT sizing etc.

- Power distribution utilities would have to undertake scientific modelling studies to understand potential growth of EVs in the long run and how it would lead to overloading of DTs and distribution lines. Significant business focus and priority should be given to EVSE as an additional load in the system and scenario planning-/-prioritization strategy needs to be developed for the following:
  - Peak load management
  - Reducing technical losses in the distribution system by controlled EV charging
  - Reducing system costs by enabling RE based generation sources to be utilized for EV charging instead of resorting to costlier conventional sources
- It is evident from the analysis that there is substantial scope for load shifting of EVs. To enable a framework for managed charging, utilities should initiate a dialogue and represent to concerned regulators for justification and subsequent introduction of managed charging practices, TOU tariff pricing, etc.
  - Managed charging can provide significant means to mitigate overloading of the distribution system at times of peak demand by modulating the charging rate of EVs and delaying the charge over a larger timeframe
  - There could be certain pockets where managed charging may not be attractive due to variations in EV charging profile by the users. Passive mechanisms like TOU tariffs can act as suitable incentive for users to shift their EV charging to off-peak periods.
- As observed from the above results, most of the DTs get overloaded before 2030, based on the overload criteria established (30 hourly overload instances in any month). However, it was observed that for the rest of the year, these DTs are usually loaded to the extent of only 40-50% or even lower. This could be a typical phenomenon for a city like Delhi. In such cases, augmentation of DTs may not be cost-effective. Hence, utilities need to analyze and model their respective load profiles and simulate scenarios to determine the most cost-effective solutions (given below) for managing EV load:
  - Active managed charging
  - Passive managed charging like TOU tariff structures-/-Demand Side Management incentives
  - Charging through distributed RE sources
  - De-congesting the network and-/-or charging through local Battery Energy Storage System (BESS) installations in the grid, etc.

This analysis has been carried out considering a lump load at a DT level. Analysis at a household/industry level using geographic information system (GIS) mapping could give more accurate results for the power distribution utilities due to precise accounting of losses. The voltage stability analysis could also be carried out when an analysis is carried at a household level for significant results. The same analysis can also be extended with the BESS for peak shaving. A sensitivity analysis could be carried out for different EV charging patterns to determine the best EV charging pattern for the network deferral.


ninebot
km/h

5. Gap assessment, recommendations and identification of enablers for development of EV charging infrastructure

5.1 Current gaps in India's framework

Table 35: Gaps in India's framework for developing EV charging infrastructure

Key Parameter	Detail and gap
Cost recovery through rate-basing "make-ready" infrastructure	Utilities in US are encouraged to invest in EV infrastructure through a range of legislative mandates such as for clean air and reducing overall emissions from transportation sector. Regulators allow utilities to undertake investment in "make-ready" infrastructure for EVSE integration as well as EVSE infrastructure itself and recover the cost through rate-basing. This allows utilities to undertake costly investment and socialize the cost of setting up "make-ready" infrastructure for EVs. Such a proactive approach creates an eco-system for setting up EV charging infrastructure. While several states in India have introduced EV policies, state utilities and regulators are yet to facilitate large-scale investments in "make-ready" infrastructure for EVs. A first step would be for regulators to encourage utilities to carry out such investments and provide pathway to cost recovery through rate basing.
Standardization	EV standards and technical specifications have increasingly moved towards standardization encouraging interoperability in developed countries. This helps create an EV ecosystem with adequate confidence from private players as well enables interoperability of equipment. While, there have been guidelines on technical specifications that have come up in India, institutions such as CEA and BIS shall have to further play a role in standardization on EVSE equipment.
Managed Charging Framework and functions	Utilities in advanced power markets with significant levels of EVSE penetration have focused on developing a managed charging framework so as to efficiently manage the additional stress on distribution system network on account of EV charging. This entails setting up various communication and hardware protocols to implement a managed charging framework as well as creating various incentives for consumers to participate in managed charging initiatives. While EV growth is still at a nascent stage in India, utilities and regulators will need to plan for implementing a managed charging framework with a long-term perspective. While absence of standardized protocols for EV managed charging is a major barrier in the Indian context, equally important is the fact that the managed charging landscape involves various stakeholders viz. utility, grid operator, aggregator, EV user, network operator, etc. and adequate coordination between everyone is required to formulate adequate systems and infrastructure which would function properly. The concept of aggregators is still being explored in India. Moreover, robust electricity grid and network infrastructure are vital for effective functioning of managed charging in India.
Demand Response Market	To take advantage of flexibility from managed operation of EV charging, ancillary markets in developed countries have provisions for demand response providers to participate in the ancillary market. This provides additional revenue stream to demand response sources and allows utilities to better manage its demand-supply position. The CERC has introduced a discussion paper on market-based procurement of tertiary services in India. Currently there is no established mechanism for demand response products in the ancillary market wherein aggregators can participate.

Key Parameter	Detail and gap
Pilots on managed charging of EVs	From the international case studies, it can be observed that many of the new technology related to managed charging of EV has been introduced first using a pilot platform. The results for these pilots are then used to carry out large scale deployment of technology. While standards and guidelines introduced in India do provide provisions for communication protocol between EVSE and other stakeholders, there has been no pilot initiative on large-scale managed charging pilots. Utilities and regulators across India need to take initiative on introducing pilot projects which can demonstrate the benefits of managed charging of EVs.
EV tariffs and incentives.	It has been observed that having dedicated tariffs and incentives for EV encourages adoption. While few states in India have taken EV policy initiatives, a large number of states are yet to introduce EV specific tariffs for public and home charging as well as incentives under state policies for purchasing EVs and setting up home and public charging stations.

5.2 Creating an enabling framework to support EV charging infrastructure

The following section delves into the various enablers which would influence increased adoption of charging infrastructure. Based on international benchmarking, these have been categorized as the following:

1. Policy and regulatory enablers
2. Technological enablers, and
3. Others, including collaboration and partnerships among utilities and other stakeholders in the EV value-chain

Understanding these levers is important in understanding the role that a particular regulator/government/utility can play in encouraging the deployment of EV charging infrastructure.

5.2.1 Policy and Regulatory enablers

1. Policy enablers

a. National / State level policy for incentivizing Distribution Utility investments in EV charging infrastructure: Through adequate support and enabling policies, power utilities should be incentivized to undertake capital investment in charging infrastructure to accelerate widespread transportation electrification and reduce dependence on petroleum. Recovery of capex could be done by rate basing them among all the electricity consumers instead of only consumers using EVs. Adequate policy mechanism should be in place to ensure that such investments are subject to regulatory jurisprudence to avoid unnecessary burden on concerned ratepayers. This, as illustrated below, is enabled through suitable policy mechanism in the state of California.

Section 740.12 of Senate Bill 350 of the state of California states that:

1. "The commission, in consultation with the State Air Resources Board and the Energy Commission, shall direct electrical corporations to file applications for programs and investments to accelerate widespread transportation electrification to reduce dependence on petroleum, meet air quality standards".
2. "The commission shall approve, or modify and approve, programs and investments in transportation electrification, including those that deploy charging infrastructure, via a reasonable cost recovery mechanism, include performance accountability measures and are in the interests of ratepayers

Furthermore, the Senate bill 350 also states that the California Energy Commission shall regularly carry out a prudence check of EVSE capital investment so that it is convinced that the same is reasonable to be recovered from all of the rate payers:-

"The commission shall revise data covering current and future electric transportation adoption and charging infrastructure utilization prior to authorizing an electric corporation to collect new program costs related to transportation electrification in customer rates. If market barriers unrelated to the investment made by an electric corporation prevent electric transportation from adequately utilizing available charging infrastructure, the commission shall not permit a additional investments in transportation electrification without a reasonable showing that the investments would not result in long –term standard costs recoverable from ratepayers".

b. Launch of Charge ready infrastructure programme by Distribution Utilities through policy initiative:

Utilities should plan and initiate investing in "make-ready" infrastructure wherein they would set up the necessary infrastructure required for EV charging service. This would enable development of EV charging infrastructure by ensuring electrical infrastructure is already provided at customer sites to support charging. "Make-ready" infrastructure may include components such as necessary transformer and transformer pads, new service meter, new service panel, associated conduit and conductor necessary to connect each piece of equipment, Smart Grid Devices, etc.

Case study of charge ready infrastructure program adopted by Southern California Edison is highlighted in Section 3.6.2

2. Regulatory enablers

a. Rate-basing of EVSE

Utility investments in infrastructure to support EVs, including system upgrades, dedicated meters, and workplace or public EVSE, could be funded by distributing the cost across all customers. This practice, although socializes the costs among all consumers, adds only a small amount to customer electricity bills. Regulators may encourage these investments due to their potential to increase utilization of the electric grid which would drive down effective rates for all consumers.

Detail case study of rate basing of investment in EV charging infrastructure have been highlighted in Section 3.6.1

b. EV Tariff structuring:

Time-of-use EV charging rates: A simple, but effective step for utilities is to implement time-of-use (TOU) rates, in which electricity prices vary over predetermined periods of the day. Typically, there are two or three rate tiers during a day, with prices also sometimes varying by season or on weekends. Costs would be higher (often by a factor of two or more) during peak demand times, but total average prices are typically designed to be revenue-neutral and reflect the marginal cost of electricity generation.

Details of TOU tariffs prevalent in various countries is highlighted in detail in Section 3.5.2

c. Electricity market structures:

Presence of market structures where EVs can provide demand response/ancillary services could provide substantial benefits to utilities/aggregators and EV owners alike.

Details of regulatory interventions in design of electricity market structures in other countries have been detailed in Section 3.6.6

d. Approval for technical standards for charging equipment in the case of managed charging:

Most countries have a national technical standards agency that either develops a standard or adopts a standard developed by an international technical agency for use in the country. This approval process often involves consultation with various other government agencies that look after fire safety, electric grid, etc. For instance, ASTAR in Singapore had been mandated by the government to develop a standard for EV charging in consultation with OEMs, the local utility and other stakeholders.

Case study of adoption of Technical standards for Managed charging by the California Public Utilities Commission (CPUC) is highlighted in Section 3.6.5

5.2.2 Technological enablers

1. Interoperability, communication and user experience:

a. Inter-operability

Several major efforts are needed toward improving the user experience of charging infrastructure by promoting interoperability between EVSE providers.

For EV users, interoperability, or "e-roaming," means that users can charge at any station with a single identification or payment method, and that all charging stations can communicate equally with vehicles. For this to work seamlessly, common standards for charging network operators must also be established. User roaming is accomplished through the widespread adoption of open standards, including the OCPP and Open Clearing House Protocol (OCHP), in various countries, which allow for efficient communication between charging stations, the grid, and back-end offices to ensure interoperability in operation and payment.

Ladentz, a government-sponsored collaboration among municipal utilities, universities, and private electric vehicle service equipment (EVSE) operators in Germany and the Netherlands, seeks to create a Europe –wide network of interoperable and user friendly charging stations.

In the United States BMW, Nissan, ChargePoint, and EVgo founded the ROEV (Roaming for EV Charging) projects to advance interoperability.

California is currently working on implementing the Electric Vehicle Charging Open Access Act, which focuses on customer interaction with the EVSE. The act applies to all electric vehicle service providers (EVSPs) operating one or more publicly available Level 2 or Direct Current fast Charger (DCFC) Electric Vehicle Supply Equipment (EVSE) installed in California. The act requires

- Publication of station locations on the Alternative Fuels Data Center (AFDC) website.
- Disclosure of all pricing before a charging event begins
- Charge points accessibility to everyone, including the ability to accept multiple forms of payments. Implementing these key features will enable broader access for customers.

Case study of guidelines for ensuring interoperability in EV charging infrastructure is highlighted in Section 3.6.5

b. Communication between EV charging stations

Communications among EV charging stations should be enabled so that users of EVs are suitably informed about availability, operating status, waiting time of various EV charging stations. A central cloud-based platform is necessary to undertake these activities. The centralized platform should enable data sharing and visualization so as to help drivers find and monitor the perfect-/-nearest charge point based on availability, operating status, waiting time, etc.

Case study of the same is highlighted in Annexure 7.

c. Communication between EV charging station and distribution utility

Communication system between EV charging infrastructure and distribution utility is vital for controlling-/-managing EV charging. Communication between the two ensures grid stability and more efficient system utilization, and can take on a variety of forms, including demand response, one-way controlled charging, or vehicle-to-grid.

The signals which utility would send to EVs and vehicle chargers combine messaging, or application, protocols (e.g., OpenADR 2.0, OCPP) and transport layer protocols, also known as network communication interfaces (e.g., Wi-Fi, cellular). Through a combination of network and messaging protocols, the utility can send signals and undertake controlled charging for particular locations as per requirement. Communication medium could range from Wi-Fi, AMI, Cellular networks, radio networks and Ethernet. Through this, the distribution utility can also input remote commands and remote firmware updates to the charging stations.

Case study of the same is given in Section 3.5.4

2. Modelling and simulation studies

With the anticipated growth of EVs as a widespread transportation choice, the incorporation of electric vehicle supply equipment (EVSE) will become a critical element of utility network planning. Selecting a site for EVSE installation will require consideration of a combination of factors. While every site is unique in nature and every EVSE host has unique set of priorities for installation, there are certain common physical elements that would characterize planning choices for any EVSE installation. Appropriate urban traffic and distribution network studies must be conducted in order to identify and establish key criteria which would enable utilities to ascertain suitable locations for siting of EVSE.

Case study of the same is highlighted in Section 3.4

3. Database management and notifications to utilities:

In order for utilities to properly plan for EV-related system upgrades and take advantage of potential grid benefits, it is imperative that utilities know which residents own EVs and how they will be charged. Maintaining a repository of such information would also aid them in planning for EV smart charging pilots.

The United Kingdom's Office of Low Emission Vehicles administers a grant for Chargepoint installers. The grant is set as a 75% contribution to the cost of one chargepoint and its installation and the grant cap is set at £500 (including VAT) per eligible vehicle. The OLEV requires Chargepoint installers to notify one's local distribution network operator (DNO) in order to claim rebates for EVSE installations as well as communicate for the purpose of installation completion.

4. Smart metering requirement:

Smart metering is an essential tool to track the electricity consumption and curb technical and commercial losses. They also enable real time monitoring of energy consumption in a particular period of time. The Government of India's (GoI) UDAY programme, launched in 2015, has mandated the deployment of smart meters with a phased timeline for curbing of commercial losses in distribution system.

Smart meters would also enable implementing of TOU rates for EV consumers and accurate monitoring of energy consumption over time.

5. Enabling Vehicle grid integration

RE penetration in the country is slated to increase in the future due to GoI's ambitious push for 175 GW of RE capacity by FY 2022. This would act as a wide opportunity for EVs in participating in the energy imbalance market by providing V2G services.

Typically, EVs have a residual value of 8-10% after 5-6 years. This can significantly increase if these residual batteries can be used as storage-based charging devices wherein they can be charged when power is cheapest and most abundant (for instance during high solar hours) and can be made to dispatch power back to the grid during periods of frequency imbalance through participating in the ancillary market operations. The demand-supply variability will largely be created during the day when solar peaks up and V2G services could be offered during this 6-7 hours of high solar time.

EVs can also participate in Demand side management programme by utilities. In the developed countries, participating of DR resources is generally through aggregators who provide DR services by aggregating smaller resources. Case study of the same has been highlighted in section 4.5.6

5.2.3 Others including collaboration and partnerships among utilities and

1. Cooperation with stakeholders

A key enabler for smart charging and other vehicle-grid integration aspects is collaboration between utilities and various stakeholders in the EVSE landscape. Such partnerships can give utilities valuable insights into new technologies and lead to new business models in this rapidly expanding field, as well as defray the costs (in money and time) of innovative new programs.

A number of utilities have already created partnerships and identified areas for collaboration to study and promote EVs. Table below highlights a few existing partnerships to date. As shown, existing utility partnerships include automakers, EVSE hardware and software providers, IT and software companies, research organizations, and governments at different levels.

Collaboration with the broader industry would also involve the following:

- agreeing on common standards for equipment interoperability and integration with existing smart grid platforms
- defining and developing point-of-sale payment standards to expand charger access
- ensuring proper charging access for all customers.

Potential Partners	Areas for Cooperation	Examples
Automakers	Smart Charging, aggregation, standards advocacy and adoption	• BMW and PG&E ChargeForward • ElaadNL with Renault in Netherlands • ROEV charging network project
Charging infrastructure providers	Connectivity, DR, V2G, open standards	• Siemens and Duke Energy VersiCharge • EVSE LLC and SCE workplace charging
IT/software companies	Charging optimization, security, aggregation	• HECO and Greenlots Battery DCFC • My Electric Avenue
Academia and research organizations	System modelling and simulation	• PJM and University of Delaware V2G • eConnect Germany Project
Local and state government	EVSE deployment, local modeling, outreach	• San Diego readiness study • Plug In BC (BC Hydro)
Central Government	Standards and R&D	• US Dept. of Energy • US Dept. of Energy - Edison Electric Institute MOU • Ofgem Electricity Network Innovation Allowance

2. Cooperation among peer distribution utilities

Some projects, such as deploying EV charging networks or creating smart charging standards, may require collaboration across jurisdictions and among multiple utilities. For instance, the Elaad Foundation, a partnership of the eight largest Distribution System Operators in the Netherlands, manages more than 3,000 public charging stations, maintains an international standard for public charge station interoperability, and continues to research smart charging technologies. Clever, a group owned by five utilities in Denmark, is the largest operator of EVSE in that country and has now expanded into Sweden, while 23 utilities in Norway have together opened a nationwide network of DC fast chargers under the Grønn Kontakt brand.

5.3 Summary of recommendations and roadmap

A phase wise roadmap for ensuring that the aforementioned enablers are attained gradually and progressively for development of EV charging infrastructure has been illustrated in the table below. The enablers have been classified into following three categories:

1. **Near term priority:** These are near-term priorities that can be tackled immediately or over the next 1-3 years through quick policy/regulatory measures and accelerated ongoing efforts.
2. **Medium term priority:** These are medium-term priorities that have been identified to be crucial and would play a pivotal role establishing a developed EVSE ecosystem. However, these would require considerable support and substantial policy, technology and/or infrastructure changes and stakeholder buy in.
3. **Long term priority:** These are complex initiatives requiring significant expertise to be built-up over a long period of time. Owing to the level of complexity, these long-term initiatives require transformational structural changes in policies, skill development, regulations, etc.

Table 36: Summary of recommendations and roadmap for utilities

Type of intervention	Policy	Regulatory	Technological	Collaboration and partnerships
Near term priority	• National / State level policy for incentivizing Distribution Utility investments in EV charging infrastructure • Launch of Charge ready infrastructure programme	Approving Rate-basing of utility investments in building EV charging stations and infrastructure	• Enabling inter-operability in EV charging stations • Enabling communication between EV charging stations • Undertaking modelling and simulation studies • Smart metering	Collaboration and partnerships amongst utilities and other stakeholders in the EV value-chain
Medium term priority		• Designing TOU tariffs for EV charging • Approval for technical standards for charging equipment in the case of Managed charging	• Enabling communication system between EVCS and distribution utility • Database management and notifications to utilities	Collaboration and partnerships amongst utilities and other stakeholders in the EV value-chain
Long term priority		• Designing electricity market structures for participation of EVs	• Enabling Vehicle grid integration	

Annexure

Annexure 1: FAME Scheme

The table summarizes the various incentives given under the scheme.

Table 37: Incentives under FAME scheme

Component under FAME Scheme	FY 2015-16 (Rs Crore)	FY 2016-17 (Rs Crore)
Technology Platform (including testing infrastructure)	70	120
Demand Incentives	155	340
Charging Infrastructure	10	20
Pilot Projects	20	50
IEC / Operations (Public awareness and information dissemination)	5	5
Total	260	535

Source: FAME

Phase I of the scheme was extended till March, 2018.
With the success of phase I of the scheme, phase II of the scheme has been launched in March 2019 with an outlay of INR 9,630 Crore till 2021-2022 for demand incentives to support one million 2W-EV, half a million 3W-EV, 35,000 4W-EV, 20,000 4W-HEV, and 7090 e-buses.

Table 38: Incentive budget under FAME scheme

(All Figures in Rs Crore)

Component	2019-20	2020-21	2021-22	Total Fund
Demand Incentives	822	4587	3187	8596
Charging Infrastructure	300	400	300	1000
Administrative Expenditure	12	13	13	38
Total for FAME-II	1134	5000	3500	9634
Committed from Phase-I	366	0	0	366
Total	1500	5000	3500	10000

Source: FAME

As of June 2019, the total numbers of EVs sold under the scheme was 2,79,371 with over Rs 343 Crore disbursed as incentives under FAME[26]. A total of 29 Original Equipment Manufacturers (OEMs) are registered under FAME scheme and offer over 120 different models of vehicles. DHI has also sanctioned 455 electric buses for 9 cities in a pilot scheme launched in October 2017[27].

[26] *https://fame-india.gov.in/*

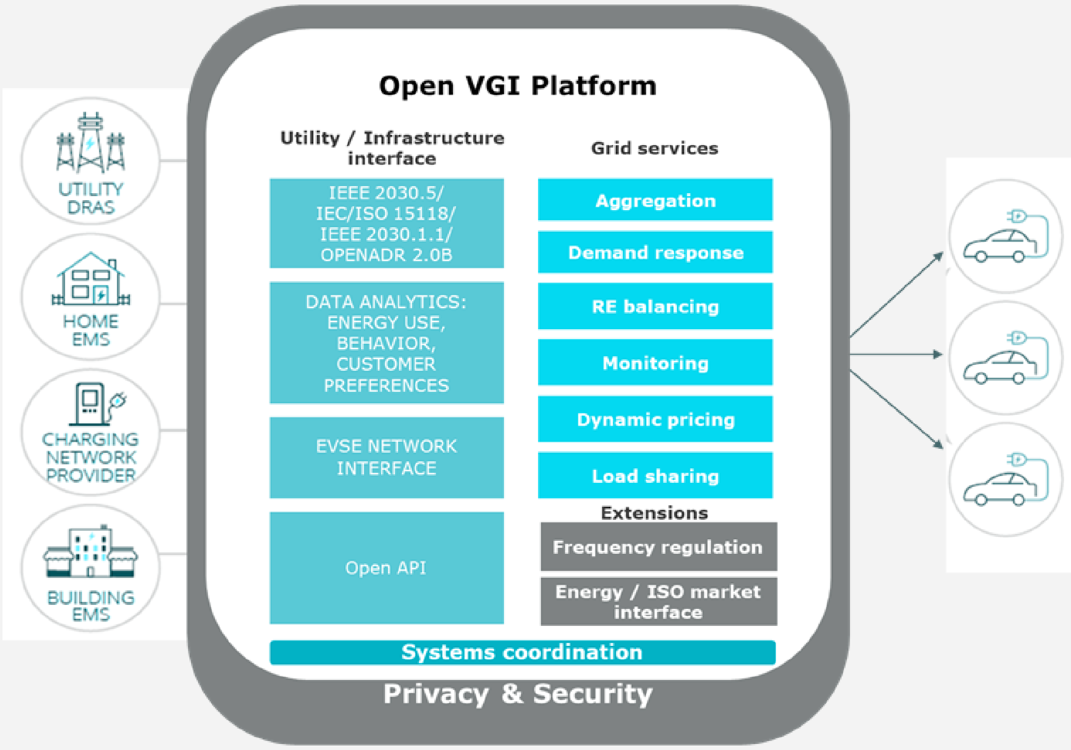
[27] *http://pib.nic.in/newsite/PrintRelease.aspx?relid=186277*

Annexure 2: CPUC VGI – Communication standards and functionalities

OPEN VEHICLE-GRID INTEGRATION PLATFORM (OVGIP)

The Electric Power Research Institute (EPRI) has been coordinating work on an Open Vehicle-Grid Integration Platform (OVGIP)93—a software application that connects EVSE and EVs to various nodes to allow utilities to more proactively manage charging activity that could help with a variety of grid services as shown below. In this approach, the utility communicates with the OEM's data center via the OVGIP, which then uses the vehicle telematics to control charging in the vehicle. The key benefit of the OVGIP is that it allows for utility-side uniformity while also supporting
OEM and EV Infrastructure flexibility.

This approach allows the use of existing on-vehicle communications protocols (i.e., IEEE 2030.5, ISO/IEC 15118, and telematics) with utility standard interface protocols (i.e., OpenADR 2.0b, IEEE 2030.5) and EV charging device application program interfaces (i.e., ISO/ IEC 15118, OCPP, and industry applied standard and proprietary APIs) through a common platform. These will ultimately allow utilities to provide: "time-of-use (TOU) pricing, peak load reduction, demand charge mitigation, load balancing for intermittent solar/wind generation, Real Time Pricing (RTP), aggregated Demand Response (DR), and scheduling dispatch for ancillary services," to EVSE or EVs across manufacturers.



Annexure 3: CPUC VGI – Communication standards and functionalities

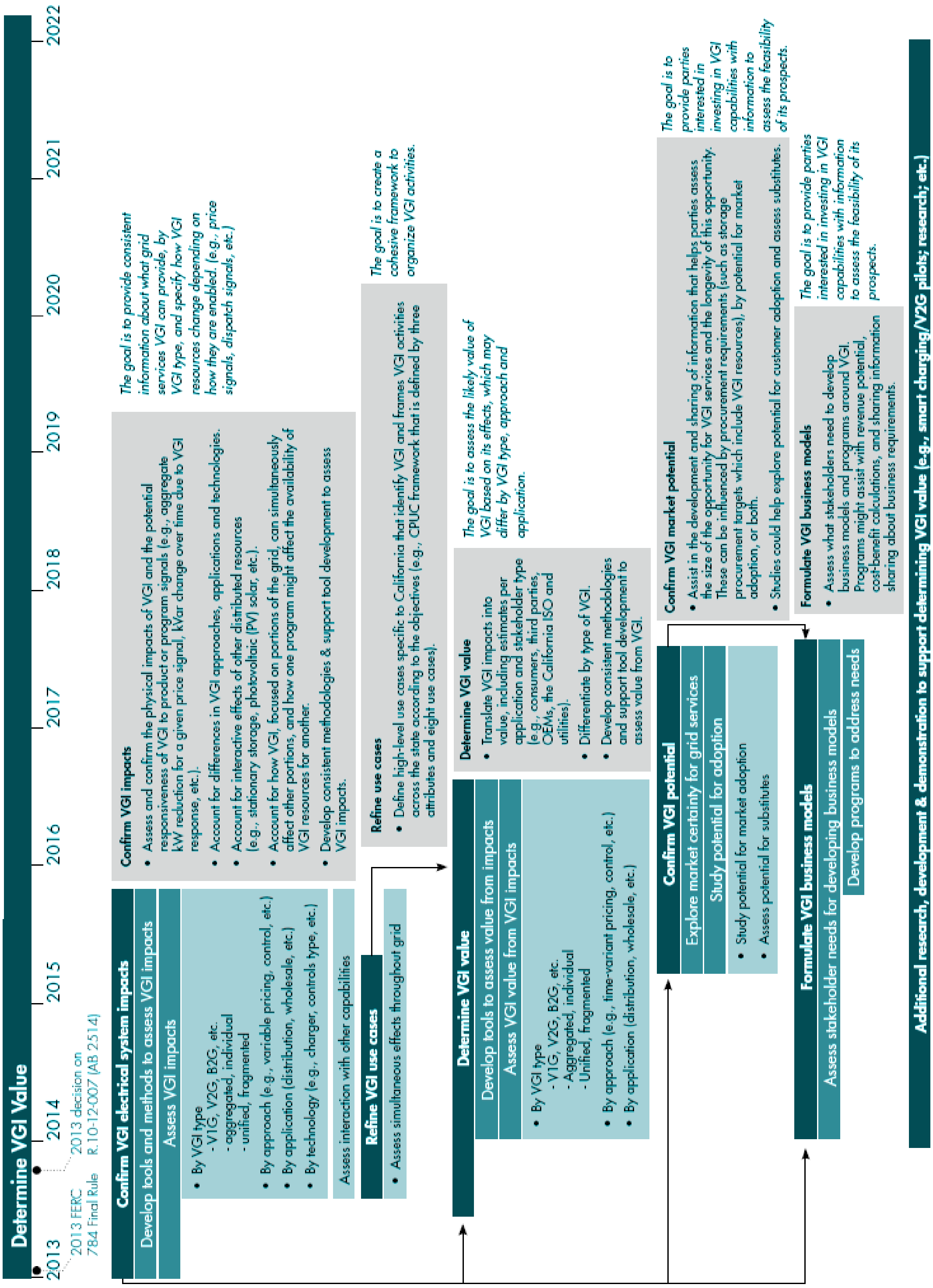
Functional Requirements Category	OpenADR	IEEE 2030.5	OCPP	Telematics	SAE Suite	IEEE 2030.1.1	ISO 15118
Rule 21	Not Supported	Supported	Not Supported	Supported in Combination	Supported in Combination	Supported in Combination	Not Supported
Pricing	Supported	Supported	Not Supported	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination
Load Control	Supported	Supported	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination
Smart Charging	Supported in combination/ Not Supported	Supported	Not Supported / Supported in	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination
Monitoring	Supported in Combination	Supported	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination
Restart	Supported	Supported	Not Supported	Supported in Combination	Supported in Combination	Supported in Combination	Supported in Combination
Miscellaneous	Not Supported	Not Supported	Not Supported	Supported in Combination	Not Supported	Supported in Combination	Not Supported

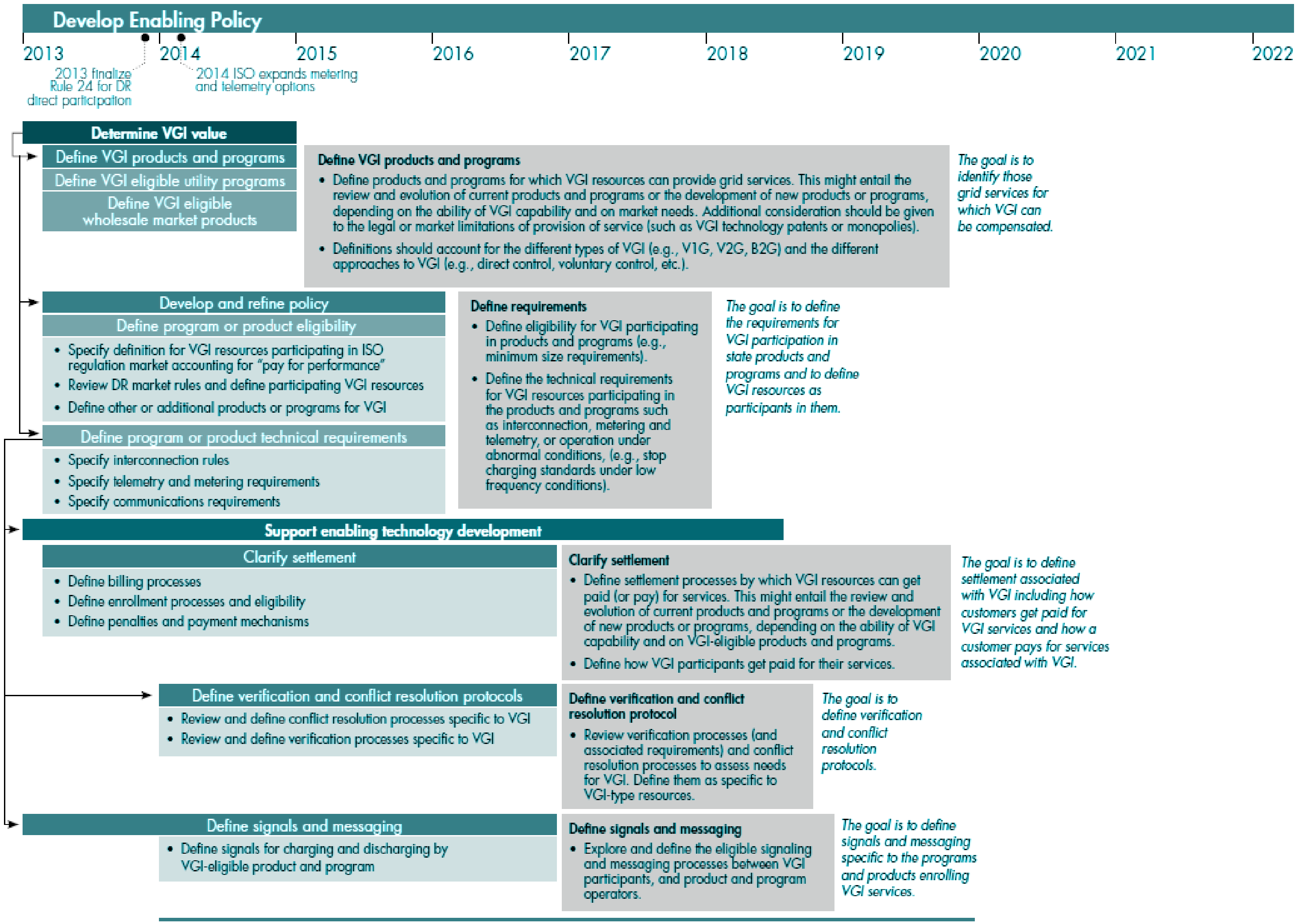
Annexure 4: Protocols provided by OEMs

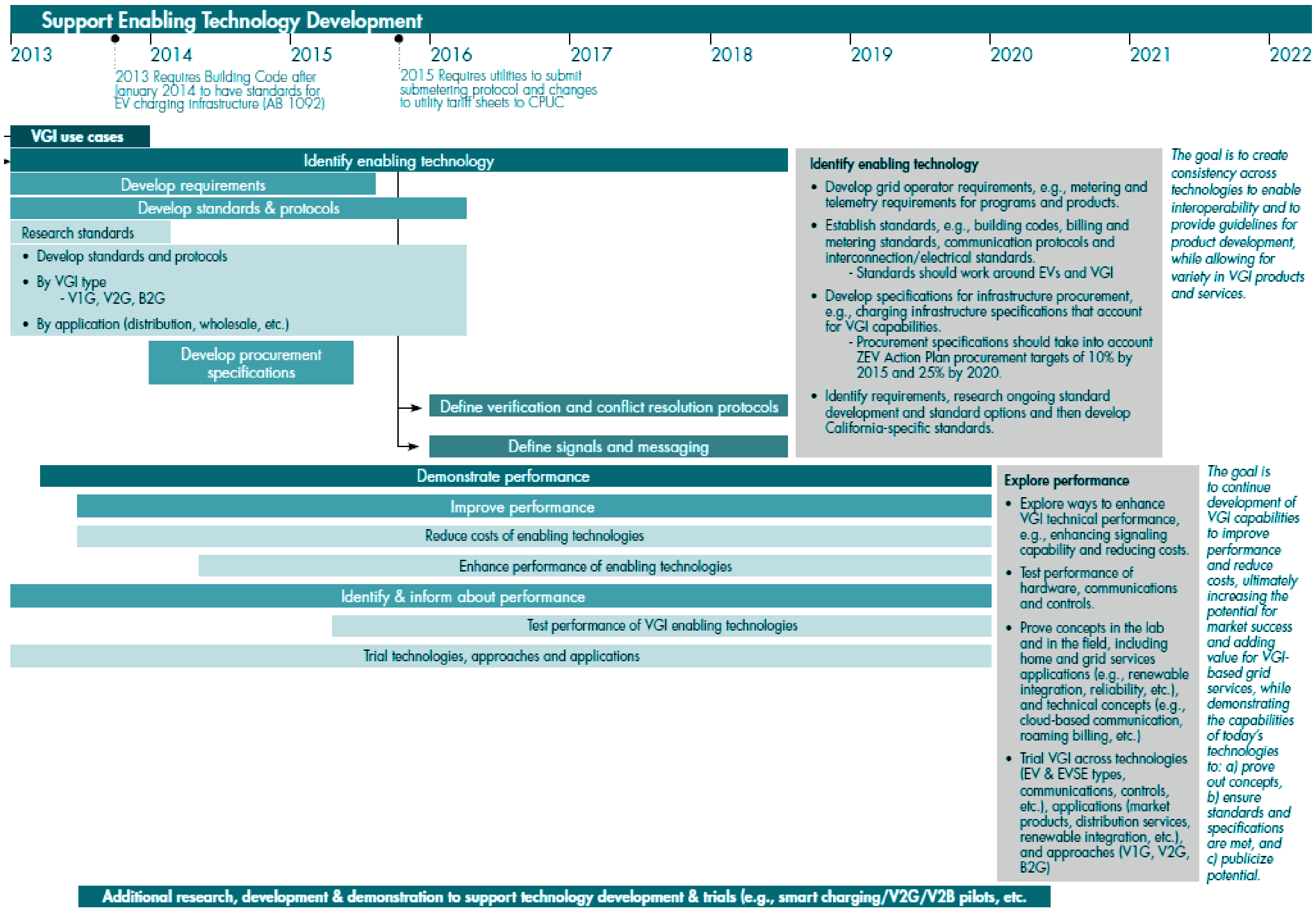
Protocols included in participating automakers' 10-year time horizon, 2017 (CPUC)

Automaker	AC Conductive	DC Conductive	Wireless Inductive
BMW	ISO 15118 (HomePlug Green PHY)	ISO 15118 (HomePlug Green PHY)	ISO 15118
Fiat Chrysler	IEEE 2030.5	ISO 15118 (HomePlug Green PHY)	WiFi, ISO 15118 v2
Ford	Telematics & ISO 15118 (future)	ISO 15118 (HomePlug Green PHY)	ISO 15118 v2
GM	No High Level Communication	DIN Spec, no timeframe for ISO/IEC	WiFi and Telematics
Honda	TBD High Level Communication, Vehicle to Grid	DIN Spec / ISO 15118, Vehicle to Grid	Premium product
Lucid	ISO 15118 (HomePlug Green PHY)	ISO 15118 (HomePlug Green PHY)	
Mercedes Benz	ISO 15118 (HomePlug Green PHY)	ISO 15118 (HomePlug Green PHY)	J2954/ ISO 15118
Nissan	Telematics	CHAdeMO	In development
Porsche/Audi/Volkswagen	ISO 15118 (HomePlug Green PHY)	ISO 15118 (HomePlug Green PHY)	ISO 15118 (in development - 2018)

Annexure 5: CEC VGI Roadmap, 2014

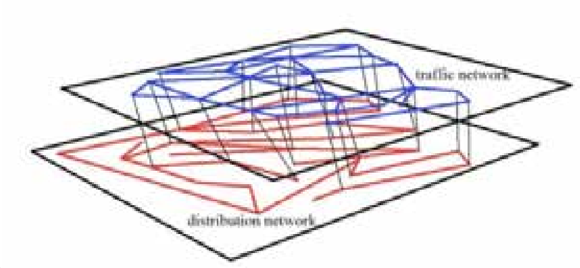



Develop Enabling Policy
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2013 finalize Rule 24 for DR direct participation
2014 ISO expands metering and telemetry options
Determine VGI value
Define VGI products and programs
Define VGI eligible utility programs
Define VGI eligible wholesale market products
Define VGI products and programs
• Define products and programs for which VGI resources can provide grid services. This might entail the review and evolution of current products and programs or the development of new products or programs, depending on the ability of VGI capability and on market needs. Additional consideration should be given to the legal or market limitations of provision of service (such as VGI technology patents or monopolies).
• Definitions should account for the different types of VGI (e.g., V1G, V2G, B2G) and the different approaches to VGI (e.g., direct control, voluntary control, etc.).
The goal is to identify those grid services for which VGI can be compensated.
Develop and refine policy
Define program or product eligibility
• Specify definition for VGI resources participating in ISO regulation market accounting for "pay for performance"
• Review DR market rules and define participating VGI resources
• Define other or additional products or programs for VGI
Define program or product technical requirements
• Specify interconnection rules
• Specify telemetry and metering requirements
• Specify communications requirements
Define requirements
• Define eligibility for VGI participating in products and programs (e.g., minimum size requirements).
• Define the technical requirements for VGI resources participating in the products and programs such as interconnection, metering and telemetry, or operation under abnormal conditions, (e.g., stop charging standards under low frequency conditions).
The goal is to define the requirements for VGI participation in state products and programs and to define VGI resources as participants in them.
Support enabling technology development
Clarify settlement
• Define billing processes
• Define enrollment processes and eligibility
• Define penalties and payment mechanisms
Clarify settlement
• Define settlement processes by which VGI resources can get paid (or pay) for services. This might entail the review and evolution of current products and programs or the development of new products or programs, depending on the ability of VGI capability and on VGI-eligible products and programs.
• Define how VGI participants get paid for their services.
The goal is to define settlement associated with VGI including how customers get paid for VGI services and how a customer pays for services associated with VGI.
Define verification and conflict resolution protocols
• Review and define conflict resolution processes specific to VGI
• Review and define verification processes specific to VGI
Define verification and conflict resolution protocol
• Review verification processes (and associated requirements) and conflict resolution processes to assess needs for VGI. Define them as specific to VGI-type resources.
The goal is to define verification and conflict resolution protocols.
Define signals and messaging
• Define signals for charging and discharging by VGI-eligible product and program
Define signals and messaging
• Explore and define the eligible signaling and messaging processes between VGI participants, and product and program operators.
The goal is to define signals and messaging specific to the programs and products enrolling VGI services.


Support Enabling Technology Development
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2013 Requires Building Code after January 2014 to have standards for EV charging infrastructure (AB 1092)
2015 Requires utilities to submit submetering protocol and changes to utility tariff sheets to CPUC
VGI use cases
Identify enabling technology
Develop requirements
Develop standards & protocols
Research standards
• Develop standards and protocols
• By VGI type
- V1G, V2G, B2G
• By application (distribution, wholesale, etc.)
Develop procurement specifications
Define verification and conflict resolution protocols
Define signals and messaging
Identify enabling technology
• Develop grid operator requirements, e.g., metering and telemetry requirements for programs and products.
• Establish standards, e.g., building codes, billing and metering standards, communication protocols and interconnection/electrical standards.
- Standards should work around EVs and VGI
• Develop specifications for infrastructure procurement, e.g., charging infrastructure specifications that account for VGI capabilities.
- Procurement specifications should take into account ZEV Action Plan procurement targets of 10% by 2015 and 25% by 2020.
• Identify requirements, research ongoing standard development and standard options and then develop California-specific standards.
The goal is to create consistency across technologies to enable interoperability and to provide guidelines for product development, while allowing for variety in VGI products and services.
Demonstrate performance
Improve performance
Reduce costs of enabling technologies
Enhance performance of enabling technologies
Identify & inform about performance
Test performance of VGI enabling technologies
Trial technologies, approaches and applications
Explore performance
• Explore ways to enhance VGI technical performance, e.g., enhancing signaling capability and reducing costs.
• Test performance of hardware, communications and controls.
• Prove concepts in the lab and in the field, including home and grid services applications (e.g., renewable integration, reliability, etc.), and technical concepts (e.g., cloud-based communication, roaming billing, etc.)
• Trial VGI across technologies (EV & EVSE types, communications, controls, etc.), applications (market products, distribution services, renewable integration, etc.), and approaches (V1G, V2G, B2G)
The goal is to continue development of VGI capabilities to improve performance and reduce costs, ultimately increasing the potential for market success and adding value for VGI-based grid services, while demonstrating the capabilities of today's technologies to: a) prove out concepts, b) ensure standards and specifications are met, and c) publicize potential.
Additional research, development & demonstration to support technology development & trials (e.g., smart charging/V2G/V2B pilots, etc.

Annexure 6: Locational planning case studies

Case study- Charging Station and Power Network Planning for Integrated Electric Vehicles - New York data[28]



Overview of the model: The research considers the charging stations as both traffic service facilities and common electric facilities and hence a multi-objective model is built with the objectives of maximizing the captured traffic flow in traffic networks and minimizing the power loss in distribution networks.

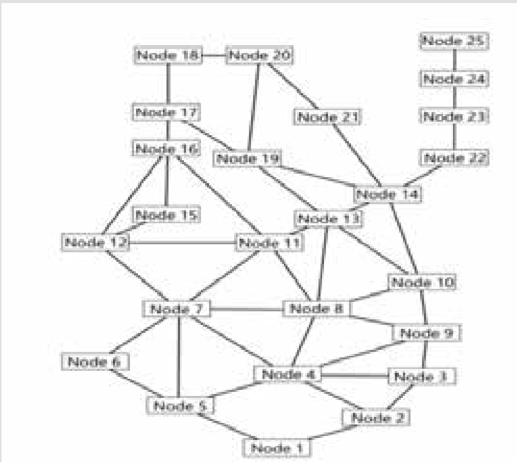
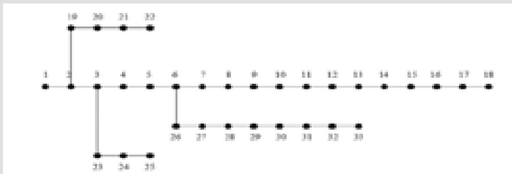
In case studies, a 33-node distribution system and a 25-node traffic network are used to juxtapose and determine optimal charging locations.
The research was done using traffic flows to simulate the charging demand with an interception model and considering some restrictive factors, such as the maximum travel distance of EVs. The objective is to choose appropriate nodes for constructing charging stations, aiming to maximize the traffic flow (to provide a charging service for more users) as well as appropriate locations of the distribution network.
Methodology used for modelling: A fuzzy multi-objective model is proposed to deal with the two objectives, and the genetic algorithm (GA) is used to find the optimal solution. The overall objective is to maximize the captured traffic flow in the traffic network and minimize the power loss in the distribution network.
Key assumptions in the modelling

1. In the indicate traffic map, analysis revealed that the driver travel destination was concentrated in a few popular places. In practice, the daily routing of most vehicles is fixed. The traffic network is composed of these traffic flows.
2. EVs cannot deviate from their shortest path
3. Two types of charging facilities are considered in this model: normal charging stations and fast charging stations. Normal charging stations operate 24 hours a day, and fast charging stations only operate during rush hours to relieve charging pressure. The size of the fast charging station (FCS) is determined by the mean arrival rate, service demand, and demand
4. Charging behavior limitations:
    - Fast charging: The FCS is important in providing electricity for EVs during peak demand hours. The service of FCSs is based on a first-come first-served (FCFS) rule signifying that the waiting time for EVs that have just arrived is determined by the mean arrival rate. The objective is to minimize the size of FCSs to decrease the cost of construction as well as cater to the charging demand

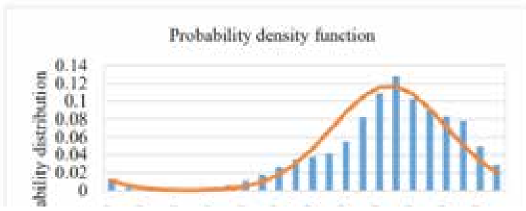
[28] *https://www.mdpi.com/1996-1073/12/13/2595*

- The capacity of charging stations should not be less than the requirement of the maximum load
- Only one type of charging station can be built at a node
- Considering the shortage of urban land resources, the number of charging poles should be limited to avoid the waste of idle resources

5. Distribution network assumptions: The power at each node and the power flow on each branch should not be greater than the limits of the distribution network to avoid damage to power grids.
6. Number of charging stations to be placed: four
7. Importance of each traffic node is set according to the degree of demand at each traffic node

Traffic network	Distribution network
	

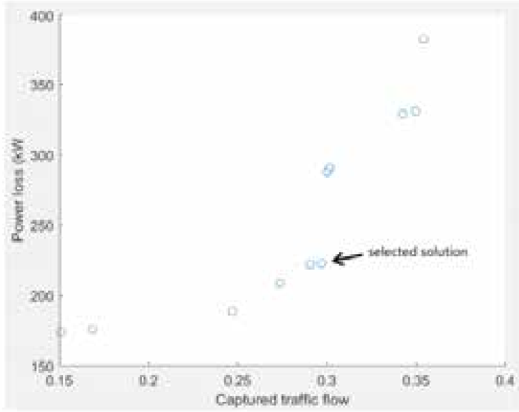
As per the survey mentioned in the research, 14% of household vehicles were unused, 43.5% travelled for 20 miles a day (about 32 km), and 83.7% travelled for 60 miles a day (about 97 km). By observing two groups of data, the ending time of the last trip is found to satisfy a normal distribution, and the daily driving distance is found to satisfy a logarithmic normal distribution. The probability density function of the ending time of the last trip and driving distance is shown alongside:

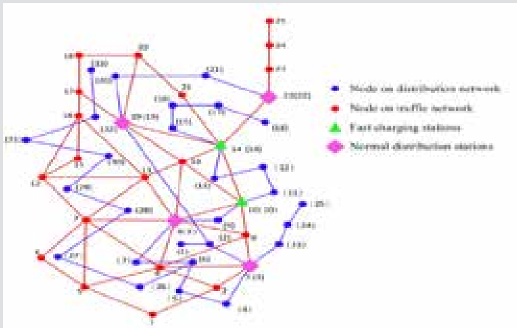


The EV selected for the case study is the Toyota RAV4. Key parameters assumed are as follows. Battery size of 27 kWh and average range: 150 km

Simulation and results: The multi-objective model is built with objectives maximizing the captured traffic flow and minimizing power loss in the distribution networks. As shown in the plots, the abscissa and ordinate values are the captured traffic flow and the power loss, respectively for different placements of charging stations in the network.

The selected solution is the one which ensures a balance between capturing adequate traffic data as well as ensuring optimal power loss in the distribution system. The simulation then produces the most optimal location and capacity of slow and fast charging locations by juxtaposing the traffic and network data as follows:



Location details	Optimized location of Normal and Fast charging stations
Normal charging stations: Station 1- Node 3- 0.3 MW Station 2- Node 8- 0.6 MW Station 3- Node 19- 0.7 MW Station 4- Node 22- 0.7 MW Fast charging stations: Station 1- Node 14- 5 MW Station 2- Node 10- 5 MW Station 3 Station 4 Total captured traffic flow: 47.47% Total power loss: 222.9647 kW	

Key inferences

1. In order to maximize the captured traffic flow, the charging stations are mainly constructed in transport hubs, which have a higher node weight
2. In order to minimize the power loss of the distribution network, the charging stations with a high capacity are mainly constructed on the front end of a system feeder.
3. The model proposed in this paper is based on an assumption that all EVs travel along the shortest path to their destination. In practice, the driving path can be influenced by traffic jams and driver negligence which cannot be adequately modelled.

Annexure 7: EV Managed Charging Case Studies

Managed charging by OEMs

Chevrolet Volt	The Chevrolet Volt offers a special delayed charging mode that can be used to mitigate a timer peak. The driver programs the desired departure time, and the vehicle calculates when charging should begin in order to be fully charged by that departure time. This particular program randomizes the start of charging, so if a number of similar vehicles employed the technology, their charging loads would be distributed as desired.

Case study - EV charging pattern analysis

FleetCarma[29] offers a connected car platform and cloud-based software system. The connected car platform not only offers real-time insights into driving and charging behavior for fleets, but can also be provided to residential EV owners as part of a utility EV load management program. The platform can also be used by utilities to understand the potential impacts of EVs on the grid and help with load forecasting as EVs scale across their service territory.

Various utilities in the US have now signed up for FleetCarma's smart charging services. The implementation will provide the concerned utilities with all the information required to understand the impact of EV charging load in the service territory. Data which is gathered and shared with the utilities includes:

- Profile of EV charging load
- Pinpoint trend of consumption on the grid
- Determine charging load patterns (duration, peak, quantum etc.)

[29] *https://www.fleetcarma.com/smartcharge/utilities/*

Key aspects of this system include the following:

Particulars	Details
Participating utilities	• Con Edison Company of New York • Tennessee Valley Authority • Tacoma Public Utilities • Duke Energy Florida • Lincoln Electric System
Objective	To collect charging information for EVs and Plug-In Hybrid Electric Vehicles (PHEV) in the service territory. Results of the study will help the utilities better understand how EVs affect the electric system
Study period	1-2 years
Incentives to participants	Participating customers may receive up to $250 per year for a maximum of $500 over the study
Eligibility	• Participants must be a residential customer • Must own or lease a fully battery electric vehicle or plug in electric hybrid, and own their own EV charging equipment.
Registration	• Participants will first register at registration website post which they would be given a FleetCarma C2 device with instructions for installation and how to activate the C2 device. • The device can be plugged into the vehicle's onboard diagnostics (OBD II) port or Tesla diagnostics connector. The OBD II port is typically located below the steering wheel and is the same port mechanics use for diagnostic checks. • Charging data will be continuously relayed to the utility through this device.
Information collected	Charging session duration, energy consumption, location, trip duration and distance travelled.
Eligible auto OEM vehicles	Audi, BMW, Chevrolet, Fiat, Ford, Hyundai, Nissan, Tesla, Toyota, etc.

Source: fleetcarma

Managed charging by Utility – OEM partnership

OMEs are also entering the managed charging space primarily through existing smart vehicle communication systems, such as GM's OnStar, or through utility pilot programs. Some case studies of the same are highlighted below:

Case study - BMW and Pacific Gas & Electric[30]	
Project overview	
Eligible participants	BMW i3, i8 or iPerformance drivers in the San Francisco Bay Area
How does it work	Charging will be optimized by BMW's intelligent charging software, with commands sent wirelessly to each participating BMW vehicle. No physical modifications would be required.

[30] *https://www.bmwchargeforward.com/#/home*

Project overview	
Intelligent charging	Key factors evaluated include: 1. Departure time of the EV 2. State of charge 3. Rider preference 4. Prevailing grid conditions If an e-mobility charging event occurs or in other words, a demand response signal is sent and the customer chooses not to participate, they will have the ability to "opt out" of the event, to allow for immediate vehicle charging. That vehicle remains "opted out" until the next time the owner plugs the vehicle into a charger.
Incentives	$300 at program launch and two additional same payments in 2018 and 2019.
Pilot implementation	The California Energy Commission awarded grant to BMW to research the benefits and opportunities that may result from shifting vehicle charging over time to meet the needs of the grid, while prioritizing each driver's expressed mobility need
	Phase 1 • BMW enrolled 96 Model i3 drivers and utilized proprietary aggregation software to delay charging via cellular (GSM-based) telematics • The drivers were provided with a L2 charging station at their homes and directed to charge primarily at home during the pilot • During the 18-month trial, the vehicles were called upon 209 times. BMW met the performance requirements for 90% of those events, **Phase 2** • It expanded to over 350 participating vehicles and focused on the customer experience by giving users more managed charging information to make smart choices • PG&E provided BMW with data on the status of renewable energy generation as well as excess supply on the system, and BMW optimized the EV charging by sending push notifications to participating drivers. • Because the vehicles are controlled using on-board vehicle telematics, a vehicle can participate regardless of where it is currently charging

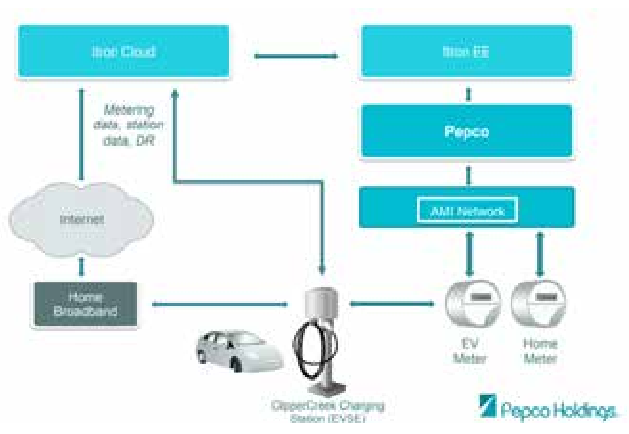
Case study - IBM, Honda, and PG&E

Project overview	
Aim[31]	To demonstrate and test an electric vehicle's ability to receive and respond to charge instructions based on the grid condition and the vehicle's battery state
	This demonstration combines grid and vehicle data to create an individualized charging plan for Honda's Fit EV battery electric vehicles (BEV), using IBM's cloud-based software platform. By utilizing the existing in-vehicle communications system in the Honda Fit EV, the EV can interact with utilities and the grid, creating a direct channel for sending and receiving usage information that could improve local grid management.

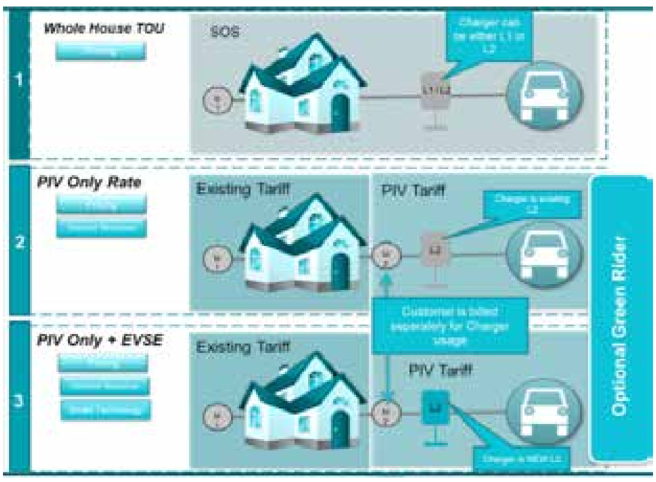
[31] *https://www-03.ibm.com/press/us/en/pressrelease/37398.wss*

Project overview	
How it works	• Once plugged into a charge post, the Honda Fit EV initiates a charge request via the vehicles telematics system, an integrated telecommunication application that is often used for navigation. • This request is sent to IBM's EV Enablement Platform where vehicle data such as location, battery state of charge and grid data, as received from PG&E, is combined to create an optimized charge schedule for the corresponding vehicle. The same is then communicated back to the vehicle in seconds. • Using this aggregated data, the vehicle has the intelligence to charge to the level that is needed while factoring any current grid constraints. • The IBM EV platform can collate historical EV charging data and create a profile that can be used to forecast the location and duration of EV charge loads. For example, the program can determine how many EVs are plugged in one neighborhood and the time it will take for each to reach a full charge. This allows PG&R to optimize grid operations and help reduce the chance of outages
Communication platform and other features	• The IBM's cloud-based platform also provides charge post location information and availability directly to the EV, using the telematics and Satellite-Linked Navigation to guide the driver to the most convenient place to charge. • The smartphone app shows the vehicles battery level, range of travel distance, vehicle location, and current energy costs in real time.

Case study-Pepco utility



Pepco, in the Maryland/Washington D.C. area, tried a residential managed charging pilot, placing 35 ClipperCreek chargers using an Itron smart charging architecture that could respond to DR events. The pilot used smart chargers with Itron meters, which worked alongside the utility's AMI for the charge point. Pepco signed up 101 customers in the pilot



Two rate structures were introduced by PEPCO:

- With the whole-home rate, which included one retail tariff for the entire home.
- Separate tariff for home and EV-specific rate. Peak charging tariff was about 23 cents/kWh. Off-peak rates dropped to 5 cents/kWh.
- Within the EV-only rate, a "green rider" was introduced by Pepco. Over 30 consumers opted for this option which allowed them to pay $2 cents/kWh extra for their energy. About 30% of

customers in the EV-only rate opted to pay slightly more for the cleaner power.

When Pepco called a DR event, they reduced the chargers from Level 2 to Level 1 rate of charge for an hour, while also providing opt-out capabilities for customers. The small scale of the residential pilot limited results with respect to customer choices and cost savings When assessing the economics of the pilot, Pepco found that that the ongoing costs of the communications link were too expensive. Identifying a cheaper solution would increase the viability of future projects.

Pepco deployed 50 smart chargers and reported that the DR programme was successful. The utility said that during days when there was a need for curtailment, charges were turned down from Level 2 to Level 1 capabilities for an hour only. The pilot successfully demonstrated "active" incentives (demand management) towards off peak charging, while providing the customer "opt out" alternatives

Case study – Aggregation

Marin Clean Energy (MCE), a Community Choice Aggregator in the US, found that it had an estimated 4,000 EV customers in late 2016 and forecasted a total of 25,000 EV customers by 2020. In response, MCE announced a private-public partnership to provide a $150 discount on new smart-grid enabled EV charging stations. Customers with existing EVSE were eligible for a free adapter that would upgrade their EVSE to be controlled via a smartphone app. Given the long-term projected demand, MCE used the eMotorWerks JuiceNet platform to manage the deployment of these chargers to better respond to grid load and pricing conditions to and thus "avoid grid bottlenecks and lower electricity procurement costs."

JuiceNet is a patented communication, control, and intelligence platform that dynamically matches drivers' historical charging patterns, real-time input and signals from grid operators and utilities to aggregate and manage charging station demand. Employing open APIs, JuiceNet can control any WiFi connected charging station and coordinates periodic, changes in charge rate and timing, which the driver can override at any time.
By deploying both smart-charging Electric Vehicle supply equipment (EVSE) and cloud software solutions on a commercial scale, electric car and truck fleet owners as well as workplace and commercial real estate facility managers can:

- Remotely manage fleets of chargers at various locations from a single cloud dashboard;
- Maximize EV charging capabilities on their properties, helping to keep costs to electrical building upgrades low; and
- Enjoy new revenues as well as offset costs from participating in energy service programs such as demand response.

Key features:

1. Through the dynamic load balancing control of the JuiceNet Enterprise solution, EV owners can install more stations on their property without costly electrical upgrades to their building infrastructure, balancing the charging load in real-time to match site electrical capacity.

1.1 Case study – Los Angeles

The Los Angeles Department of Water and Power (LADWP), through its "Charge Up L.A.!" program, offers up to $500 for Level 2 residential chargers or $4,000 for commercial chargers. As a condition of the rebate program, recipients must agree to participate in LADWP's demand response program for the life of the installation in the event the utility needs to curtail that load. Further, LADWP can disconnect the load from the EV charger for the duration of the event without notice.

1.2 Case study- Managed charging for bidding in CAISO

eMotorWerks, which developed a Vehicle Grid Integration platform called JuiceNet, has its own smart grid enabled JuiceBox EV charger, and provides JuiceNet platform capabilities to five other Electric Vehicle Supply Equipment (EVSE) manufacturers. Additionally, eMotorWerks has started deploying its platform to control vehicle charging directly over the telematics link with select OEMs. By controlling how and when large quantities of EVs charge throughout the day, eMotorWerks can bid that capacity into wholesale power markets such as the California Independent System Operator (CAISO), use it to balance renewable generation, or provide traditional DR services to the utilities, while observing driver behaviors and allowing driver override to avoid customer dissatisfaction.

1.3 Case study- New York-EV Connect

Partnership with VGI platform providers
EV Connect, a leading provider of EV (EV) charging solutions, including development of the industry's most innovative, robust and open cloud-based software platform for managing the EV charging ecosystem, was awarded a $4 million contract from the New York Power Authority (NYPA) to install and manage approximately 300 additional Level 2 EV charging stations throughout New York State. This follows a contract that NYPA awarded to EV Connect for a public charging station pilot program within the State. EV Connect provided management of the charging ecosystem, which includes the charging stations, host locations, electric utility interaction and the driver experience.

For this expanded program, EV Connect partnered with GE and EV Box to provide the charging stations, and local contractors for installation work. EV Connect was also entrusted with activities such as initial site assessment, to recommending the right charging stations to fit the need, installation, on-boarding/training utility administrators and configuring admin portal with utility preferences. EV connect also provides on-going care and management 24/7.

EV Connect's EV Cloud is currently used by NYPA to manage charging stations from multiple station manufacturers who apply both OCPP and proprietary cloud protocols. EV Connect's platform provides NYPA with access to its OpenADR Virtual End Node (VEN) to manage charging loads throughout its territory regardless of station manufacturer, type, or protocol. The platform architecture can also manage dynamic pricing signals, load aggregation, carbon credit monetization, data analytics, and other features and functionality required by other industry stakeholders.

Key inclusions in EV charging as a service
• Site Planning • General Electric EV Charge Station • Base EV Connect Management Software for managing EVs • 24/7 Management Services • Maintenance **Additional options** • Enhanced EV Connect Software by Industry or Application • Custom Branding for the Charge Stations • Installation • >3 Year Term Packages

Overview of the EV cloud platform

The EV Connect management system is consisted of a cloud-based network that communicates with the charging station, driver mobile app, site host portal, and utility. Communication from the EV Cloud to the stations is either via OCPP or a cloud-to-cloud integration. The platform can manage an unlimited number of geographically dispersed charging stations and provides the following features:

- **Charge point management and operation:** The platform can manage chargers and sessions remotely, letting the user to monitor and adapt charging sessions based on up-to-date analytics. Chargers can be connected via an M2M connection to the Microsoft Azure cloud-based platform, which supports open protocols such as OCPP, OCPI and OSCP. Utility can also input remote commands including start/stop charging, unplug connector, remote firmware updates or change charger configuration and access a live KPI dashboard.

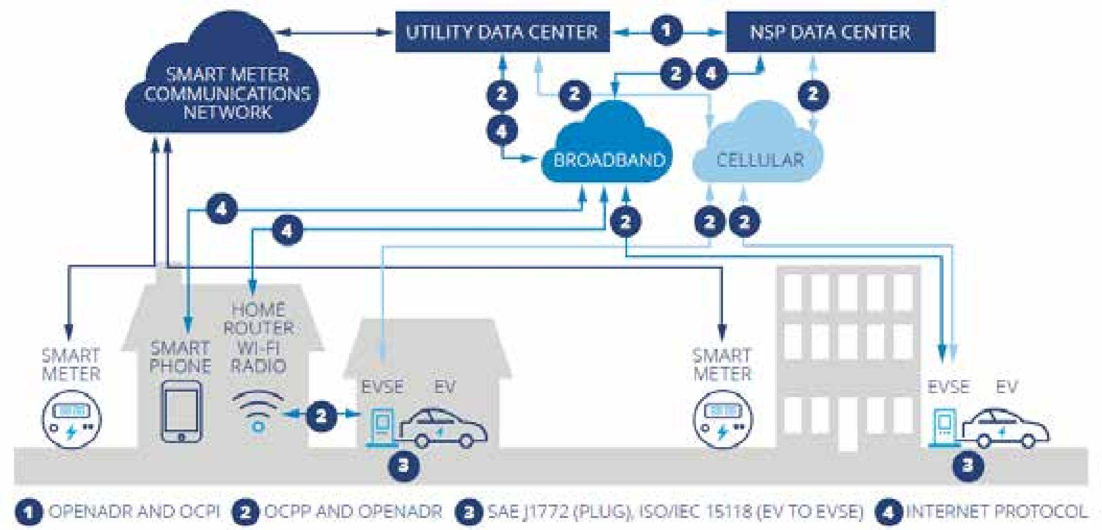
- **Smart charging:** Smart Charging through the EV cloud uses algorithms to manage EV charging sessions. Thus the utility can smartly balance between the supply of power and available grid capacity and the demand for energy for charging the cars.

- **Price control:** Set pricing policies unique to different stations, station groups, locations, and drivers. Some of the pricing policies include: charging per kWh, per connected time, per charging time, etc.

- **EV-driver app and interactive map:** The EV connect can helps drivers find and monitor the perfect charge point; charge and pay with your app; see exactly how fast, how much and at which rate the car is charging etc. The platform also provides users information of health of charging stations, geographical locations and real-time availability.

- **Insights and Reporting:** The dashboard gives detailed insights on historical charging station data analytics, session data, energy usage, utilization by station or driver, and more.

Annexure 8: Use of open protocols in managed EV charging



The scenario above illustrates managed charging network communication interface options. The transport layer is illustrated in two scenarios, one using cellular for the home and the other using broadband for a workplace program. The scenario also illustrates how multiple messaging protocols may be layered between the EV, the EVSE, and the aggregator, which can be leveraged for different purposes. This diagram demonstrates complexity of managed charging ecosystem. There are currently no industry-wide standards for the entire "ecosystem" of information exchange and communication, which is an obstacle the industry, is currently working to solve. Most of the managed charging debate today is related to which messaging protocols to use in charging equipment. Many industry stakeholders are advocating for open, non-proprietary communications messaging protocols to reduce the cost of managed charging implementation and prevent future stranded assets.

In a report, California Public Utilities Commission (CPUC) does not require the use of a single protocol but provides an elaborate discussion on two standards in particular, ISO/IEC 15118 and IEEE 2030.5 (SEP 2.0). Some details on these standards and some other standards is mentioned in the figure below

Standard	Description
OSCP 1.0, OCPP 1.5, OCPP 1.6, OCPP 2.0	The Open Charge Point Protocol (OCPP) and the Open Smart Charging Protocol (OSCP) were developed by the members of the Open Charge Alliance and are an open protocol for communications between charging points and the EV charging network administrator. These protocols provide charging station owners the option of changing EV charging network administrators without stranding equipment assets. The OSCP acts between the charging station and the energy management system, can provide 24-hour prediction for local available capacity, and fits charging profiles to grid capacity. OCPP 1.6 includes smart charging support for load balancing. The most recent version, OCPP 2.0, includes support for ISO/IEC 15118 (among other things). Although not yet formalized as a standard and managed by a recognized standards defining organization (SDO), there is significant adoption of the OCPP protocol and efforts are underway to develop it into a full standard within the IEC.

Standard	Description
OpenADR 2.0	The Open Automated Demand Response (OpenADR 2.0b is the most updated version) standard is currently managed by the OpenADR Alliance, and provides an open and standardized way for Virtual Top Nodes (e.g., electricity providers and system operators) to communicate with various Virtual End Nodes (e.g., aggregators, EV charging network operators, etc.) using a common language over any existing IP-based communications network. Originally developed as a peak load management tool, it has since expanded to include other DERs. Messaging protocols such as OpenADR can also be used in combination with other protocols, such as those used to communicate between a charging station and a network operator (e.g., OCPP76, IEEE 2030.5, etc.).
ISO/IEC 15118	ISO/IEC 15118 (also referred to as "OpenV2G"), enables the managed charging functionality in an EV, such as optimized load management. More specifically, it specifies the communication between the EV and the EVSE and supports the EV authentication and authorization (also known as "Plug & Charge"), and metering and pricing messages. Version 2 is currently under review with the final version anticipated by mid-2020 that will include V2G.
IEEE 2030.5/ SEP2.0	IEEE 2030.5 (formerly Smart Energy Profile 2.0 or SEP2.0), is an application layer protocol that defines messages between any client/server. Pricing, demand response, and energy use are among the types of information that can be exchanged using the protocol and can integrate a wide variety of DER devices, including EVs and EVSE.
IEC 63110	IEC 63110 is an international standard defining a protocol for the management of EV charging and discharging infrastructures. It is part of an IEC group of standards for electric road vehicles and electric industrial trucks, and is assigned to the Joint Working Group 11 of the IEC Technical Committee 69. At the date of publication it was still under development

Annexure 9: Cost Recovery and Rate Structures.

Cost Recovery Process for Network Upgrades – Department of Public Utilities in US

<table>
<tr><th>Utility</th><th>Proposed Investment</th><th>Approved Cost Recovery Mechanism</th></tr>
<tr><td>National Grid (Massachusetts)</td><td>Grid Modernization Plan (GMP) investments as proposed by national grid has the following four main components:
1. Field deployment:
• Advanced metering infrastructure ("AMI")
• Customer load management (load control switches, smart thermostat etc)
• Advanced distribution automation
• Volt/Volt-ampere reactive optimization ("VVO , including capacitor banks, voltage regulators, transformer tap changers etc)
• Feeder monitors (Power monitoring device)

2. Enabling infrastructure:
• Advanced distribution management system, SCADA, Information/operational technology, billing systems.
• Cybersecurity and workforce training.
• Asset management, and marketing, education and outreach

3. Distributed energy resources (voltage ground fault protection and direct transfer trip protection)

4. Research development and deployment (targeted inverter conversion, high density community energy storage, short term renewable forecasting, DC to DC charging, fault location analysis, a sensor analytics development program, and analytics for asset management)
National Grid has proposed three investment scenarios with a timeline of five years:
1. Balanced Plan : $792.9 million
2. AMI-Focus: $619.6 million.
3. Grid-Focus: $584.6 million.
4. Opt-in: $ 238.6 million.</td><td rowspan="2">Department of public utilities (DPU) has approved the utility to recover cost for grid modernisation through a short-term targeted cost recovery mechanism

Key steps taken by regulator and utility:
1. Proposal: National Grid submits a five year timeframe investment proposal(s).
2. Preauthorisation: DPU preauthorizes investments for a specific period (three years) with a spending cap ($82 million-NG, $45 million- Eversource) and selected components:
• VVO,
• advanced distribution automation,
• feeder monitors, communications, and
• Information/operational technologies, ADMS).
3. Deployment: Preauthorisation is an approval by DPU for National Grid to go ahead with investments.
4. Proof of benefits: During cost recovery approval, National Grid has to showcase that the assets are in use and beneficial to customer.
5. Expense approval: Capital investments will be eligible for inclusion in base rates after DPU has approved final cost recovery in a grid modernization proceeding at the end of three-year term.
6. Final Recovery: Post approval, National Grid shall collect DPU approved grid modernisation expenses and revenue requirements from ratepayers using a volumetric rate. A distribution revenue allocator is used to allocate cost to each rate class.

Note:
1. Under GMP, National Grid can only recover cost of investment for new technologies relative to its current investment practices. It should be with a purpose to accelerate progress in achieving grid modernisation objective.</td></tr>
<tr><td>Eversource (Massachusetts)</td><td>Proposed EV research and demonstration projects initiative, which includes investments of $45 million for development of EV charging infrastructure. Key components of make-ready infrastructure is as follows:
1. Distribution primary lateral service feed;
2. Necessary transformer and transformer pad
3. New service meter
4. New service panel
5. Associated conduit and conductor necessary to connect each piece of equipment</td></tr>
</table>

Source: Department of Public Utilities, Massachusetts

Rate Structure for EV charging in US:

Utility/Program	Number & Type of EVSE	Market Segment	EVSE Ownership	Rate Structure
Kansas City Power & Light Clean Charge Network	Level 2 with 15 DCFC stations provided by Nissan	Municipally-owned locations	Utility ownership, installation, O&M	Free charging provided by city for first two years
Avista EVSE Pilot Program	265 stations: 120 residential Level 2, 145 non-residential Level 2 chargers, 7 DCFC	Workplace, fleet, MUD, public	Utility ownership	Residential Level 2 charging added to monthly bill; public Level 2 host sites to determine rate charged in coordination with utility; $0.30/minute for DCFC use
Georgia Power Get Current Program	Over 550 Level 2 and DCFC already installed	Workplace, residential	Utility ownership, O&M	$0.25/minute for DCFC charging; $1/hour for the first 3 hours and $0.10/minute thereafter for Level 2 use; TOU rates available to residential PEV owners
Austin Energy Plug-In Everywhere Network	Over 250 charging stations currently in network	Workplace, MUDs	Host site ownership, installation and electricity costs; utility provides maintenance	$25 for unlimited charging with 6-month membership, or $2.00/hour; residential TOU pricing with $30 fixed cost
Green Mountain Power EVgo Network	20 Level 2 stations and 11 DCFC stations installed as of early 2016	Municipalities	Municipality ownership, O&M, electricity costs	EVgo pricing options
Southern California Edison Charge Ready Pilot	Phase I: 1,500 charging stations; Phase II: 30,000 stations	Workplace, MUDs, public/retail, 10% DACs	Host site ownership, O&M, electricity costs	TOU rates as applicable, subject to change based on Phase I result
SDG&E Power Your Drive Program	3,500 Level 2 stations	50% Workplace, 50% MUDs, 10% DACs	Utility ownership, O&M, host site pays electricity costs	Rate-to-Driver or Rate-to Host pricing options, host site participation fee
PG&E Smart Charge and Save Program	7,500 Level 2 stations	50% Workplace, minimum 20% with 50% goal MUDs, 15% with 20% goal DACs	Utility ownership, host site O&M and pays electricity costs	Site host can choose between two options: TOU Rate-to-Driver or TOU Rate-to-Host pricing options, host site participation fee

Utility/Program	Number & Type of EVSE	Market Segment	EVSE Ownership	Rate Structure
Massachusetts National Grid EV Market Development Program	Level 2: 600 stations; 1,200 ports DCFC: 80 stations; 80 ports	Long-dwell locations for Level 2 sites; High traffic locations for DCFC sites; 10% of EVSE in DACs	Host site EVSE ownership, O&M for minimum of 5 years after installation	Site host to pay for electricity consumed at charging site at current rate for at least first 5 years and decide how driver pays at station
Massachusetts Eversource EV Infrastructure Program	Phase I: 32 DCFC stations, 1,000 Level 2 ports Phase II: 35 DCFC stations, 3,100 Level 2 ports	Long-dwell locations for Level 2 sites High traffic locations for DCFC sites 10% investment in DCFC sites; 10% of EVSE in DACs	Host site EVSE ownership, O&M for minimum of 10 years after installation	NA
Pacific Power Public Charging Pilot Program	Total of 7 charging "pods" consisting of both dual standard DCFC and Level 2 stations	Pacific Power to choose locations based on proximity to travel corridors, MUDs, other charging stations; proximity to existing electrical network; ease of public access; ease of permitting	Utility ownership, O&M	Pacific Power to develop and implement TOU rates to encourage off-peak charging
Portland General Electric Community Charging Infrastructure pilot	Six new charging sites, each with 4 dual-head DCFC stations and one dual port Level 2 station	PGE to choose locations based on proximity to travel corridors, MUDs, other charging stations and transportation networks; proximity to existing electrical network; ease of public access; cost of real estate; potential installation barriers	Utility ownership, O&M	Proposed two pricing option: monthly subscription for PGE customers or pay-per-use for nonsubscribers

Source: Utility Regulatory Filings and M.J. Bradely and Associates

References

1. https://dailyenergyinsider.com/news/19530-utilities-make-progress-with-electric-vehicle-managed-charging-but-more-work-needed-sepa/
2. https://sepapower.org/resource/utilities-electric-vehicles-evolving-unlock-grid-value/thank-you/
3. http://www.floridapsc.com/ClerkOffice/ShowDocket?orderNum=PSC-2017-0451-AS-EU.
4. http://www.floridapsc.com/library/filings/2017/09951-2017/09951-2017.pdf
5. https://www.mauielectric.com/products-and-services/electric-vehicles/electric-vehicle-rates-and-enrollment
6. https://www.mauielectric.com/products-and-services/electric-vehicles/electric-vehicle-rates-and-enrollment/residential-rates-for-maui
7. https://www.mauielectric.com/documents/billing_and_payment/rates/maui_electric_rates_maui/maui_rates_tou_ri.pdf
8. https://www.mauielectric.com/a/5052
9. https://www.mauielectric.com/documents/billing_and_payment/rates/maui_electric_rates_maui/maui_rates_sch_r.pdf
10. https://www.mauielectric.com/products-and-services/electric-vehicles/electric-vehicle-rates-and-enrollment/commercial-pilot-rates-for-maui
11. https://www.energy.ca.gov/rules-and-regulations/energy-suppliers-reporting/clean-energy-and-pollution-reduction-act-sb-350
12. https://www.revisor.mn.gov/statutes/cite/216B.1614
13. https://www.cpuc.ca.gov/sb350te/
14. https://www.fleetcarma.com/smartcharge/utilities/
15. https://www.epri.com/#/pages/product/3002008705/?lang=en-US
16. https://azure.microsoft.com/en-in/blog/azure-iot-drives-next-wave-innovation-in-infrastructure-and-energy/
17. https://www.fleetcarma.com/what-is-smart-charging/
18. https://www.bmwchargeforward.com/#/home
19. https://www-03.ibm.com/press/us/en/pressrelease/37398.wss
20. https://www.hawaiianelectric.com/products-and-services/save-energy-and-money/time-of-use-program
21. https://www.utilitydive.com/news/pge-sce-sdge-pursue-subscriptions-time-of-use-rates-to-drive-more-cali/545907/
22. https://wpstatic.idium.no/elbil.no/2016/08/EVS30-Charging-infrastrucure-experiences-in-Norway-paper.pdf
23. https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging/
24. https://www.projectfinance.law/blog/electric-vehicle-charging-recent-developments-in-the-united-states
25. https://www.nedo.go.jp/content/100864936.pdf
26. https://www.nissanusa.com/ev/media/pdf/incentives/nissan-leaf-incentive-176.pdf
27. https://www.engerati.com/article/demand-response-california-pepco-electric-vehicle-owners-flexibility
28. https://www.transmissionhub.com/articles/2013/08/maryland-psc-approves-pepco-bge-pilot-electric-vehicle-programs.html

29. https://www.fleetcarma.com/docs/ProfileandManage2019-FleetCarma-web.pdf
30. http://roadmapforth.org/program/presentations17/SmartCharging-MarkGoody.pdf
31. https://www.cpuc.ca.gov/vgi/
32. http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M211/K654/211654688.PDF
33. https://theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf
34. https://www.utilitydive.com/news/avista-utilities-asks-washington-state-regulators-to-approve-electric-vehic/413995/
35. http://mediaroom.avistacorp.com/news-releases/news-release-details/avista-launches-electric-vehicle-supply-equipment-pilot-program
36. https://www.prnewswire.com/news-releases/greenlots-selected-by-avista-utilities-for-electric-vehicle-charging-pilot-300304441.html
37. https://bladenonline.com/wp-content/uploads/2019/04/Duke-Energy-Electric-Vehicle-Filing.pdf
38. https://www.greentechmedia.com/articles/read/michigan-approves-its-first-utility-ev-charging-infrastructure-pilot#gs.o303tt
39. https://www.edison.com/content/dam/eix/documents/innovation/electric-transportation/charge-ready-2-ev-charging-infrastructure-proposal.pdf
40. http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/139969.PDF
41. http://www.caiso.com/Documents/Presentation-EnergyStorageandAggregatedDistributedEnergyResource-EducationalForum.pdf
42. https://www.raponline.org/wp-content/uploads/2018/04/enabling_third_party_aggregation_distributed_energy_resources2.pdf
43. https://www.utilitydive.com/news/how-california-plans-to-integrate-distributed-resources-into-its-iso-market/401123/
44. https://ww2.energy.ca.gov/transportation/vehicle-grid-integration/
45. https://www.edsoforsmartgrids.eu/wp-content/uploads/EDSO-paper-on-electro-mobility-2.pdf
46. https://www.cpuc.ca.gov/General.aspx?id=8314
47. https://www.sce.com/partners/partnerships/demand-response-service/rule-24-frequently-asked-questions
48. https://www.pge.com/en_US/residential/save-energy-money/energy-management-programs/demand-response-programs/rule24/electric-rule-24.page
49. https://www.cpuc.ca.gov/General.aspx?id=6306
50. https://www.cpuc.ca.gov/General.aspx?id=5924
51. https://www.pge.com/en_US/residential/save-energy-money/energy-management-programs/demand-response-programs/rule24/faq.page
52. http://www.caiso.com/participate/Pages/Load/Default.aspx
53. http://www.caiso.com/Documents/ChecklistforProxyDemandResourcesSeekingTelemetry.pdf
54. http://www.caiso.com/Documents/FlowchartforDemandResponseTelemetryResources.pdf
55. http://www.caiso.com/Documents/ParticipationComparison-ProxyDemand-DistributedEnergy-Storage.pdf
56. http://www.caiso.com/participate/Pages/Load/Default.aspx

57. http://www.caiso.com/Documents/ReliabilityDemandResponseResourceParticipationOverview.pdf
58. http://www.caiso.com/Documents/PDR_RDRRParticipationOverviewPresentation.pdf
59. http://www.caiso.com/Documents/ReliabilityDemandResponseResourceOverview.pdf
60. https://www.utilitydive.com/news/emotorwerks-provides-caiso-with-30-mw-of-dr-through-smart-ev-charging/532110/
61. https://www.greentechmedia.com/articles/read/emotorwerks-wholesale-markets-ev-charger-network#gs.owp1lg
62. https://emotorwerks.com/utilities
63. https://emotorwerks.com/images/azura-pages/utilities/eMotorWerks_SCP_Case_Study_2018-04.pdf
64. https://www.cooperative.com/programs-services/bts/Documents/TechSurveillance/Surveillance-Article-EVSE-Load-Control-Strategies-Jan-2019.pdf
65. http://www.hitachi.com/rev/pdf/2014/r2014_08_102.pdf
66. https://static1.squarespace.com/static/570b03987c65e49ce6174883/t/5849bd2dd1758e9d8e900275/1481227568794/Pepco+MD+EV+Pilot+Overview+120816+V1.pdf
67. https://www.greencarcongress.com/2018/05/20180510-emotorwerks.html
68. https://emotorwerks.com/products/juicenet-software/juicenet
69. https://www.epri.com/#/pages/product/000000003002008705/?lang=en-US
70. https://www.iitk.ac.in/ime/anoops/FOR-17/FOR-17%20photos/PPTs/IITK%20Outreach%20Centre%20Day%202/ppt%20on%20Electric%20Vehicles%20Impact%20on%20%20Utility%20and%20Regulatory%20Interventions%20ver%20%203.pdf
71. https://www.mckinsey.com/~/media/McKinsey/Locations/Europe%20and%20Middle%20East/Netherlands/Our%20Insights/Electric%20vehicles%20in%20Europe%20Gearing%20up%20for%20a%20new%20phase/Electric%20vehicles%20in%20Europe%20Gearing%20up%20for%20a%20new%20phase.ashx
72. https://theicct.org/sites/default/files/publications/EV-charging-best-practices_ICCT-white-paper_04102017_vF.pdf
73. https://theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf
74. http://www.forumofregulators.gov.in/Data/study/EV.pdf
75. https://cdn2.hubspot.net/hubfs/415845/White%20papers/Using%20managed%20charging%20to%20mitigate%20EV%20peak%20load/Using%20managed%20charging%20to%20mitigate%20EV%20peak%20load.pdf
76. https://cdn2.hubspot.net/hubfs/415845/Fact%20sheets/DERMS%20fact%20sheet%202019-03.pdf
77. https://www.powerstream.ca/innovation/electric-vehicles-and-charging-stations/alectra-drive.html
78. https://www.powerstream.ca/attachments/News_Release_Alectra_Drive_for_the_Workplace.pdf
79. https://www.powerstream.ca/attachments/Backgrounder_Alectra_Drive_for_the_Workplace.pdf

80. https://www.tdworld.com/distributed-energy-resources/alectra-utilities-schneider-electric-derms-helping-canada-charge-ahead
81. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/772619/evhs-guidance-for-installers-v-2-3.pdf
82. http://mohua.gov.in/upload/whatsnew/5c6e472b20d0aGuidelines%20(EVCI).pdf
83. https://www.innovations.harvard.edu/sites/default/files/1108934.pdf
84. https://www.allego.eu/business/ev-cloud
85. http://www.evconnect.com/wp-content/uploads/2018/05/EV-Connect-Charge-Station-Management-Platform-Overview-11-1-17.pdf
86. http://www.evcaas.com/
87. https://chargedevs.com/tag/ev-connect/
88. https://www.evconnect.com/business-2/
89. https://www.eqmagpro.com/ev-connect-closes-8-million-financing-round/
90. https://www.allego.eu/business/ev-cloud#
91. https://sustainableamerica.org/blog/charging-ahead-in-the-cloud/
92. https://www.ase.org/blog/new-york-state-wants-drivers-go-electric-heres-how-its-preparing-fast-charger-network-make
93. https://sepapower.org/knowledge/ev-managed-charging-lessons-from-utility-pilot-programs/
94. https://www.niti.gov.in/writereaddata/files/document_publication/India-Energy-Storage-Mission.pdf
95. https://powermin.nic.in/sites/default/files/webform/notices/scan0016%20%281%29.pdf
96. https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-battery-electric-vehicles.pdf
97. https://fame-india.gov.in/
98. http://pib.nic.in/newsite/PrintRelease.aspx?relid=186277
99. https://www.standardsbis.in/Gemini/search/Browse.action?saleModeName=SOFT_COPY&subDivisionId=406#
100. https://www.researchgate.net/publication/330498865_Role_of_reactive_power_STATCOM_in_the_planning_of_distribution_network_with_higher_EV_charging_level
101. https://theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf
102. https://www.nyserda.ny.gov/Researchers-and-Policymakers/Electric-Vehicles/Resources/Best-Practice-Guides-for-Charging-Stations
103. https://arxiv.org/pdf/1801.02129.pdf
104. http://www.hitachi.com/rev/pdf/2014/r2014_08_102.pdf
105. https://www.mauielectric.com/products-and-services/electric-vehicles/electric-vehicle-rates-and-enrollment
106. https://www.mauielectric.com/documents/billing_and_payment/rates/maui_electric_rates_maui/maui_rates_tou_ri.pdf
107. https://www.mauielectric.com/a/5052
108. http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/B2DF49B34871148088257FBE0073125F/$FILE/R1309011-A1410014-SCE%20PEV%20Smart%20Charging%20Pilot%20Final%20Report%20.pdf
109. http://www.floridapsc.com/library/filings/2017/09951-2017/09951-2017.pdf

110. https://www.revisor.mn.gov/statutes/cite/216B.1614
111. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442460144
112. https://www.cpuc.ca.gov/General.aspx?id=8314
113. https://www.cpuc.ca.gov/General.aspx?id=6306
114. http://www.caiso.com/participate/Pages/Load/Default.aspx
115. https://www.niti.gov.in/writereaddata/files/document_publication/EV_report.pdf
116. https://www.niti.gov.in/writereaddata/files/document_publication/India-Energy-Storage-Mission.pdf
117. https://www.niti.gov.in/writereaddata/files/document_publication/RMI_India_Report_web.pdf
118. http://www.cea.nic.in/reports/others/planning/rpm/ev_cea_report.pdf
119. https://dhi.nic.in/writereaddata/UploadFile/meeting%20of%20Standarization%20of%20Protocol%20of%20AC636662999110274672.pdf
120. https://dhi.nic.in/writereaddata/UploadFile/EOI%20for%20EV%20charging%20in%20cities%2012%20july.pdf
121. http://cea.nic.in/reports/others/planning/rpm/mom_100519.pdf
122. https://dhi.nic.in/writereaddata/UploadFile/Standardization%20of%20protocol.pdf
123. https://dhi.nic.in/writereaddata/UploadFile/publicationNotificationFAME%20II%208March2019.pdf
124. https://pib.gov.in/newsite/PrintRelease.aspx?relid=186277
125. https://www.mass.gov/files/documents/2017/08/30/ma-plug-in-electric-vehicle-and-charging-infrastructure-case-study.pdf
126. https://economictimes.indiatimes.com/industry/transportation/nagpur-gets-indias-first-fleet-of-electric vehicles/articleshow/58863716.cms?from=mdr
127. http://www.autosarena.com/niti-aayogs-quick-pilot-ev-charging-infrastructure-gets-thumbs-ev-players/
128. https://www.financialexpress.com/auto/car-news/magenta-power-sets-up-indias-first-solar-based-charging-station-aims-to-expand-by-end-2018/1204443/
129. https://www.autocarpro.in/news-national/magenta-power-launches-smartphone-app-for-ev-charging-40790
130. https://www.eqmagpro.com/inauguration-of-reil-built-electronic-vehicle-charging-infrastructure-at-mnit-jaipur/
131. http://www.newindianexpress.com/cities/hyderabad/2019/may/21/hmrl-launches-smart-parking-system-at-begumpet-metro-station-1979779.html
132. https://www.indiatimes.com/auto/current/kochi-to-get-15-electric-vehicle-charging-stations-soon-a-first-in-kerala-367460.html
133. https://www.telegraphindia.com/states/west-bengal/vehicle-charging-hubs-in-new-town/cid/1668687
134. https://timesofindia.indiatimes.com/city/bengaluru/first-public-e-charging-point-opened-at-kr-circle/articleshow/62989053.cms
135. https://www.thehansindia.com/posts/index/Andhra-Pradesh/2018-08-25/Electric-Charging-Station-inaugurated-at-Simhadri/407587
136. https://www.indiatimes.com/auto/current/electric-buses-will-run-on-roads-of-jammu-kashmir-first-batch-of-10-buses-inducted-in-fleet-365453.html

137. https://mercomindia.com/srinagar-30-ev-buses/
138. https://swachhindia.ndtv.com/assam-electric-vehicles-guwahati-goes-green-as-it-takes-steps-towards-public-e-mobility-gets-15-electric-buses-10-more-to-come-soon-33929/
139. https://www.mjbradley.com/sites/default/files/MJBA_Accelerating_the_Electric_Vehicle_Market_FINAL.pdf
140. https://www.eversource.com/content/docs/default-source/investors/d-p-u-15-120-15-121-15-122-order-(5-10-18).pdf?sfvrsn=a49fc262_0
141. https://www.mass.gov/files/documents/2016/11/vf/electric-grid-modernization.pdf
142. https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20180605_cpuc_approves_new_pge_projects_to_help_accelerate_electric_vehicle_adoption_in_california_
143. https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_5532-E.pdf
144. https://www.greentechmedia.com/articles/read/california-regulators-open-a-new-chapter-in-utility-electric-vehicle-chargi#gs.o4h4q4
145. https://www.greenbuttonalliance.org .
146. http://www.uperc.org/App_File/EV-pdf225201950008PM.pdf
147. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/PGE-EPIC-2.02.pdf
148. https://beeindia.gov.in/content/e-mobility
149. https://www.sce.com/sites/default/files/inline-files/SCE%20Quarterly%20Charge%20Ready%20Pilot%20Program%20Report%202018Q4_0.pdf
150. https://www.smev.in/ev-sales
151. https://webstore.iea.org/global-ev-outlook-2019
152. https://www.utilitydive.com/news/emotorwerks-provides-caiso-with-30-mw-of-dr-through-smart-ev-charging/532110/
153. https://www.fame-india.gov.in/
154. https://www.fame-india.gov.in/ModelUnderFame.aspx
155. https://www.tatapower.com/businesses/next-gen-power-solutions/ev-charging-stations.aspx
156. https://fossbytes.com/tesla-gigafactory-india-chinese-electric-battery-company/
157. https://www.livemint.com/news/india/tesla-shows-interest-in-india-s-plans-to-build-battery- plants-1566150165528.html
158. https://www.livemint.com/news/india/india-readies-plan-for-4-billion-tesla-scale-battery-storage-plants-1564077561033.html
159. https://economictimes.indiatimes.com/news/economy/policy/companies-may-soon-be-invited-to-set-up-battery-plants/articleshow/69733332.cms?from=mdr
160. https://www.livemint.com/news/india/india-readies-plan-for-4-billion-tesla-scale-battery-storage-plants-1564077561033.html
161. http://mydocs.epri.com/docs/PublicMeetingMaterials/0712/D2-7.pdf
162. https://www.nrel.gov/docs/fy10osti/47336.pdf

About Greening the Grid Program

USAID's Greening the Grid (GTG) is a five-year program implemented in partnership with India's Ministry of Power (MOP) under the USAID's ASIA EDGE (Enhancing Development and Growth through Energy) Initiative. The program aims to support the Government of India's (GOI) efforts to manage the large-scale integration of RE into the grid and combines the following three components which interact with each other.

This report is available at no cost from the GTG-RISE initiative at *https://www.gtg-india.com/resources/*

USAID/India Renewable Integration and Sustainable Energy (RISE) Initiative
Deloitte Consulting India Project
503-504, Fifth Floor, DLF Place Mall Office Block, Saket, New Delhi - 110017
Tel: +91-11-4045-0737/38
www.gtg-india.comE