Lucknow Comprehensive **Electric Mobility Plan**

ROADMAP FOR TRANSFORMATION OF LUCKNOW
TO A GLOBAL EV LIGHTHOUSE CITY IN INDIA

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Disclaimer

Foreword By

India stands at the cusp of a paradigm shift towards electric mobility. To overcome the barriers and accelerate this transition, the Government of India has taken several initiatives. The country supports the global EV30@30 campaign, which aims for at least 30% new vehicle sales be electric by 2030. According to India's 2030 EV ambition signalled by NITI Aayog, India intends to have EV sales penetration of 30% for private cars, 70% for commercial vehicles, 40% for buses and 80% for two- and three-wheelers by 2030.

At the 2021 United Nations Climate Change Conference (COP 26), India signed up to the Clean Transport Breakthrough, whose goal is 'Zero emission vehicles (ZEVs) are the new normal and accessible, affordable, and sustainable in all regions by 2030'. India pledged to 'work intensely towards accelerated proliferation and adoption of ZEVs. In the 4th ministerial dialogue of Zero Emission Vehicles Transition Council (ZEVTC), NITI Aayog extended its support to the non- binding and COP26 declaration focused on global level accelerating transition to ZEVs.

Metropolitan cities are at the forefront of the on-ground shift to e- mobility. Being locations of high vehicular demand with significant planning and regulatory powers, they are emerging as hubs of early EV adoption. Lucknow is the capital of Uttar Pradesh, a state that has made great strides in Ease of Doing Business.

This report presents a phased plan for transforming Lucknow to a global EV lighthouse city in India. It addresses the challenges faced in EV adoption by different government and private stakeholders and showcases the learnings from best practices of electric mobility both domestic and international. Its findings and recommendations could help promote EV adoption, reduce greenhouse gas emissions, attract investment, and create jobs within the state and also help Lucknow to become EV Lighthouse city and the role model for other cities to follow.

I would like to thank Asian Development Bank for their generous support that made this Comprehensive Electric Mobility Plan possible. I hope that this study will be of interest to policymakers, city planning authorities, transport corporations, distribution companies and manufacturers and that its recommendations will translate into action.

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List of Acronyms

Abbreviation	Full Form
ADB	Asian Development Bank
AQI	Air Quality Index
BESS	Battery Energy Storage System
CEMP	Comprehensive Electric Mobility Plan
CNG	Compressed Natural Gas
DISCOM	Distribution Companies
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of Electric Vehicles
GHG	Green House Gas
ICE	Internal Combustion Engine
IEDUP	Institute of Entrepreneurial Development UP
IIDD	Industrial Development Department
ITMS	Integrated Traffic Management System
LCTSL	Lucknow City Transport Services Limited
LCV	Light Commercial Vehicles
LMRC	Lucknow Metro Rail Corporation
MoHUA	Ministry of Housing and Urban Affairs
MoP	Ministry of Power
MoRTH	Ministry of Road Transport and Highways
MVVNL	Madhyanchal Vidyut Vitran Nigam Limited
NITI	National Institute for Transforming India
NMT	Non-Motorized Transport
OEM	Original Equipment Manufacturer
PICUP	Pradeshiya Industrial & Investment Corporation of UP
PLI	Production Linked Incentive
PUC	Pollution Under Control
PWD	Public Works Department
REIL	Rajasthan Electronics and Instruments Ltd
SCIDC	State Construction and Infrastructure Development Corporation
SERC	State Electricity Regulatory Commissions
SNA	State Nodal Agency
TCO	Total Cost of Ownership
ToD	Time of Day
UDA	Urban Development Authorities
ULB	Urban Local Body
UPEIDA	Uttar Pradesh Expressways Industrial Development
UPERC	Uttar Pradesh Electricity Regulatory Commission
UPPCB	UP Pollution Control Board
UPPCL	Uttar Pradesh Power Corporation Limited
BESS	Battery Energy Storage Solutions
AC & DC	Alternating Current & Direct Current
Solar PV	Solar Photo-voltaic
LT & HT	Low Tension & High Tension (Cables)
kW, MW, GW	Kilowatt, Megawatt, Gigawatt
Li-on	Lithium Ion
LFP	Lithium Ferrous Phosphate
PCC	Public Charging Station
PUC	Pollution Under Control
RE	Renewable Energy
CPO	Charging Point Operator

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About this Report

1. About this Report

Lucknow has undergone rapid economic progress and a sharp rise in the number of vehicles on-road. Rising personal incomes have also led to a greater proportion of 4-wheelers within the city. This prosperity is accompanied by rising traffic congestion and transportation related emissions. Responding to these issues, the Government of Uttar Pradesh has emphasized the importance of clean transportation for improving the quality of life of its citizens, through the deployment of Electric Vehicles (EVs). It has come out with the UP EV Manufacturing and Mobility Policy 2022, which includes up-to-date policy recommendations and a broad range of incentives for both buyers and manufacturers.

NITI Aayog has selected Lucknow as one of the nine EV Lighthouse cities based on its potential for electric mobility. In connection to this, Asian Development Bank (ADB) and NITI Aayog has provided support for the creation of a Comprehensive Electric Mobility Plan (CEMP) for Lucknow. This report covers a range of topics under e-mobility including EV adoption, public awareness, setting up of charging infrastructure, skilling of an EV workforce, and capacity building of officials. It provides a roadmap of recommendations, solutions, and initiatives for the city over the short-, medium-, and long-term.

The scope of work for the overall assignment, for which the CEMP is an output is-

1) **To identify opportunities and mitigate barriers** for the effective development of an e-mobility ecosystem for selected Tier-I city with appropriate incentives, planning mechanisms, EV awareness creation, etc., to create a scalable framework for urban areas in the country
2) **To establish a city-specific roadmap** for accelerating the E-mobility ecosystem across various modes of transport and mobility segments, by focusing on the EV thrust areas as well as capacity building programs and workshops with city officials
3) **To create a capacity-building program** to implement and test pilot programs, technology, and regulations across the identified EV thrust areas for an innovation-based approach to developing the EV ecosystem and related infrastructure.

The aim after this is also to spread the city's success across the state and the nation. The new UP EV Policy also recognizes the importance of a CEMP, and seeks to replicate such a study for the following 16 other cities containing municipal corporations.

Agra	Firozabad	Moradabad	Saharanpur
Aligarh	Ghaziabad	Prayagraj	Shahjahanpur
Ayodhya	Kanpur	Gorakhpur	Varanasi
Bareilly	Meerut	Jhansi	Vrindavan-Mathura

Methodology

In order to understand the barriers and challenges to e-mobility, and the shape they take specific to Lucknow, a wide variety of stakeholder consultations were carried out across all involved state agencies. Current initiatives and future plans of these stakeholders were also recorded. Once specific areas of action were identified, best practices across India and the world were considered to arrive at certain initiatives that can be taken across the short, medium, and long term.

A list of some of the stakeholders consulted is as follows, with details on their jurisdiction and role under e-mobility:

Table 1: State Agencies and Contractors

Agency	Jurisdiction	Roles under E-mobility
Housing Urban Development	Responsible for formulating the rules, regulations, and laws regarding urban local bodies and their administration, which includes the Lucknow Municipal Corporation	1. Overseeing the development of charging infrastructure through its subordinate agencies.
Lucknow Municipal Corporation (LMC)	Waste collection and management, General sanitation, maintenance of smaller roads, running of public parking lots, clearing of encroachments, water and drainage services.	1. Transition of 1500+ municipal fleet to electric vehicles. 2. Leasing out land and parking space for EV charging
Housing and Urban Planning (HoUP) and Lucknow Development Authority	Land use decisions, planning and regulatory oversight of areas, sanction of maps, development of colonies.	1. Issuing appropriate byelaws facilitating the inclusion of charging points and parking spaces for EVs, with guidance from MoHUA's model byelaws. 2. Participation in working group on "Fast Track Development of Charging Infrastructure"
Public Works Department (PWD)	Construction, maintenance, and repair of public works including roads	1. Assistance in infrastructure set-up and maintenance of public charging infrastructure. 2. Participation in working group on "Fast Track Development of Charging Infrastructure"
Office of the Transport Commissioner	Running the Regional Transport Offices, registration of vehicles, issuance of licenses and permits, approval of bus routes and fares, collecting taxes and fees, road safety regulations.	1. Assistance in approval of green routes for electric buses and setting of fares. 2. Approval of corridors where electric rickshaws may function. 3. Guidelines for setting up retrofit centers, registration and approval of these centers. 4. Participation in working group on "Fast Track Development of Charging Infrastructure"
Transport Department, GoUP	Oversees the office of the Transport Commissioner, notifies the rules and orders set out by the government	1. Will act as Nodal Agency for EV Adoption or will appoint one for this role. 2. Adoption related incentives to buyers and dealers (for example subsidies) shall be processed and disbursed through a single platform by the department 3. Will support implementation of EV Policy by notification of rules and orders.
Lucknow City Transport Services Limited (LCTSL)	An SPV dedicated to providing bus services (including e-buses) to the city, it acquires and operated buses, plans routes and fares.	1. Planning of further green routes, increasing number of electric buses, conferring benefits of fuel savings onto customers. 2. Participation in a multi-modal transport integration program
Lucknow Metro Rail Corporation (LMRC)	An SPV dedicated to the planning, implementation, and	1. Usage of metro power infrastructure to provide charging for last-mile connectivity (e-autos

	operation of metro projects across the city.	etc.) at stations with sufficient space. 2. Participation in a multi-modal transport integration program
UP Pollution Control Board (UPPCB)	A statutory organization tasked with implementing environmental laws and rules. Provides Pollution Under Control (PUC) certificates for vehicles.	1. Advising state government in setting up battery waste management and recycling centers for EV batteries. Will be guided by Battery Waste Management Rules 2022.
Madhyanchal Vidyut Vitran Nigam Limited (MVVNL) **Uttar Pradesh Power Corporation Limited (UPPCL)**	Responsible for providing electricity to customers, billing, and revenue collection. Fares are set by ERCs.	1. Providing connections to charging/ swapping stations, upgrading grid infrastructure to accommodate high draw, and maintaining connections. 2. Providing power for charging at special tariff rate already notified by UPERC. 3. Participation in working group on "Fast Track Development of Charging Infrastructure"
Pradeshiya Industrial & Investment Corporation of UP (PICUP)	A government agency with the mission to provide broad-based investment and financial assistance for special economic zones and infrastructure projects. It is the nodal agency for policies such as- • UP EV Manufacturing Policy 2019 • Industrial Investment & Employment Policy 2017	1. Possible nodal agency for manufacturing and industries related portion of 2022 EV policy. 2. Supporting OEMs in setting up manufacturing.
UP State Construction and Infrastructure Development Corporation (UP SCIDC)	Responsible for tendering of construction and infrastructural projects along with auditing and quality management of existing projects.	1. Construction and inspection of charging infrastructure on government land. 2. Helping develop standards and guidelines for setting up charging infrastructure.
Institute of Entrepreneurial Development UP (IEDUP)	A premier institute and Center of Excellence in the field of entrepreneurship promotion and Human Resource Development. Organizes skill development and capacity building programs for officials related to industrial development.	1. Provide skilling for an EV ready workforce to meet the demand generated by e-mobility.

The chapters of the roadmap connect to certain thematic areas such as charging infrastructure, EV skilling, business models to promote adoption, and so on to tackle each challenge effectively.

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Executive Summary

2. Executive Summary

Lucknow is the capital of Uttar Pradesh (UP) as well as its largest city. Its population of 3.85 million people is seeing steady growth of 2.6% a year. This growth, accompanied by rapid economic development (at a CAGR of 8.76% for the state) has led to rapid increase in the number of vehicles on-road and severe strain on the urban transportation system in the city. The associated emissions have led to spikes in Air Quality Index of over 290, reaching 'very unhealthy' levels during winter months.

In this context, the shift towards electric mobility has become the need of the hour. Lucknow's economic development, extensive road & rail connectivity, multiple technical institutions, and access to UP's immense talent pool makes it well suited to become an EV Lighthouse city whose success can be replicated across the state and country. EV sales projections for the city show nearly 350,000 e-vehicles on-road by 2030, saving more than 90,000 tons of CO_2 equivalent emissions per year.

There are a host of benefits to e-mobility in addition to emission reductions, such as fuel savings, better motor efficiency, and reduction in dependance on fossil fuels. However, there remain major challenges that need to be addressed to accomplish this. Given below is a list of thematic areas address in this roadmap along with a summary of associated solutions and initiatives.

Urban Transport and Development

Solutions under Urban Transport and Development were arrived at after extensive stakeholder consultations with each involved agency. Best practices and initiatives in this area were identified and for each subject, one or more possible activities planned out. Focusing on the challenges of increased traffic, low public transport usage, and low coordination between state agencies, the following can be done-

1. The formation of a committee to coordinate deployment of public transport, e-rickshaw corridors, create a shared charging network across government offices, and form guidelines on charging station construction. Member agencies have been identified and their roles outlined.
2. Improving Air Quality Index via greater attention to idling vehicles, scrapping of older vehicles, and more stringent pollution checks.
3. Promotion of non-motorized transport by improving pedestrian access, use of bicycles, and promoting electric cycles for purchase and rentals- for example, outside metro stations.
4. Deployment of Integrated Traffic Management Systems along identified corridors and improving data collection and monitoring by taking advantage of EV telematics and other sources of data.
    a. Incorporating a "One Lucknow Card" for combined payments of bus, metro, parking, and first and last mile transport.
    b. Setting up and incorporating e-bicycle stands, e-suvidha centers, public toilets, etc.
    c. Integration with parking management for both EV and Internal Combustion Engine (ICE) vehicles.
5. Implement parking management via multi-level parking, smart ticketing and parking lot monitoring. Alongside, reserve certain spaces for EVs and deploying charging points where power infrastructure is available- for example, metro station parkings.
6. Expansion of E-bus fleet, under an Opex model to remove burden of up-front costs and planning of green routes both new and replacing existing non-electric bus routes. Newer model e-buses with longer ranges make many more routes possible to use.

EV Adoption- Personal, Commercial, and Public

Aside from 3-wheelers and electric buses, EV adoption across vehicle segments remains very low. Even government has not yet begun deploying EVs in their own vehicle fleets. In order to give an impetus for EV adoption across all sections and achieve the expected rates of penetration, priority

business cases have been identified based on how suitable they are for the deployment of electric vehicles.

The criteria for their selection included utilization in km/day (for maximum fuel savings), predictability (to plan charging and driving), and visibility (to demonstrate EV's capabilities to business and the public. The identified priority business cases are as follows-

1. Electrification of Government 4-wheeler Fleets
2. Municipal Solid Waste Collection
3. Electric 2-wheelers for Personal Use
4. Corporate Employee Transport
5. Urban Frieght

E-mobility versions of their business models have been laid out along with steps to make the transition. Government interventions such as adoption mandates, reserved parkings, toll exemptions, etc. have been identified to drive these cases forward. A possible pilot program has been laid out for the use of EVs in door-to-door waste collection, for which the Lucknow Municipal Corporation has already shown interest.

A Total Cost of Ownership analysis (given in Appendix 2) was carried out for each vehicle segment to compare the lifetime costs of EVs and ICE vehicles, and arrive at additional expenditure (over an ICE vehicle) and possible savings for each use case. The total expenses by 2030, considering sales projections, stand to be upwards of INR 2,716 Crore or USD 326 Million. The benefits however far outstrip this figure, with operational savings through new EVs adding up to INR 13,210 Crores or USD 1,585 Million. Interventions such as concessional loans and subsidies to hasten adoption would have an outsized impact in terms of benefit to the public. These monetory benefits would also be accompanied by immense emission reduction over the vehicles' lifetimes- more than 2,866,000 tons of CO_2 equivalent.

Power Sector, EV Charging, and Renewable Energy Integration

Promoting EV adoption covers the demand side of the equation, but electric vehicles cannot compete with their ICE counterparts without a network of charging infrastructure that supplies vehicles with the power they need. The impact on the city's power grid needs to be accounted for, and certain infrastructural and systemic interventions identified to support the charging network and increase the renewable energy (RE) mix. The analysis includes-

1. Calculating the number and type of chargers required, and the associated investment.
2. Geospatial demand mapping, possible locations, site layouts, business models, and safety requirements for charging stations.
3. Impact on the grid in terms of total and peak demand, and interventions to manage the same such as smart charging, V2X applications, and upgrading the networks of distribution transformers.
4. Synergies of e-mobility with renewable energy, and means of integrating it into EV charging infrastructure such as ToD tariffs (to align with solar generation), rooftop solar, and open access from green sources.
5. An estimate for rooftop solar installation in the Dubagga bus depot, for which a 550 kW solar installation costing INR 2.4-2.6 Crores (USD 288,000-312,000) can be deployed to support e-bus charging.
6. Energy storage solutions to support EV charging and RE grid integration, in order to smoothen peaks and valleys in the day's power demand curve.

The required investment by 2030 for setting up chargers comes out to be INR 154 Crores or USD 18.5 million. The associated upgrades to the power distribution network would cost around INR 74.3 Crore or USD 8.92 Million. The international cost for energy storage is quite high, at INR 12-13 Crore per MWh, however due to increasing competition and tendering costs in India have been brought down to INR 8-10 Crore or USD 0.96-1.2 million per MWh.

A highlight of the analysis is the relationship between the emission factor of the state's power generation and the savings in emissions produced by switching to electric vehicles. Calculations using

India's overall emission factor show positive savings, however, looking only at Uttar Pradesh's power generation paints a different picture. Due to UP's overreliance on thermal generation, EVs adoption alone is unable to reduce overall GHG emission. Shifting away from thermal energy and increasing the RE mix is necessary to unlock EV's pollution benefits. The Central Electricity Authority's (CEA) projections show a 2030 target of 47.7% RE in generation, and a reduction in thermal output of 55%. Accordingly, Uttar Pradesh will achieve a positive impact on transport emission by the year 2027-28.

Another important concern is the large amount of battery related waste that will be generated along with the transition to electric vehicles. Fortunately, large portions of the resources use in batteries can be recovered and re-used. Certain battery recycling related measures to accomplish this are outlined below, based on international best practices and identified policy gaps-

1. Development of policy on state level battery recycling: An investor friendly policy attracting more players in the battery recycling/reuse space needs to be developed.
2. Tie-ups for setting up collection channels: Several informal sector players can be leveraged to establish proper battery collection channels. Informal battery collectors can tie up with recycling centers.
3. Mandating specific recovery rates: The recovery rates can be set as per the battery technology/ chemistry and should be suitably reviewed and updated continuously.
4. Establishing labs for faster sample checks: Determining purity and composition of batteries to be recycles will require laboratory support.
5. Skill development and R&D for efficiency improvement in the recycling process

EV Awareness, Skilling, and Capacity Building of Officials

Common themes in the public's ideas about EVs include ignorance about savings and concerns regarding safety. Awareness measures targeting these misconceptions need to be carried out so that EV adoption is not slowed. Certain awareness building activities, based on best practices domestically and internationally can be-

1. Tools and Information: An EV portal serving as a one-stop provider of all e-mobility related information
2. Public events providing practical exposure and awareness of e-mobility, including EV expos, rallies, and experience centers
3. Exposure through EV fleets, both corporate and government
4. Regional planning activities related to e-mobility
5. Campaigns and forums, both online and offline
6. Awards and recognition of innovators and EV entrepreneurs
7. Consistent signage and labelling of EV products to better faciliate customers' understanding
8. Exposure to EVs through inclusion in tourism, deployment of rental EVs in tourist destinations

As the electric vehicle sector booms, the demand for skilled personnel to act as researchers, designers, technicians, and even software developers will shoot up. According to the UP EV Policy 2022, the EV industry has the potential to create nearly 50 million jobs, which will require a fresh set of skills different from the ICE-based automobile industry. Lucknow and UP as a whole needs to develop a host of certifications, training courses, technical institutes, college degrees, etc. to meet this rising demand for personnel. Currently, such skilling opportunities are rare, and most EV companies rely on internal training to bring people up to speed.

Therefore, certain EV skilling measures and activities can be as follows-

1. Establishing a curriculum collaboration committee for Automotive and Mobility sector
2. Development of industry interaction programs for prospective candidates joining EV sector
3. Development of online upskilling and reskilling platforms
4. Execution of pilot courses to cater priority job roles
5. Formation of an advisory committee for Diversity, Equity and Inclusion (DEI) in Automotive sector
6. Establishing 5 centers of excellence (CoE) for developing indigenous research capabilitis.

The investment for each CoE is INR 19.78 Crore or USD 2.37 Million, including setting up charging infrastructure for testing and development. There will be annual operational expense of INR 0.49 Crore or USD 580,000 per CoE

This roadmap is dedicated to addressing these challenges by providing short-, medium-, and long-term recommendations to help Lucknow realize its potential to be a flagship city for e-mobility, whose successes can then be replicated across the state and the country. The roadmap is provided in Chapter 14.

Summary of Possible Investment and Key Sources

The key sources of investment can be broadly classified into three categories – Non-Banking Financial Companies (NBFCs), Long-Term Investors and Banks. The table below identifies different stakeholders in each of these categories along with their roles. The required investment by 2030 for different category is also listed in the table below –

Table 2: Investment Size Required

Category	Areas of Investment	Investment Amount (in USD)
Charging Infrastructure	Setting up Charging Stations	18.5 million
	Upgrade Power Distribution Network	8.92 million
	Energy Storage	0.96-1.2 million per MWh
Rooftop Solar	550 kW installation at Dubagga Bus Depot to support e-bus charging	288,000-312,000
Skilling	Center of Excellence	2.37 million
EV Adoption	EV Sales	326 million

Table 3: Key Sources of Investment

Category	Stakeholder	Description
NBFCs	Captive vehicle financiers	OEM-owned NBFCs that provide specialized and subvention-linked products to customers
	Non-Captive vehicle financiers	Other privately owned NBFCs that provide smaller pools of finance at higher interest rates in non-metro areas
	Fintech companies	Privately owned companies that lend through technology and digital platforms
National Government Schemes	Central Government	The Revamped Distribution Sector Scheme (RDSS) allows DISCOMs to apply for funding to build upstream infrastructure for charging stations
Long-Term Investors	National development banks	State-owned Indian FIs that provide equity and/or debt to mobility startups, large fleet owners, and businesses for sustainable economic development
	Multilateral/ bilateral development banks	Publicly owned international FIs that provide equity and/or debt to banks, NBFCs, and businesses for transitioning fleets for sustainable economic development
	Venture capital funds	Private investors that provide equity to mobility startups, early-stage ventures and fintech
Banks	Public sector undertaking (PSU) banks	State-owned commercial FIs that provide longer tenure, lower interest loans
	Private sector banks	Privately owned FIs that specialise in larger transactions for institutions, fleets, and vehicles in urban areas

03

Introduction

3. Introduction

Lucknow is Uttar Pradesh's legislative, judicial, and executive capital as well as its largest city. It is the 12th most populous urban agglomeration in the country. It is a center of arts and culture with a rich history and a number of heritage sites such as the Bada Imambara, Chota Imambara, Rumi Darwaza, etc. In modern times, Lucknow has emerged as a center of automotive, aeronautics, and other advanced industry. It is home to several distinguished academic institutions such as an Indian Institute of Management and King George's Medical University. It has shown steady population growth over the years at 2.6% per annum, with the current population of 3,854,000[1] in 2022.

3.1. Demographics

The city has excellent road, rail, and air connectivity with infrastructural upgrades planned or underway for both Charbagh Railway Station and Chaudhary Charan Singh (CCS) International Airport. It has invested deeply in expanding public transport, with an established metro line and nearly 1500 buses operational in the city. As seen below, the city is split by the Gomti River with dense urban centers on either side and is surrounded by an outer ring road. The North-South Corridor of the Lucknow Metro became operational in 2017, running 23 km from Lucknow Airport to Munshi Pulia. An 11 km East-West corridor is planned from Charbagh to Vasant Kunj.

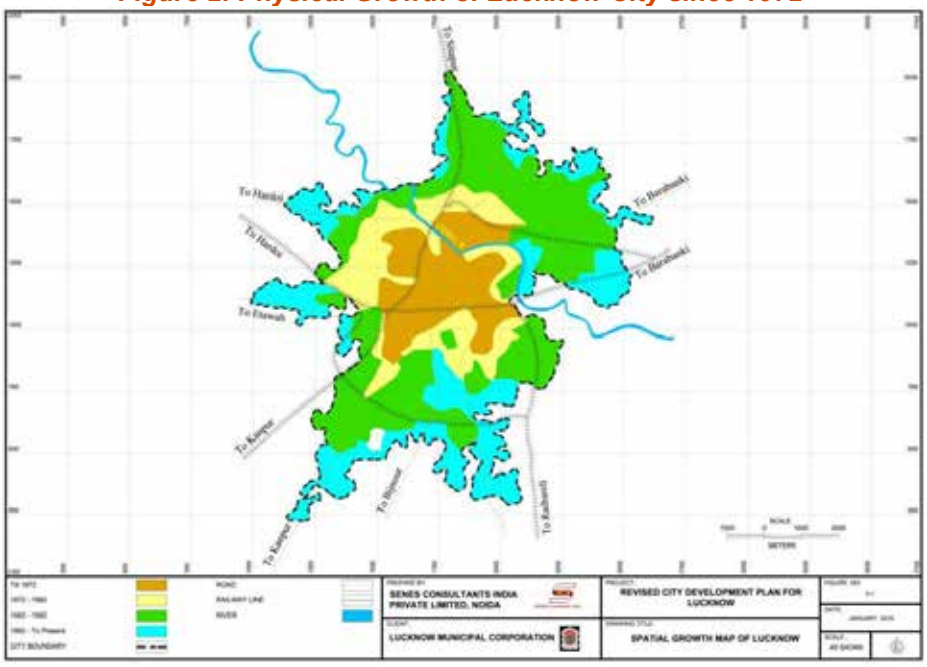
Figure 1: Lucknow City Statistics.[2]

Metro Area Population- 3,854,000	Area of City- 402 km^2	Latitude 26° 55' N	Longitude 80° 59' E
Population Density- ~9600 persons per km^2	Road Density- 77.67 km road per km^2 area	Active Stock of Vehicles- ~2,500,000	Total Number of Buses (Public & Private)- 1,500
Car Ownership- 153 per 1000 people	Two-Wheeler Ownership- 468 per 1000 people	Daily Metro Ridership 70,000	Daily Public Bus Riderships 45,000

With economic growth and investment comes additional employment, which has made Lucknow an attractive destination for UP's burgeoning young workforce. The city itself has rapidly expanded in area over the past 50 years-

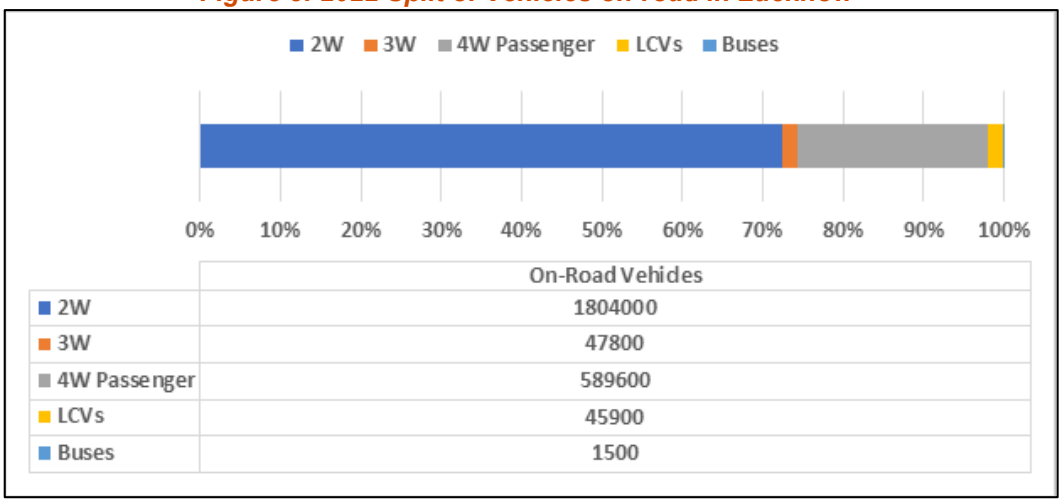
[1] https://www.macrotrends.net/cities/21318/lucknow/population
[2] Vahan 4.0 vehicle registration data and stakeholder consultations with LCTSL and LMRC

Figure 2: Physical Growth of Lucknow City since 1972[3]



With the expansion of the municipal area, the flow of commuters and the needed coverage of public transport has also increased.

Figure 3: 2022 Split of Vehicles on-road in Lucknow[4]



	On-Road Vehicles
2W	1804000
3W	47800
4W Passenger	589600
LCVs	45900
Buses	1500

In terms of vehicle distribution, car ownership in 2022 has increased two-and-a-half times since 2011. Pre-pandemic yearly vehicle registration rose nearly 50% from 2013 to 2018. A rise in per capita income and city-wide economic development has led to a higher proportion of 4-wheelers amongst registered vehicles. National Family Health Survey conducted from 2019 to 2021 showed that more than 50% of urban households owned a two-wheeler.

The share of ride hailing and public transport has risen with the advent of ride hailing apps, expansions of the bus fleet, and the opening of metro lines across the city. However, reliance on public transport is low compared to other metro cities, with most commuters using personal vehicles, 6-seater Vikram autos, and rickshaws for their daily commute due to first- and last-mile connectivity. The Lucknow Metro currently faces low utilization and needs to attract more customers to achieve financial success.

[3] Lucknow Revised City Development Plan 2015
[4] Vahan 4.0 Portal vehicle registration data

The need for Electric Mobility in Lucknow

Transport Related Emissions, 2018 (Tons/year)	
PM 2.5	4,900
PM 10	5,150
Black Carbon	1,750
Organic Carbon	1,650
NOx	22,750
CO2 and CO	187,650
Volatile Organic Compounds	51,050
SO2	400

The Revised City Development Plan (2015) highlights the environment impact of such rapid development. Higher vehicles emissions and dust are some of the consequences of this transition. Average Air Quality Index (AQI) in the city has seen spikes of over 290, reaching 'unhealthy' and 'very unhealthy' levels at their peak in November. In 2018, 49% of the city's CO_2 and CO emissions were due to vehicles, along with 17% of its PM 2.5[5]. The most polluted areas are Talkatora industrial area and Lalbagh, both hotbeds of freight and passenger traffic. Transport related pollution is covered in further detail onwards under the GHG emission section of this chapter.

The ambient negative effects of pollution are accompanied by increased choking of roads due to excessive traffic because of the rapid increase in the number of vehicles. The consequences come in the form of delayed commutes, excessive exposure to road dust and tailpipe emissions, lost man-hours and increased daily stress. Even more severely, the number and intensity of road accidents has increased. In the Ministry of Road Transport and Highway's Road Accident Report 2019, Lucknow ranked 19th in the number of traffic accidents and 9th in terms of fatalities across the country. The following is a list of especially high traffic locations in the city-

1. Bhitauli Crossing, Mubarakpur
2. Tedhi Puliya Chauraha, Jankipuram
3. Munshipulia Chauraha, Indira Nagar
4. Saheed Path Chowk, Gomtinagar
5. Dugga Bagh Chauraha, Dubagga

In such a scenario, the continued use of conventional ICE vehicles would further increase GHG emissions, lower air quality, and aggravate the health effects of pollution. With this in mind, the switch to zero-emission electric vehicles is the need of the hour. Parallelly, it is crucial to consider the kind of infrastructural upgrades and urban transport planning measures that can be taken to enable this transition and reduce the strain on the city's road network. To achieve this objective in an impactful as well as timely manner, the development of a roadmap outlining the short, medium and long-term action measures is important.

3.2. Lucknow's Potential as an EV Lighthouse City

Economic Development and Demand

Lucknow is very well placed to become an EV lighthouse city that can serve as a success story for other cities across both Uttar Pradesh and India as a whole. It has access to UP's vibrant automotive industry and its large pool of talented workers. It is a center of automotive demand, with economic development leading to higher vehicle ownership in the coming years.

Backwards & Forward Linkages

Its excellent road and rail connectivity gives it excellent backward linkages to raw material, industries, and warehouses both in and outside the city. In terms of forward linkages, it has a host of dealerships, retail outlets, banks, financial institutions, and workshops to facilitate the purchase and maintenance of electric vehicles. The state itself has provided for a number of manufacturing, charging infrastructure, and purchase related subsidies in its new EV Policy 2022, the full details of which have been elaborated in the next chapter of the roadmap.

Technical Institutions & Talent Pool

The presence of multiple technical institutions and institutions of higher study such as IIIT Lucknow, IET Lucknow, Lucknow University, and Uttar Pradesh Technical University shows that Lucknow has the talent pool to fulfill the new skilling requirements that will come with e-mobility transition, engage in R&D, and develop EV manufacturing excellence.

[5] https://urbanemissions.info/india-apna/lucknow-india/

3.3. New UP EV Policy 2022

The Uttar Pradesh government has announced the New Electric Vehicle Manufacturing and Mobility Policy, 2022, to promote faster adoption of clean mobility solutions and create a conducive ecosystem for EVs in the state. The policy provides for a three-pronged incentive regime that includes benefits to consumers for purchasing EVs; to manufacturers of EVs, batteries and related components; and to service providers developing charging/ swapping facilities.

The main objective of the policy is uptake of electric vehicles within the states, for benefits such as reducing pollution and a transition to sustainable mobility. The aim of the policy is not only to create an eco-friendly transportation system in the state, but also to make Uttar Pradesh a global hub for the manufacturing of electric vehicles, batteries and associated equipment. The policy targets at attracting investment of more than Rs 30,000 crore and generate direct and indirect employment for over one million people.

The EV Policy divides incentives and measures into three categories – charging infrastructure incentives, consumer demand incentives and manufacturing incentives. Along with the incentives for boosting these three major sectors, EV policy also looks into recycling Ecosystem where it encourages the reuse and recycle of EV batteries that are set to exhaust, as well as job creation where policy supports to create jobs in the EV ecosystem and set up skill centers for training in EV related jobs.

Table 4: Major sections of New EV Policy 2022

Objective	Key Strategies	Provision
Driving EV adoption: Drive large scale EV adoption, focusing primarily on 2 Wheelers, 3 Wheelers, and public/ shared transport.	Registration Fees and Road Tax exemption	100% on EV purchased and registered in UP (upto 3 years)
		100% on EV manufactured, purchased and registered in UP (4th and 5th year)
	Purchase Subsidy as early bird incentives (1 year)	2-Wheeler EV: @15% of ex-factory cost upto Rs 5000 per vehicle (maximum budget of Rs 100 Cr to maximum of 2lac Evs)
		3-Wheeler EV: @15% of ex-factory cost upto Rs 12000 per vehicle (maximum budget of Rs 60 Cr to maximum of 50000 Evs)
		4-Wheeler EV: @15% of ex-factory cost upto Rs 1 lakh per vehicle (maximum budget of Rs 250 Cr to maximum of 25000 EVs)
		E-Buses (Non-Govt, i.e. School buses, ambulances, etc.): @15% of ex-factory cost upto Rs 20 lakh per vehicle (maximum budget of Rs 80 Cr to maximum of 400 E-Buses)
		E-Goods Carriers: @10% of ex-factory cost upto Rs 1,00,000 per vehicle (maximum budget of Rs 10 Cr to maximum of 1000 E-Goods Carriers)
	State Targets	100% transition of public transportation to EV in the 17 cities under Smart City Mission by 2030
		100% transition of Govt vehicles (for official use) to EV by 2030
		Identify Green routes in each District by 2025 and ensure E-buses to ply on these selected routes
		Vehicle Advances provided for State Govt Employees to purchase EV
		Promote retro fitted EVs
		Go-Electric campaign to create awareness to promote faster EV adoption
Charging Infrastructure: Create an	Public Area	Public parking spaces, Metro stations, Bus depots/ Terminals, petrol pumps, Govt Buildings, Corporate Buildings, Educational/ Health Institutes, shopping malls &

Objective	Key Strategies	Provision
enabling environment of provision of private and public charging and swapping infrastructure.		other commercial places, Group Housing societies and RWAs, etc.
	Cities and Urban Area	Creation of charging / swapping infrastructure in a grid of 3km X 3km in cities and urban conglomerates as per MoHUA
	Expressway/Highway	Development of charging infrastructure shall be promoted every 25kms along Expressways/ Highways
	Land to Govt Entities	Provided on lease for 10 years at revenue sharing model @ Re 1 per kWh as per MoP guidelines; MoU to be signed
	Land to Private Entities	Provided on lease for 10 years at revenue sharing model @ Re 1 per kWh as per MoP guidelines; Tender based on bidding parameter like min service charge; tender to be managed by ULB providing land
	Tariff Rate	GoUP coordinate with UP Electricity Regulatory Commission (UPERC) to rationalise tariff rate
	Open Access	Allow 'Open Access' at charging/ swapping station or swapping kiosk, having contract cumulative demand of 1MW & above
	State Targets	Setting up atleast 20 charging stations and 5 swapping stations during policy period
	Capital subsidy to Service Providers Charging Stations	20% of eligible fixed capital investment (maximum INR 10 lakh per unit to first 2000 Charging Stations in the State)
	Capital subsidy to Service Providers Swapping Stations	20% of eligible fixed capital investment (maximum INR 5 lakh per unit to first 1000 Charging Stations in the State)
Promote EV/battery manufacturing	1st two Integrated EV Project and 1st two Ultra Mega Battery Project	30% of eligible fixed capital investment (max. INR 1000 Cr over 20 years)
	1st five Mega EV and 1st five Mega battery Project	20% of eligible fixed capital investment (max. INR 500 Cr over 10 years)
	Large EV and Large Battery Project	18% of eligible fixed capital investment (max. INR 90 Cr over 10 years)
	MSME	10% of eligible fixed capital investment (max. INR 5 Cr over 2 years)
	Stamp Duty	Reimbursement to manufacturers
Recycling Ecosystem: Encourage the reuse and recycle of EV batteries that are set to exhaust	Battery Recycling	Setting up Collection Centres for end-of-life batteries at dealership by EV/Battery manufacturers
	Battery Disposal	Facilities to be promoted at swapping/charging stations
Job creation: Create jobs in the EV ecosystem and set up skill centres for training in EV related jobs	Centre of Excellence (COE)	5 CoEs shall be incentivised with a 50% grant cost up to IINR 10 crores each; released over 5 years
	Skill development incentive	Reimbursement of stipend shall be provided one time at the rate of INR 5,000 per employee per year to a maximum of first 50 employees to all defined manufacturing projects
	Quality certification charges reimbursement	Provided one time at the rate of 50% of fees paid for obtaining certification upto INR 10 lakhs per unit to large and MSME EV/Battery projects

Objective	Key Strategies	Provision
	Patent registration fees reimbursement	Provided one time at the rate of 75% of cost/expenditure incurred up to INR 50000 for acquiring domestic patent and up to INR 2 lakh for acquiring international patent to Large and MSME EV/ Battery projects

3.4. Current Status of EV in Lucknow

Uttar Pradesh stands at the forefront of EV adoption in the country. Lucknow has achieved a milestone 10.2% EV sales penetration rate in 2022 so far, driven almost completely by electric 3-wheelers (90% sales penetration). The current status of electric vehicles in Lucknow is as follows-

Figure 4: EV Registration in Lucknow till 2022[6]

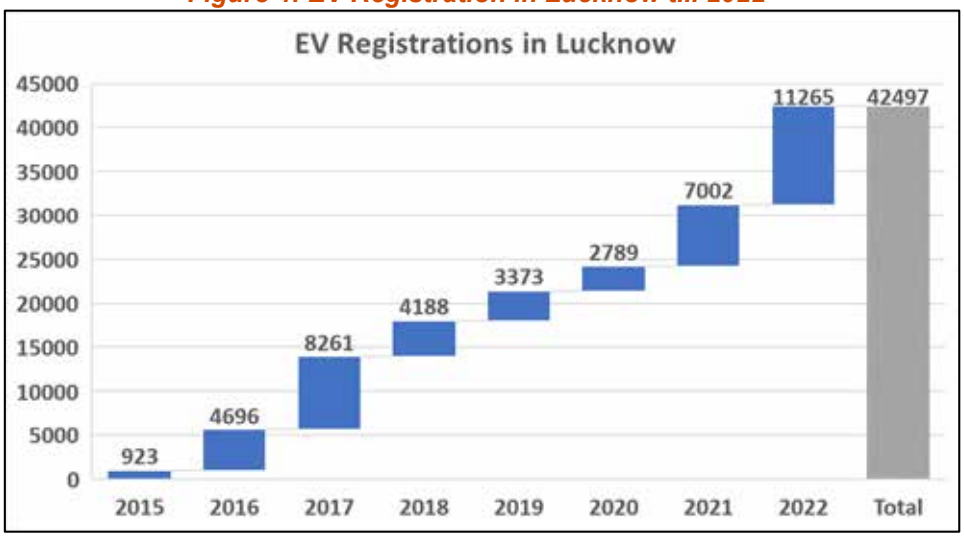


Table 5: Current EV Segment Wise Penetration Rates

Segment	Total Vehicles On Road 2022	Electric Vehicles On Road 2022	Overall penetration
2W	1804000	2640	0.15%
3W	47760	39620	82.96%
Passenger 4W (Private & Commercial)	589500	85	0.01%
Light Commercial Vehicle (LCV)- Good carriers	45900	13	0.03%
Buses	1470	140	9.53%

Lucknow has been one of the front-runners in the passenger 3-wheeler segment, with nearly all operational autos and rickshaws being battery powered. Manual rickshaws have largely been replaced by economical, 5-seater e-rickshaws that offer affordable short-distance rides to customers along approved routes. The government has also taken initiative to accelerate the replacement of CNG autos by no longer renewing the permits of these vehicles, triggering a move to their electric variants. Passenger 3-wheelers registrations have reached peaks of more than 800 per month in 2022.

Lucknow City Transport Services has taken another major step forward for electric mobility by running 140 electric buses over 11 routes in the city, making up nearly one-tenth of all buses running in the city. Out of 45,000 daily public bus users, 35,000 use electric buses replacing the equivalent of 8,750 passenger cars on the road. They are highly popular with commuters, running at nearly 185% occupancy due to their smooth operation and low fares.

[6] Vahan 4.0 Portal vehicle registration data

On the other hand, the number of 2-wheelers and 4-wheelers remain very low untill 2022. While 3-wheelers and e-buses have propagated on the basis of high savings and immense environmental benefits respectively, the high up-front cost and unavailability of charging infrastructure has held back the other segments in terms of adoption. For LCVs, there are only a handful of models available in the market due to which adoption is very low. However, new models of electric vehicles are arriving that are addressing the design and performance gaps, and are expected to be available in the next few years. Electric 2-wheelers are also beginning to thrive, with the lowest cost parity with its ICE counterpart, out of all vehicle segments. Electric 2-wheelers have immense potential for savings in fuel costs, especially in high utilization roles such as delivery and police patrolling.

In view of the new developments, models, and extensive policy support for electric vehicles, it is important to analyse how EV sales will look in the coming years.

3.5. EV Sales Projection up to 2030

While overall penetration outside of buses remains very low, 2022 registrations of 2-wheelers and 4-wheeler passenger vehicles have grown four times and two times respectively, compared to 2021. This indicates the start of an upwards trend in EV adoption, that can be projected into the future to arrive at the electric vehicle status of the city by 2030.

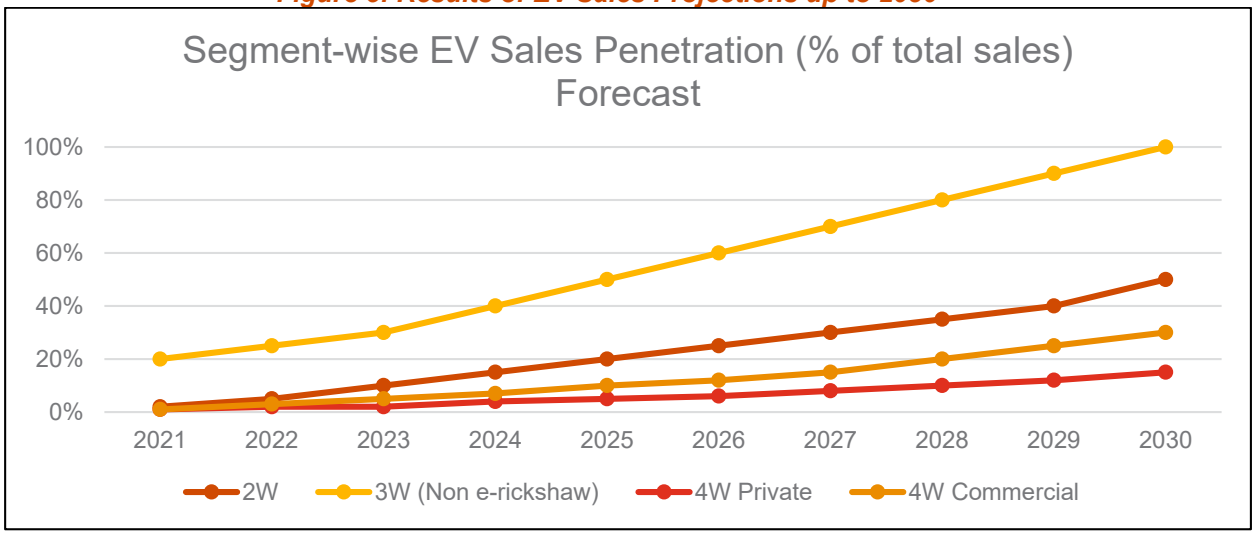
Segments	2030 Sales Penetration Targets
2W	50%
3W	100%
4W Private	15%
4W Commercial	30%

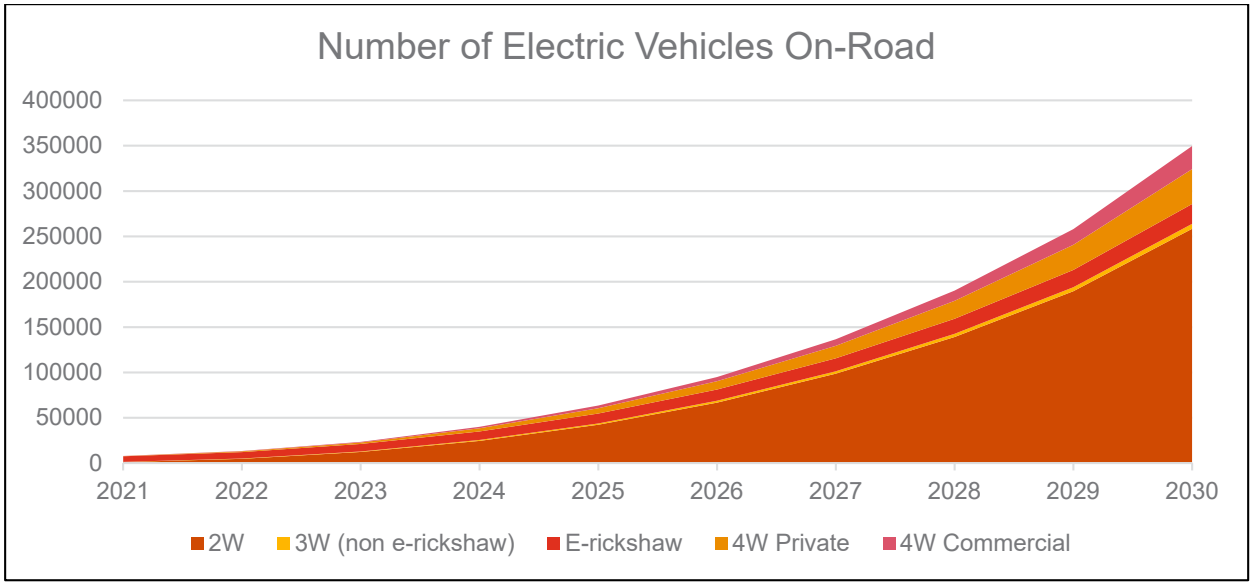
The following are the results from an excel based analysis using likely EV penetration rates in the next 8 years, covering the 2-, 3-, and passenger 4-wheeler category. NITI Aayog has set ambitious targets for EV penetration by 2030 which is listed in the table for each vehicle segment. The analysis follows the following step to arrive at the expected number of EVs on-road-

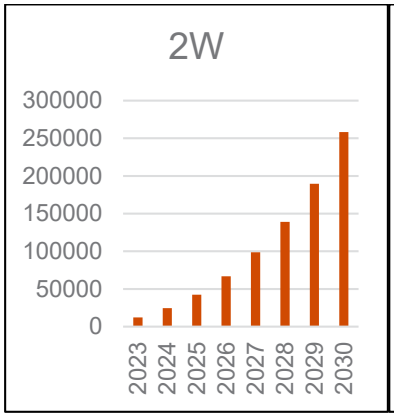
1. Projecting overall vehicle sales based on population growth, growth in disposable income, and past vehicle registration numbers.
2. Plotting increasing EV sales penetration percentages across the coming years, up to 2030 targets.
3. Calculating EV sales per vehicle segment using expected total vehicle sales and EV penetration rate for each year.
4. Arriving at the total number of electric vehicles on road for each year by summing up previous years' sales.

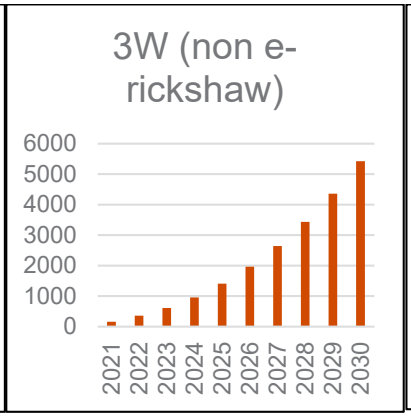
The results of the analysis are as follows:

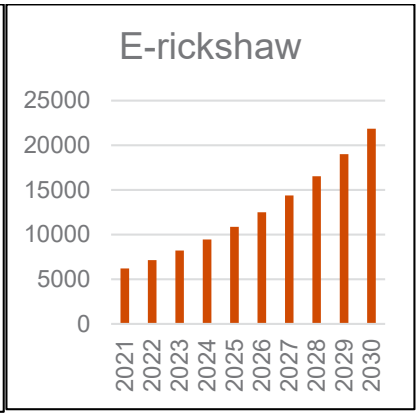
Figure 5: Results of EV Sales Projections up to 2030

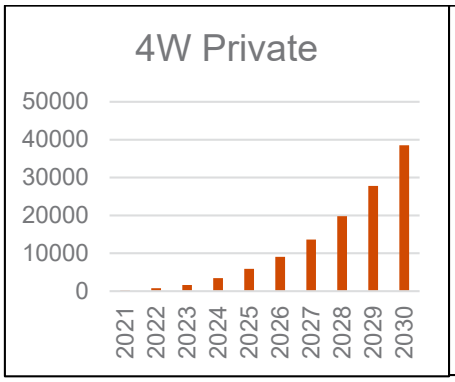


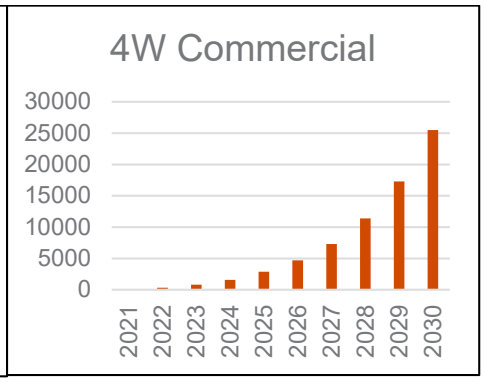












Segments	Number of EVs on-road by 2030
2W	258366
3W (Non e-rickshaw)	5422
E-rickshaw	21864
4W Private	38540
4W Commercial	25506

- The affordable nature of smaller electric vehicles makes them the most accessible out of all EV segments. Fuel savings more than make up for the difference in up-front costs in the case of 2- and 3-wheelers.

- 2- and 3-wheelers' economic advantages make penetration rates of 50% and 100% respectively possible to achieve by 2030. The government has given great impetus to adoption by deciding not to renew permits of old CNG autos.

- Additionally, the cost-conscious nature of cargo and passenger 3W drivers makes EVs naturally attractive due to their much lower fuel and maintenance costs.

- E-rickshaws especially have already been a success in replacing manual rickshaws to a large extent. Currently, most rely on lead acidbased batteries but will switch to lithium ion as it becomes more affordable. In the meantime, processing and disposal of lead acid batteries will be challenge for the city.

- Larger vehicles such as 4-wheelers have a higher disparity in up-front costs, and current models are difficult to afford for the average population. Range anxiety, lack of fast charging infrastructure, unattractive financing, and lack of private parking spaces to install charging points are some of the constraints for their adoption as well. Therefore, the penetration levels are relatively lower.

- Overall, due to longer distances and higher fuel costs, commercial users would be more likely to switch to electric vehicles due to the resulting savings. Therefore, the 2030 sales penetration figure for them is higher at 30% compared to private vehicles at 15%.

3.6. GHG Emission

In order to estimate the GHG emission from transport sector in Lucknow city by 2025 and 2030, the number of EVs on road is projected using EV penetration rates and ICE registration data. The estimation for the GHG emissions is done based on the projected data for ICE and EV sales between 2021 to 2030 as shown in Appendix 1.

Based on the EV penetration, estimates of ICE vehicles and the emission factor of UP, the savings in GHG emissions from transport sector remains negative. Even when the number of EVs increase, the savings in GHG emissions will remain negative due to the high emission factor of UP as the state has high dependency on thermal generated power. However, due to an increase in the percentage of EV penetration in sales from 2% in 2022 to 20% in 2030, the emission savings over the period increases to 100 kilo tons. If we consider the Indian emission factor, the amount of carbon dioxide (CO_2) emissions (well to wheel) from the transportation sector for the scenario with vs without EV will decrease from 2.37 Mega tons to 2.28 Mega tons in 2030, which is 3.79% less. The main causes of the increase in emissions are population growth, economic expansion, and higher rates of motorization between 2022 and 2030. The graph below shows the savings in GHG emissions when using Indian emission factor of 0.79 kg CO_2 eq. per kWh.

Figure 6: Effect of EV Penetration on Total Emissions up to 2030

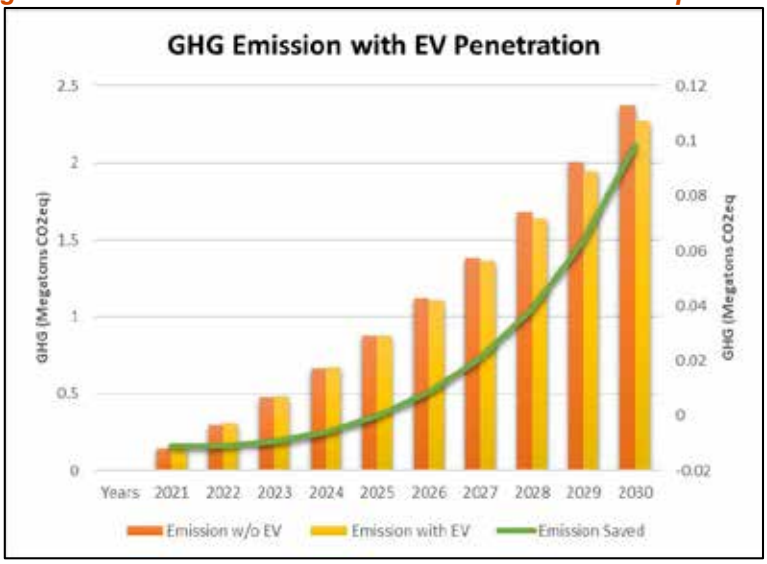
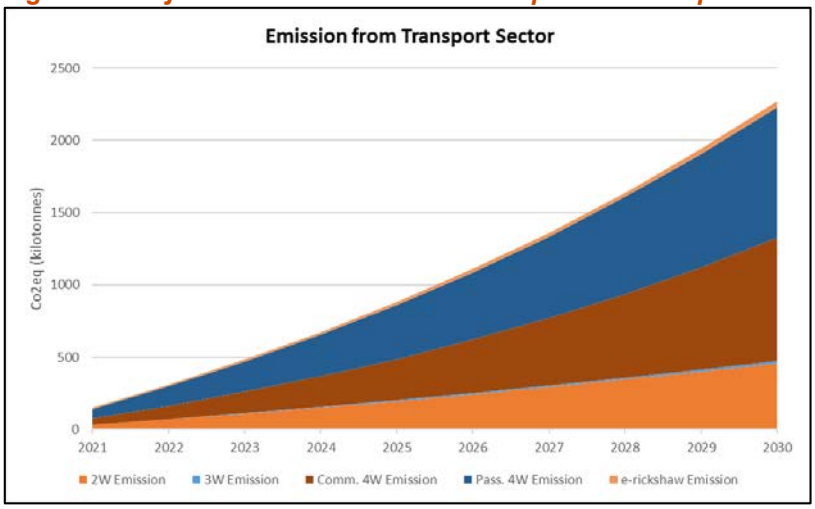


Figure 7: Projected Emissions from Transport Sector up to 2030



The sales number for EVs show highest penetration in the share for registrations for e-3Ws and e-rickshaw (100%) followed by e-2W (50%), e-4W commercial (30%) and e-4W private (15%) by 2030. However, four wheelers produce the highest share of wheel emissions per km over other segments by 2030. The share of four-wheelers in the overall GHG emissions increases from 69% in 2021 to 77% in 2030. As a result, the vehicle segment with highest emissions saving is four-wheelers. Two-wheelers form the highest share in the overall stock but the lower values for their lifecycle emissions per km leads to lower emissions saving among other segments. Three wheelers due to the lowest values for available stocks among all segments and lower lifecycle emissions per km produce minimal emissions saving.

3.7. Issues to Address and Challenges for E-mobility in Lucknow

There are a host of benefits to e-mobility, in addition to the possible emission reductions and related health benefits, such as fuel savings, better motor efficiency, and reduction in dependance on fossil fuels. However, there remain major challenges that need to be addressed to accomplish this. Given below is a list of these challenges.

Urban Transport

Rapid Growth of on-road vehicles and related dust and pollution

Low share of public transport

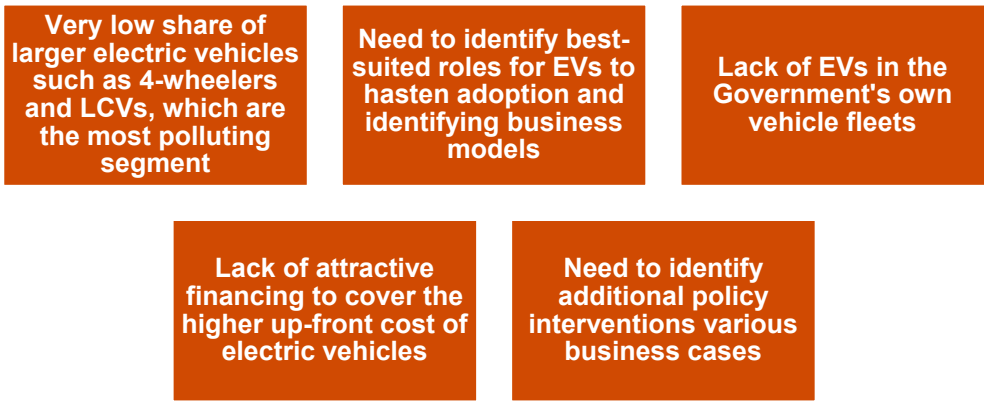
Need for first- and last-mile connectivity at public transport hubs for a complete customer journey

Traffic Congestion and need to modernize urban transport ecosystem

Coordination between multiple state agencies to adapt urban transport scenario for EVs

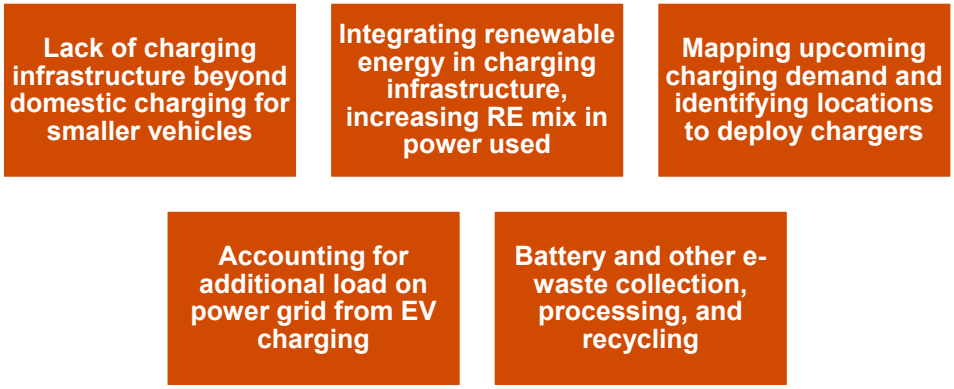
As highlighted through the chapter, traffic and pollution are one of the key issues facing the city. Contributing to these is the low share of public transport, which is essential to reducing the number of vehicles on-road along with the related emissions. The enormous savings in GHG emissions from the switch to electric vehicles have been shown in the analysis above, but there can be more steps taken regarding the overall urban transport ecosystem.

EV Adoption- Personal, Commercial, and Public



Currently, larger electric vehicles like 4-wheelers and LCVs are in their infancy in terms of overall penetration in Lucknow, at 0.1% and 0.3% respectively. Even electric 2-wheelers are rare, at 0.15%. A number of factors such as higher up-front costs, availability of charging infrastructure, and limited models in the market use act as challenges for adoption. Although the government has shown commitment towards e-mobility through the EV Policy and the deployment of electric buses, the use of EVs in government agencies' own vehicle fleets has not yet begun.

Power Sector and EV Charging



Promoting EV adoption covers the demand side of the equation, but electric vehicles cannot compete with their ICE counterparts without a network of charging infrastructure that supplies vehicles with the power they need. The impact of EV charging on the power grid then needs to be accounted for, and the necessary interventions to strengthen it carried out. Another important concern is the large amount of battery related waste that will be generated along with the transition to electric vehicles

EV Awareness, Skilling, and Capacity Building of Officials

For developing the entire EV ecosystem in the city, a consistent level of demand, trained personnel, and support from state officials are crucial. The vast majority of citizens are still unaware of the benefits of electric vehicles, and the related maintenance and fuel savings. They also harbor certain anxieties regarding safety of EV batteries owing to fire-related incidents in the news, even though EVs have shown themselves to be consistently safer than their ICE counterparts.

As the electric vehicle sector booms, the demand for skilled personnel to act as researchers, designers, technicians, and even software developers will shoot up. According to the UP EV Policy 2022, the EV industry has the potential to create nearly 50 million jobs, which will require a fresh set of skills different from the ICE-based automobile industry. Lucknow and UP as a whole needs to develop a host of certifications, training courses, technical institutes, college degrees, etc. to meet this rising demand for personnel. Currently, such skilling opportunities are rare, and most EV companies rely on internal training to bring people up to speed.

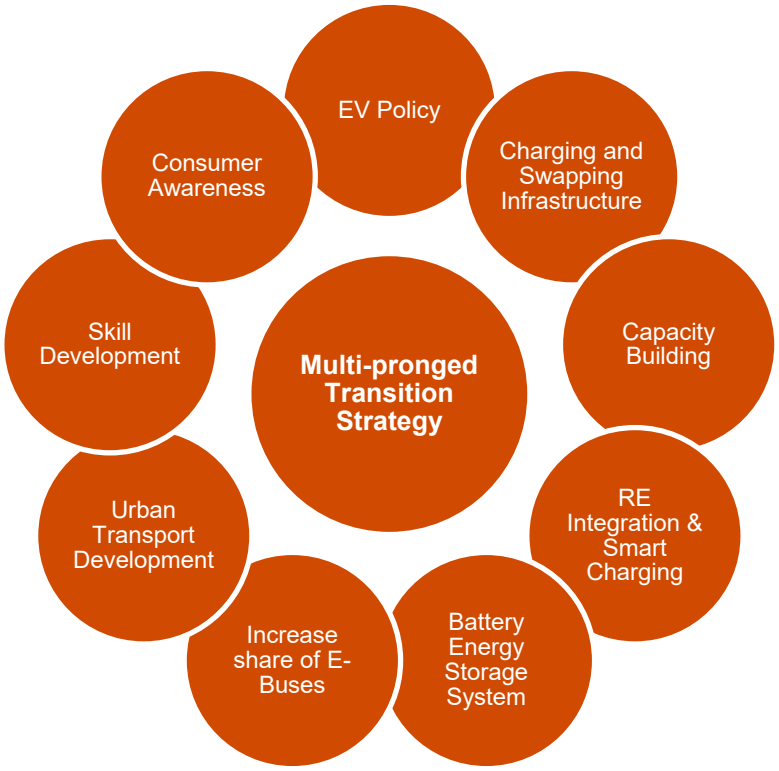
These challenges and the solutions to overcome them have been grouped together in chapters according to certain thematic categories, creating the overall CEMP.

3.8. Roadmap for Lucknow to become a Global EV Lighthouse City

Given the barriers and challenges mentioned above, Lucknow's transition to become a global EV lighthouse city will require a multi-pronged strategy comprising a compendium of actions to be performed in a coordinated manner. This would include setting up the charging and swapping infrastructure, increasing awareness and workforce skill development, increasing adoption of public transport and improving first and last mile connectivity.

The roadmap presented in this report suggests steps to deal with each of them in a phased manner. Given the challenges highlighted earlier it is clear that a globally recognizable transition, across a wide spectrum of vehicles, will be difficult to achieve in the short term. A phased strategy will be needed, typically comprising of a short-, mid- and a long-term phase. The short-term phase is defined for 0-2 years (2022-2024), medium term phase is defined for 3-5 years (2025-2028) and long-term phase is defined for 6th year and onwards (2029 onwards). The below figure shows the multi-pronged transition strategy on which the roadmap for Lucknow can be built upon.

Figure 8 : Areas to cover under a multi-pronged strategy for e-mobility



04

Prioritized Business Cases for EV Adoption

4. Prioritized Business Cases for EV Adoption

4.1. Introduction

With the release of the UP EV Policy (2022), the government has shown a strong commitment towards electric mobility and can focus on certain priority business cases to get electric vehicles on the road faster. Lucknow has achieved a milestone EV sales penetration rate of 10.2% in 2022 so far, driven almost completely by passenger E3Ws (90% share of 3-Wheeler sales) and Electric Buses (140 out of around 1500 buses running in the city). The progress in these two segments is the combined result of superior economics and a push from the government, but the share of other electric vehicles segments remains very low.

For example, according to MoRTH, only 0.6% of India's government vehicles are electric as of February 2022. From a total of 847,544 vehicles in use across all government bodies, only 5,384 were electric. At an average CO_2 emission of 121.3g/km and a lifetime of 300,000 km, 100% electrification would prevent nearly 30.85 million tons of emission.

In this context, there is a need to identify priority business cases that can act as front-runners in these segments, boosting adoption and building citizens' confidence in electric vehicles. With the development of charging infrastructure in the city, it is important that the adoption of electric vehicles does not lag behind. Considering Lucknow's issues with pollution and the pressure from rising fuel costs, it is important to create momentum in e-mobility wherever viable, be it through mandates, incentives, or awareness building. These cases need to financially viable and operationally sound, with the government taking action to ensure adoption and tackle inertia among the relevant stakeholders.

This chapter covers the selection of priority business cases based on certain parameters, an overview of each selected case, adapting current business models to EVs, and the steps the government can take to enable each business case.

4.2. Selecting Priority Business Cases

The list of cases considered, including the vehicle segments involved, is as follows-

Table 6: Possible business cases and respective vehicle segments

Business Case/Vehicle Segment	2W	3W	4W	Mini-Truck	Light Duty Truck
Passenger- Vehicle as a Service					
Rental Vehicle	*		*		
Leased Vehicles- Government	*		*		
Passenger- Rides as a Service					
Corporate Employee Transport			*		
App-based Ride Hailing		*	*		
Conventional Taxi Services		*	*		
Passenger- Self-Driven					
Enabling employee purchase	*		*		
Cargo- Government					
Solid Waste Collection		*		*	*
Post & Courier Delivery		*		*	
Cargo- E Commerce					

Long distance freight					*
Last mile delivery	*	*		*	
Cargo- Perishable Delivery					
Food delivery	*				
Local grocery delivery	*	*			
Refrigerated goods delivery		*		*	
Cargo- Special Goods					
Medicine/Vaccine Delivery		*		*	
Live Animal Transport		*		*	

This set of business cases were examined and judged on the following parameters-

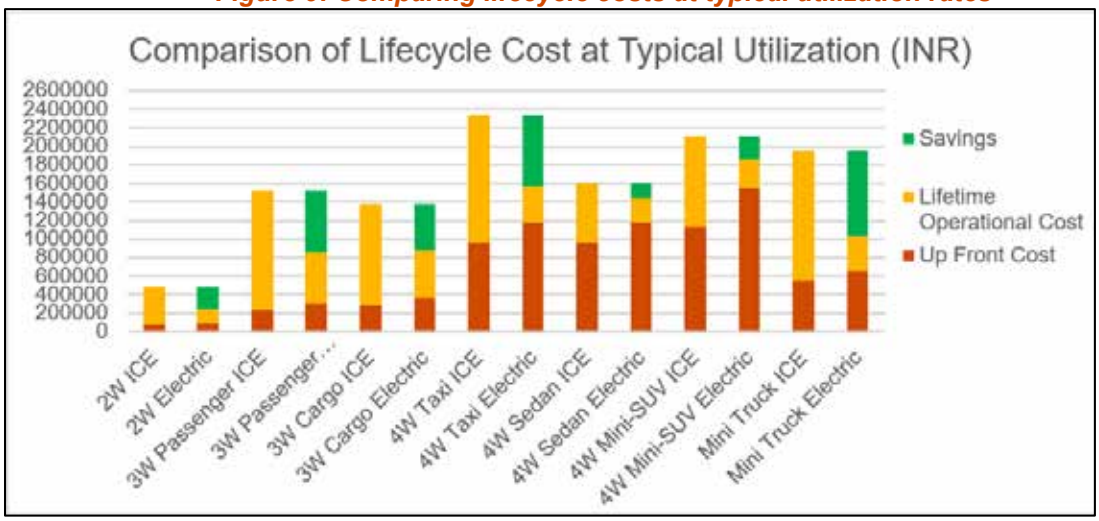
1.Utilization: The main strength of electric vehicles, aside from their zero-emission nature, is their lower operational cost. The savings generated from foregoing the use of fossil fuels are proportional to the daily utilization of the vehicle. The more kilometers it travels, the higher the savings compared to a similar ICE vehicle. It is easy for smaller vehicles like 2-, and 3-Wheelers to achieve economic levels of utilization compared to larger ones. Similarly, transitioning a high utilization ICE vehicle to an EV achieves much greater emission reductions.

2.Predictability: As the city's public charging infrastructure is currently in its infancy, most business would have to rely on captive charging points or partner with a private charging operator. Therefore, to alleviate concerns regarding availability of charging within range of the electric vehicle, a predictable area of operation is desirable. Being able to provide space for setting up charging infrastructure on a company or government body's land is another favorable factor. This also covers the ability to plan charge and duty cycles, increasing the efficiency and lifetime of the battery

3.Visibility: The public still holds certain apprehensions regarding the range and reliability of electric vehicles, which have largely been addressed as EV technology advances and newer models come out. Witnessing the successful use of electric vehicles in these business cases will dispel the public's doubts and motivate further adoption. Therefore, business cases where EVs are most visible to the public are desirable in enhancing uptake.

Business cases that rate highly on these parameters are designated as priority business cases. The most critical of these parameters is **utilization**, as it forms the basis for a total cost of ownership (TCO) analysis of a vehicle. An in-depth Total Cost of Ownership analysis for each vehicle segment is available in Appendix 2. A summary of the results is given below-

Figure 9: Comparing lifecycle costs at typical utilization rates

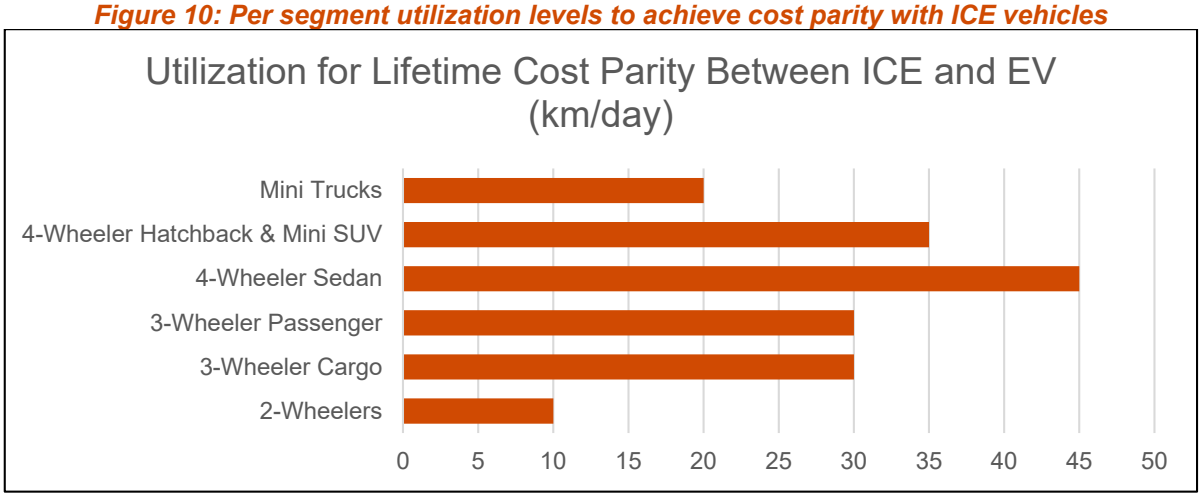


Typical utilization numbers have been taken as 45 km/day for 2-wheelers, sedans, and Mini SUVs and 100 km/day for 3-wheelers, 4-wheeler taxis, and Mini Trucks. This is to reflect private versus commercial use. There are several notable results-

1. As shown by the analysis, electric vehicles used for commercial purposes are able to provide 30-40% lower lifetime cost due to their high utilization.
2. 2-wheelers are able to provide more than 50% savings even in private usage, due to only a small difference in up-front cost and the efficient nature of these vehicles.
3. Even for sedans and mini SUVs, cost parity is achieved at typical usage levels. In exchange, the user receives a zero-emissions, low-noise, and modern vehicle.

Focusing on cost parity, the following are the thresholds of utilization at which lifetime costs equalize between ICE and electric vehicles.

Figure 10: Per segment utilization levels to achieve cost parity with ICE vehicles



When a business case's utilization exceeds these thresholds, electric vehicles offer a superior lifetime cost compared to their ICE counterparts. Multiple vehicle segments may be involved in each business case, taking up different roles with different utilization levels. Of these, not all vehicle segments may meet the threshold.

Based on the above criteria, the selected priority business cases, and the vehicle segments within, are as follows- Even within the selected cases, certain segments fail to meet the utilization threshold and are highlighted in red.

Table 7: Selected priority business cases and their vehicle segments

Business Case/Vehicle Segment	2W	3W	4W	Mini-Truck	Light Duty Truck
Passenger- Vehicle as a Service					
Leased Vehicles- Government	✓		✓		
Passenger- Rides as a Service					
Corporate Employee Transport			✓		
Passenger- Self-Driven					
Enabling employee purchase	✓		✗		
Cargo- Government					
Solid Waste Collection		✓		✓	✗
Post & Courier Delivery		✓		✓	
Cargo- E Commerce					
Last mile delivery	✓	✓		✓	
Cargo- Perishable Delivery					
Food delivery	✓				

4.3. Leasing of Government Vehicles

Vehicle Segments- Passenger 4-Wheeler (Sedans, Hatchbacks, and Mini SUVs)

As cities grow and the difficulty of commuting to work increases, employers have become increasingly aware of the need to manage their employees' transportation requirements. For this purpose, the government maintains a motor pool for each department, serving the mobility needs of its officials. In addition to cars provided to senior officials for their daily use, passenger fleet vehicles are used in police patrols and other roles which require frequent mobility

Lucknow, as the capital city of Uttar Pradesh, has a large number of government officials who are eligible for a government provided vehicle. As a city of over 3.8 million, it has a large-scale police presence which extends to the suburban areas around the city. The large number of commuters as well as freight flowing in and out of the city requires extensive traffic personnel to manage. All these tasks require patrol vehicles as well.

Departments in need of such vehicles float tenders covering the kind of vehicles required, the number, the power train type, the maintenance costs, the warranties, etc. Businesses specialized in leasing out such vehicles answer these tenders and provide the vehicles for government use. These vehicles are leased to the concerned department under the following business models-

1. **Wet lease:** Covers the case where vehicles are provided alongside manpower and fuel, paid for by the lessor. The lessor maintains operational control of the vehicles.

2. **Dry Lease:** Covers the case where vehicles are provided without manpower or fuel. These must be separately provided by the lessee. Operational control is handed over to the lessee. Government vehicles generally follow this model. Vehicle maintenance may also be part of the contract.

Such fleets, being leased in bulk and operated by government staff, are very well suited for electrification

Utilization	Predictability	Visibility
• Vehicles assigned to officials have government drivers, and often cover the commuting needs of immediate family as well. The ease of use makes utilization higher than a self-driven vehicle. • Patrol vehicles need to cover a lot of ground on a regular basis, and provide a naturally high level of utilization • For example, a utilization rate of 45km/day would lead to per vehicle operational cost savings of nearly INR 42,000 a year.	• Both government offices and government housing are located within older, well-developed areas of the city such as Gomtinagar, which are likely to have more charging points. • Patrol vehicles have pre-planned routes and generally operate within fixed zones, making it easier to plan charging and duty cycles. • Existing motor pool infrastructure and parking spaces can be used for deployment of charging infrastructure, in partnerships with charging point operators.	• Government officials as public servants have a high level of visibility. Their vehicles are instantly recognizable, and the use of electric vehicles would show the government's solid commitment to e-mobility. • Similarly, their use in police patrols would show off their reliability and have a large impact on the public psyche.

In addition to the above, bulk purchase, related maintenance contracts, and charging requirements would create a reliable source of demand, supporting the development of e-mobility markets

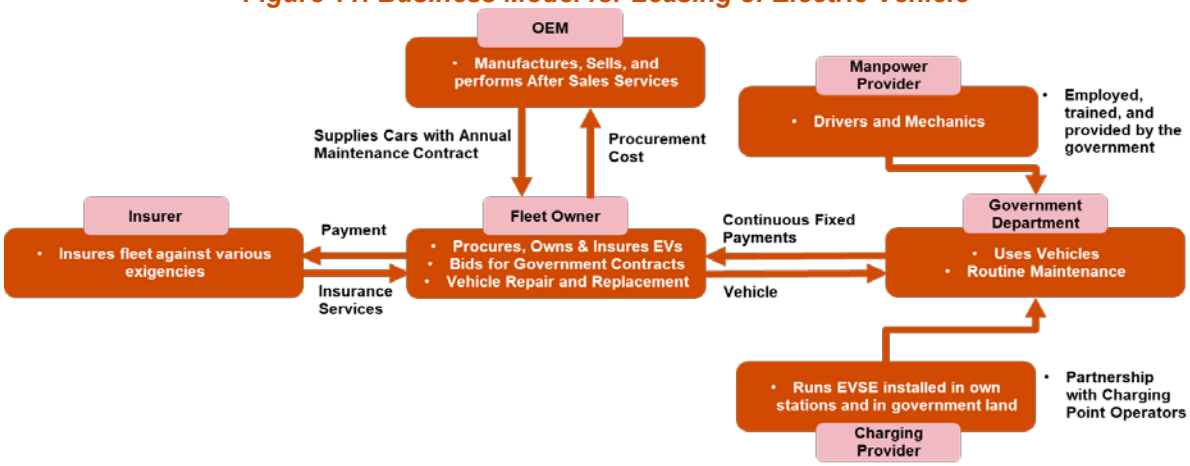
Union Minister of Power and New & Renewable Energy's message on electrification of government fleets

"The Union Minister of Power and New & Renewable Energy has written to all the Union Ministers including the Minister of States (Independent Charge) and Chief Ministers of all the States/UTs to join the Government of India's initiative on transformative mobility and advice their respective Ministries/Departments to convert their fleet of official vehicles from present Internal Combustion

Steps for Electrification

As these vehicles are leased from fleet owners, government departments can switch from ICE vehicle providers to EV providers in a phased manner. The new business model would consist of the following stakeholders and roles-

Figure 11: Business Model for Leasing of Electric Vehicle



The respective departments would handle the operation and charging of these vehicles and would enjoy a large amount of savings in terms of fuel and maintenance costs. These savings would more than make up for the higher fees EV fleet owners would charge to make up for their higher up-front cost.

This is an immediate step the government can take to advance e-mobility in the city, and should be implemented with a combination of mandates, guidelines, and procurement exercises-

Table 8: Steps to be taken for Government Leasing of Electric Vehicles

Heading	Steps to be Taken
Adoption Mandate	• As a matter of internal policy, each department needs to set goals for the electrification of their vehicles fleets. An increase of 10% per year can be targeted, and in order to enable this, all future purchases should mandatorily be electric once a department has access to the needed charging infrastructure. • Older vehicles with lowered fuel efficiency should be examined and replaced as soon as possible.

Procurement	• A state-wide strategic guideline to be created on current electric vehicle models available in the market and the procurement procedures that can be followed for a department or office, along with instructions on the kind of charging infrastructure available in the city- including the use of online EV portals and charging network apps. • In order to bring down costs across the board, a demand aggregation exercise can be conducted for all government departments in the city. By pooling current and future demand and placing as large an order as possible, the higher up-front cost of electric vehicles can be lowered. Demand aggregation can be extended to the state-level, to increase the scale and benefits of the exercise. • CESL under EESL, a public joint venture, is the largest procurer and lessor of electric vehicles in India, as part of its mission to enable consumers, companies, and the government to adopt green energy technologies. It has conducted large scale demand aggregation exercises across the country, and the UP EV Policy recommends the leasing of vehicles from them even outside the regular tendering process. They are one of the best choices for procuring such vehicles.
Training and Manpower	• Drivers for vehicles are provided either internally by the department, or from police and other security related organizations like the Special Protection Group. Training and sensitization regarding the operation of electric vehicles, their regular maintenance, and proper usage to maintain battery life is required to ensure the longevity of these vehicles.
Charging availability	• Departments can provide land and parking space at their offices and motor pools for charging network providers to install charging points. The EV Policy 2022 covers revenue-sharing agreements with these providers, in exchange for space to run their stations. • A central database of all charging points installed in government offices should be maintained, so that government vehicles can use chargers across different departments and agencies. If possible, some of these chargers should be open to the public as well.

EESL through CESL has aggregated demand for electric vehicles across the country

"EESL through its wholly owned subsidiary CESL (Convergence Energy Services Limited) has undertaken consultations with State Transport Utilities (STUs), State Governments, OEMs, NITI Aayog etc. to aggregate demand. Demand for 930 number of electric 4-wheeler across Central and State governments has been aggregated as of March 2022. CESL has aggregated demand for 82,000 E 3-wheelers, bringing down price by as much as 22%"

Kolkata Police and CESL sign MoU for dry lease of electric cars

For an agreed period of 8 years, CESL will provide 20 electric cars on dry lease, with the option of increasing the number of vehicles if the need arises. Additionally, CESL is putting up one slow charger per vehicle and 6 fast chargers on Kolkata Police land to charge these vehicles.

International Examples

Government of New South Wales, Australia- The NSW Government will set a target to electrify its passenger vehicle fleet of 12,000 cars by 2030, which will significantly reduce CO_2 emissions. It began this initiative by acquiring more than 2700 hybrid and fully electric vehicles for its government fleet and has set an interim target of 50% EV procurement by 2026.

It has used its bulk purchasing power to reduce the cost of acquisition and incentivize carmakers to make more models available within NSW. It has re-written its Approved Vehicles List to include electric vehicles and created a guideline on their procurement and use. It also provides separate incentives for local council bodies to replace their fleets with electric vehicles.

Government of New Zealand- As part of their Carbon Neutral Government Program (CNGP), all government agencies have been mandated to reduce their number of vehicles and make all future replacements with electric vehicles. Agencies may only procure petrol or diesel vehicles after applying for a special exemption.

Kāinga Ora, a crown agency that provides rental homes for citizens, has received $1.6 million in initial funding from the Energy Efficiency and Conservation Authority to transition its fleet of 760 vehicles. 86% of these are allocated to various staff and are parked in private homes, so the agency is piloting the installation of home chargers alongside the vehicles themselves.

Investment, Savings, and Emission Reduction

A step-wise summary of the required additional investments, the operational savings, and the overall monetary benefits is given as follows-

Table 9: Investment, savings, and benefits for Government Leasing of Electric Vehicles

S. No.	Heading	Value	
1	Number of Government Employees in Uttar Pradesh (as per 2017-18)	840,000	
2	Fraction of Group A and Group B employees	Group A: 2.8% Group B: 8.5%	
3	Number of Staff Cars in UP.(Assuming all Group A employees and half of group B employees receive vehicles)	60,000	
4	Per Vehicle additional Up-front Cost for EV vs. ICE Vehicles	INR 220,000	
5	Lifetime Operational Savings per Vehicle, at utilization of 45km/day	INR 375,000	
6	Total Additional Investment	INR 1320 Cr.	USD 158 Million
7	Total Operational Savings	INR 2250 Cr.	USD 270 Million
8	**Total Monetary Benefits**	**INR 930 Cr.**	**USD 112 Million**

In terms of emission savings, the calculation is as follows-

Table 10 : Emission savings for Government Leasing of Electric Vehicles

S. No.	Heading	Value
3	Number of Staff Cars in UP	60,000
4	Production and Maintenance related emissions (including battery production for EVs) per vehicle	ICE: 5.8 tons CO_2 Equivalent
		EV: 6.9 tons CO_2 Equivalent
5	Fuel related emissions per vehicle	ICE: 30 tons CO_2 Equivalent
		EV: 18.8 tons CO_2 Equivalent
6	Emissions savings per EV	10.1 tons CO_2 Equivalent
7	**Total Emission savings**	**606 thousand tons CO_2 Equivalent**

4.4. Solid Waste Collection Vehicles

Vehicle Segments- 3-Wheelers, Mini Trucks, Light Duty Trucks

The Lucknow Municipal Corporation (LMC) has a large fleet of vehicles dedicated to solid waste collection across the city. Around 1500 such vehicles are in operation throughout the city, split between door-to-door collection and secondary transport of solid waste. They range from 3-wheeler ICE tempos to large 20+ ton garbage compactors. Certain areas of the city are covered by vehicles owned by LMC itself, while a private contractor, EcoGreen, is responsible for collection in the rest. Both organizations purchase these vehicles directly, bearing the full capital costs along with fuel, staffing, and maintenance.

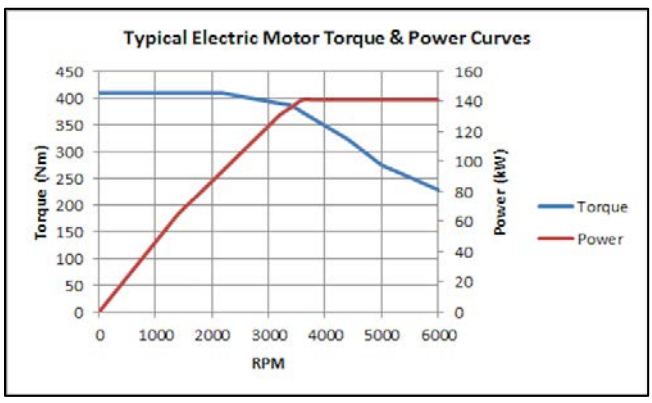
Door to Door Collection

Collection is done either door-to-door or from neighborhood dump sites by mini trucks and taken to larger waste collection sites. These vehicles can enter most neighborhoods and visit various locations until full, contributing to the city's nearly 100% door-to-door garbage collection rate. They have a carrying capacity of 500-700 kilograms and make several trips per day. Both electric mini trucks and cargo 3-wheelers are available to serve this purpose.

The operational conditions for door-to-door collection vehicles are very strenuous, leading to very low mileage and faster breakdowns. Very frequent loading and unloading, heavy loads, and frequent starts and stops while navigating residential neighborhoods are some of the contributing factors for these issues. These factors also reduce the vehicle's lifetime to only 7-8 years. They cycle through different zones of the city, and each zone is visited at least fortnightly. On average, these vehicles only cover 20-25km a day yet consume 3 liters of fuel due to operational conditions. Drivers under the private contractor practice are given limited fuel per day to promote disciplined use and avoid waste but LMC drivers are able to use fuel freely, increasing costs even further. For each vehicle, this adds up to more than INR 90,000 per year in fuel expenses alone.

Keeping this in mind, there are several reasons for why electrification of door-to-door solid waste collection is an important business case for e-mobility in Lucknow

Utilization	Predictability	Visibility
• Although these vehicles have low utilization, their terrible fuel economy makes savings of up to INR 75,000 per vehicle per year possible by switching to EVs. • Their ranges of 100-150km per charge are more than sufficient for this purpose. • Solid waste collection is an ongoing, round-the-year activity that requires vehicles to be in operation nearly every day.	• Zone wise and neighborhood wise scheduling and route planning is already done. • The distances to be travelled by each vehicle are already known. • The LMC has a large number of depots, parking spaces, and empty lots under its jurisdiction, which makes charging point installation simple.	• Door-to-door collection vehicles are a fixture in any city, and regularly interact with almost every citizen. • The strenuous conditions in which these vehicles operate are visible to all, and the use of EVs for this purpose would showcase their reliability very well.



Transitioning these vehicles to electric variants, spread between cargo 3-wheeler and mini trucks according to the level of demand in the area, would lead to immense savings in operational costs. Electric motors are also better suited to handle the frequent starts and stops under heavy load, due to regenerative breaking and consistent torque[7]. Fuel savings. lower maintenance costs, and less frequent breakdowns make electric vehicles an excellent option for this purpose. The quality and longevity of batteries used by mini trucks ensures that only a single replacement may be required, if that, within the lifetime of the vehicle. Finally, the zero-

[7] https://theconversation.com/heres-why-electric-cars-have-plenty-of-grunt-oomph-and-torque-115356

emission nature of these vehicles complements the government's dedication to keeping the city clean and protecting the citizens from pollution.


Electric Mini Truck and Cargo 3-wheeler

Seondary Transport

From larger waste collection sites, garbage is taken to end locations such as composting facilities, recycling plants, and landfills. This is done using larger multi-ton trucks, whose electric variants have only recently entered the Indian market. While door-to-door vehicles face adverse operating conditions, secondary transport trucks are more regular in their operation. They have a lower frequency of operation and pick up waste from large collection sites across the city. Typical ICE trucks are large, with load capacity of more than 7 tons, which often includes the weight of hydraulic equipment.

Currently, electric light duty trucks available on the market have a capacity of only up to 5 tons, with a range of up to 100kms. Total Cost of Ownership analysis indicates that these trucks have not yet been able to achieve cost parity with their ICE counterparts, and thus cannot yet be considered as a priority business case for adoption. Technical consultations with OEMs and pilot projects are required to ascertain whether upcoming models can fulfill this purpose in the future. Internationally, large trucks 20+ ton trucks are being used successfully in this role, but such models are a long time away from becoming available in India.

Steps for Electrification

Since the operation of solid waste collection follows the capex model, and the savings accumulate over time due to lower operational costs, the focus should be on reducing up-front costs and increasing the speed of adoption.

While e-rickshaws have been used successfully in cities like Chennai, Lucknow would be the first in India to deploy electric cargo carrier 3-wheelers and mini-trucks in this role. Based on feedback from the Lucknow Municipal Corporation, before low-cost large-scale adoption through demand aggregation can take place, a pilot study needs to be conducted to prove the technical capabilities of these vehicles.

With the results providing a solid backing, widespread adoption can go forward throughout the city. The following steps can be taken to conduct this study-

1. Arrange meetings between OEMs and LMC where the technical capabilities of electric vehicles can be showcased and compared with the operational requirements of solid waste collection.

2. Selecting a zone or multiple zones where 5-10 such vehicles can be deployed on a pilot basis, and their operations studied over three months.

3. Expected savings can be verified and compared with actual savings. A small group of drivers can be trained in the operation of EVs, and a wider-scale training program created with their feedback once they have familiarized themselves with the vehicles.

4. Once the capabilities of electric vehicles in these roles is proven and established, the study results would form the basis of future large-scale tenders for electrification throughout the city.

5. Capacity building of officials in the technical specifications and economics of these vehicles would be conducted, for a faster tendering and procurement process.

In order to scale up this pilot study and meet the charging requirements of these vehicles, the following steps can be taken-

Table 11: Steps to be taken for the implementation of EVs in Solid Waste Collection

Heading	Steps to be Taken
Adoption Mandate	• Post a successful pilot, the LMC should set ambitious targets for replacement of ICE vehicles. All ICE 3-wheelers and mini-trucks that have reached the end of their life should mandatorily be replaced by electric vehicles. A minimum replacement rate of 10% a year can be set, targeting the oldest and least efficient ICE vehicles. Exemptions should only be granted if a zone's charging infrastructure is not enough to support more vehicles, but the difference should be made up for in the next year.
Procurement	• The high up-front cost can be mitigated via bulk purchase discounts and tenders. Under the UP- EV Policy (2022), state departments and their agencies are encouraged to procure EVs without tender or nomination basis from demand aggregating agencies like Energy Efficiency Services Ltd. (EESL).
Training and Manpower	• Feedback from drivers participating in the pilot can be used to create a comprehensive training program for the operation, maintenance, and longevity of the vehicles. Details on how such a program would work are available in the chapter on EV Skilling.
Charging availability	• Partnerships with charging point operators, to deploy charging points in LMC spaces as well as provide access to their charging stations across the city. Due to the shorter distances these vehicles cover, overnight charging at depots and parking lots would be sufficient. • For chargers installed within municipal depots and parking spaces, Rajasthan Electronics & Instrumentation Limited (REIL) can be called on for the installation of charging infrastructure, as recommended in the EV Policy (2022) due to their selection as nodal agency in setting up charging stations under FAME II.
Interaction with OEMs	• The LMC should establish maintenance contracts with EV OEMs, as well as partnerships for training its own personnel. • OEMs should be encouraged to develop models better suited for these roles, based on the results of the pilot project and future mass deployment. • For secondary transport as well, OEMs need to be advised on the need of larger electric trucks in this role and encouraged to develop such models for India.

Tamil Nadu Procures 1600 Battery Operated Vehicles (BOV) for Waste Collection (2018)

"E-rickshaws chassis fitted with solid waste containers, classified as 'e-carts' are in operation collecting sold waste across Tamil Nadu, increasing door-to-door collection coverage with zero emissions. These vehicles have a carrying capacity of 500 kg and can cover 50km per charge, at a cost of INR 125000 per unit. Although these vehicles primarily use lead-acid batteries which need replacement every 1.5 years and generate toxic waste, advances in battery technology and lowered costs are making lithium-ion variants more viable. These have their higher up-front cost mitigated by fewer battery replacements and a higher range."

New York employs seven Mack LR Electric Trucks for Garbage Collection (2021)

"Battery operated refuse collection vehicles with a range of 160km per charge and 11 tons of carrying capacity were purchased and are operational in New York city. Their advanced regenerative braking system allows them to maintain their range in a role that requires more than a hundred starts and stops a day. They are indicative of the kind of larger models that could become available in India over the coming decade."

Investment, Savings, and Emissions Reduction

A summary of the investments required, savings, and emissions reduction is as follows-

Table 12: Investment and savings for EVs in Solid Waste Management

S. No.	Heading	Value	
1	Number of Vehicles involved in Solid Waste Management in Lucknow	1,400	
2	Fraction of 3-wheelers and mini-trucks (based on EcoGreen fleet data)	3-wheelers- 35%	
		Mini-truck- 14.3%	
3	Number of 3-wheelers and mini-trucks working in Lucknow	3-wheelers- 490	
		Mini-trucks- 200	
4	Per Vehicle additional Up-front Cost for EV vs. ICE Vehicles	3-wheelers- INR 90,000	
		Mini-trucks- INR 110,000	
5	Lifetime Operational Savings per Vehicle, at utilization of 25km/day.	3-wheelers- INR 110,000	
		Mini-trucks- INR 614,000	
6	Total Additional Investment	INR 6.61 Cr.	USD 0.8 Million
7	Total Operational Savings	INR 17.67 Cr.	USD 2.1 Million
8	**Monetary Benefits**	**INR 11.06 Cr.**	**USD 1.3 Million**

In terms of emission savings, the calculation is as follows-

Table 13 : Emission savings for EVs in Solid Waste Management

S. No.	Heading	Value
1	Number of 3-wheelers and mini-trucks working in Lucknow	3-wheelers- 490
		Mini-trucks- 200
2	Production and Maintenance related emissions (including battery production for EVs) per vehicle	ICE 3-wheeler: 2.8 tons CO_2 Equivalent
		EV 3-wheeler: 4.1 tons CO_2 Equivalent
		ICE Mini-Truck: 7.6 tons CO_2 Equivalent
		EV Mini-Truck: 9.2 tons CO_2 Equivalent
3	Fuel related emissions per vehicle	ICE 3-wheeler: 7.7 tons CO_2 Equivalent
		EV 3-wheeler: 5.9 tons CO_2 Equivalent
		ICE Mini-Truck: 13.2 tons CO_2 Equivalent
		EV Mini-Truck: 9.3 tons CO_2 Equivalent
4	Emissions savings per EV	3-wheeler: 0.5 tons CO_2 Equivalent
		Mini-Truck: 2.3 tons CO_2 Equivalent
5	**Total Emission savings**	**705 tons CO_2 Equivalent**

4.5. Electric Vehicles for Personal Use

Vehicle Segments- 2-Wheelers

2-wheelers are the most common form of personally owned transport in the city with 1.8 million units currently on-road. Their affordability, fuel efficiency, and ability to navigate through traffic makes them the most popular option among commuters, be they students, workers, or homemakers.

As the most affordable and accessible of all EV segments, electric 2-wheelers are poised to overtake their ICE counterparts in the coming few years. They are especially well-suited as a priority business case due to the following reasons-

Utilization	Predictability	Visibility
• 2-Wheelers achieve cost parity at the lowest utilization of all segments. • The average officegoers commute, both ways combined, is 30-40kms. At 30km of use a day, savings in operational cost can exceed INR 25,000 a year. • Their ranges of 80-100km per charge make them more than able to fulfill daily personal transport needs.	• While personal use is never completely predictable, commutes to offices and schools remain consistent over time. • These vehicles can easily be charged at home, and only require a regular 15A power socket for their portable charger. Some even have removable batteries, which can be carried indoors for easier access. • They take up little parking space, making setting up workplace charging easy as well.	• 2-Wheelers are by far the largest vehicle segment in the city and would have an enormous impact on EV visibility. • Word of mouth is highly effective at increasing adoption of any unfamiliar technology. A single adopter can motivate their coworkers and family as well.

In fact, the lifetime savings from these vehiclesis so high that it exceeds the cost of the vehicle at even low levels of use. Therefore, it makes financial sense to not only buy them to meet new demand, but to immediately replace your existing 2-wheeler with an electric variant. Already, electric 2-wheelers are becoming visible on the road as more and more citizens become aware of their benefits and choose them as their first vehicle. Still, they face the same barriers to adoption as other electric vehicles. To reiterate these barriers-

1. Lack of truly widespread awareness regarding their benefits. For example, many drivers express doubts about the reliability of electric vehicles, not knowing that they break down less often and require less maintenance than their ICE counterparts.
2. Anxiety regarding availability of charging infrastructure where needed- many are not aware of the ease of domestic and workplace charging.
3. Higher up-front costs. This creates further difficulty for people opting for EMIs and automotive loans.

Steps for Electrification

The first barrier needs to be addressed by promoting awareness of EV benefits and possible savings through publicity campaigns, testimonials, social media, etc. as covered in detail in the chapter on EV Awareness.

The second barrier, anxiety regarding the availability of charging, can be overcome similarly by educating citizens on ease and utility of domestic charging for electric 2-wheelers.

Model byelaws on EV charging infrastructure released by MoHUA permit individuals to use their domestic power supply and charge their vehicles using a standard 230V/15A socket. Similar charging points can be set up in workplace parking spaces. Independent sheds can be put up for charging removable batteries, so that they need not be carried into the workplace itself.

A guide on setting up these charging points should be created and circulated online and in print media as follows, to ensure proper safety-

1. The socket should be in an area not exposed to weather, i.e., within a garage or under a shed roof.

2. It should be installed as an independent unit, accompanied by safety devices such as circuit breakers and fuses.

3. A CO_2 or ABC powder fire extinguisher should be kept nearby in case of electrical fire.

4. Installation should be done by a professional electrician and not by a layperson.

Additionally, pre-made charging points with integrated safety features and app-based usage tracking are also available on the market. Bharat AC-001 chargers can serve three vehicles at a time, supplying 3.3kW of power. Business models and locations for their deployment are covered in depth in the chapter on Charging Infrastructure.

Finally, the third major barrier consists of the higher up-front cost. Increased FAME-II subsidies of INR 15,000 per kWh have helped bridge this gap, but electric 2-wheeler prices remain more than 30% higher than their petrol counterparts. Nevertheless, the operational savings make taking automotive loans and EMIs less financially burdensome.

For government employees, there are two additional measures available to cover the additional up-front costs. Specifically, group C employees can be targeted for taking up electric 2-wheelers-

1. Under the UP EV Policy (2022), they are encouraged to avail their Vehicle Advance of INR 30,000 to help cover the up-front costs. This is an interest-bearing advance not limited to electric vehicles, with lower rates compared to automotive loans in the market. Other states such as Odisha have taken steps to provide interest free advances for the exclusive purchase of electric vehicles, and UP can follow a similar strategy as well.

2. States such as Andhra Pradesh have engaged in large scale demand aggregation exercises for the purchase of electric 2-wheelers by employees, in partnership with CESL. Not only do they receive a discounted price, but employees can also purchase these vehicles through no down payment EMIs. Offices in Lucknow and across the state can engage in a similar exercise.

For private individuals, there are certain banks such as Axis, SBI, and Union Bank that provide loans for electric vehicles at a concessionary rate. The government can encourage state owned banks such as SBI and Union Bank in providing EV loans at further concessionary rates to hasten uptake. Current concessionary schemes should also be highlighted in the media to improve their reach.

Odisha Government Provides Interest-free Advances to Government Employees for the Purchase of Electric Vehicles

"Group A and Group B employees can avail an advance of up to 75% of a 4-wheeler's ex-factory cost, up to a limit of INR 1500,000. In addition, Group C and D employees and above can avail a similar advance for electric 2-wheelers, up to a limit of INR 200,000. The amount can be recovered in up to 100 installments from the monthly salaries of these employees."

Andhra Pradesh Government Acquires 25,000 E-2 wheelers for its Employees

"CESL and New & Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP) has worked together to aggregate demand for 25,000 E-2 wheelers for government employees. These vehicles can be bought by employees on an EMI basis with no down-payment. CESL is also working with Delhi, Kerela, and Goa governments for similar schemes"

Investment, Savings, and Emissions Reduction

Table 14 : Investment and savings for Electric 2-wheelers for Personal Use

S. No.	Heading	Value	
1	Number of Electric 2-wheelers expected to be on-road in Lucknow by 2030	258,000	
2	Per Vehicle additional Up-front Cost for EV vs. ICE Vehicle	INR 16,000	
3	Lifetime Operational Savings per Vehicle, at utilization of 40 km/day	INR 2,60,000	
4	Total Additional Investment	INR 412.8 Cr.	USD 49.5 Million
5	Total Operational Savings	INR 6708 Cr.	USD 805 Million
6	**Monetary Benefits**	**INR 6295.2 Cr.**	**USD 780 Million**

In terms of emission savings, the calculation is as follows-

Table 15 : Emission savings for Electric 2-wheelers for Personal Use

S. No.	Heading	Value
1	Number of Electric 2-wheelers expected to be on-road in Lucknow by 2030	258,000
2	Production and Maintenance related emissions (including battery production for EVs) per vehicle	ICE: 0.67 tons CO_2 Equivalent
		EV: 0.85 tons CO_2 Equivalent
3	Fuel related emissions per vehicle	ICE: 10.1 tons CO_2 Equivalent
		EV: 5.3 tons CO_2 Equivalent
4	Emissions savings per EV	4.62 tons CO_2 Equivalent
5	**Total Emission savings**	**1.2 million tons CO_2 Equivalent**

4.6. Corporate Employee Transport

Vehicle Segments- 4-Wheeler Sedans, Hatchbacks, SUVs

Many companies now offer cab services to their employees, arranging pickups to and drops from their workplaces. The employee transport market for corporates has been booming in India, with commercial hubs across the nation creating immense strain on road and parking infrastructure. Employees working flexible hours and professionals providing services across different time zones now require on-demand transportation round the clock. IT companies serving oversees clients are one of the major drivers of this trend.

There are a wide variety of reasons why companies are interested in sponsoring their employees' daily transport-

- Ease of access, late night availability, and safety for those travelling at odd hours
- Reliability in terms of reaching office at predictable times, removing the uncertainty involved in using ride-hailing on a personal basis. It reduces unforeseen absences and late arrivals and allows better coordination.
- Employee satisfaction and loyalty. Employees are willing to stay with companies longer and time work according to the needs of the company as long as it provides them the necessary support.
- Employees who spend less time driving are healthier and take less leaves of absence, which is especially relevant as the time spent by Indian commuters in traffic is one of the highest in the world.
- Young professionals who do not own vehicles have an easier time reaching offices, while older employees are able to dedicate their family vehicle towards sending children to school or other such tasks.
- Carpooling and chained pickups and drop-offs reduce the number of vehicles on the road, lowering overall emissions and contributing to a company's environmental commitments.

The vehicles provide both short range mid-day trips and longer drop-offs during the start and end of office hours. Corporate employee transport can take place under three business models-

1. **Company owned Vehicles:** Where the vehicles are owned and operated by the company. This requires significant expense on acquiring, staffing, and running the vehicle. The company must handle the various modalities of operation such as fueling, maintenance, scheduling, and route planning. Selling and replacing older vehicles is also a highly involved process. All these characteristics make company owned vehicles rare.

2. **Leased Vehicles:** Where vehicles ownership is with the fleet operator, and the company does not have to bear the capital expense of buying a vehicle. Regular maintenance and repair may be the responsibility of either party, depending on the terms of the contract.
   a. In the dry lease model, the vehicle is provided as-is, and the company handles its operation while providing both manpower and fuel.
   b. In the wet lease model, the vehicle is provided with both manpower and fuel, the costs for which are accounted for in the payments by the company. This is preferred over dry lease by companies as they can avoid keeping additional staff on payroll

   The decision for the number of vehicles to be leased must be made keeping in mind the expected utilization of these vehicles. If there is a mismatch with the actual demand, it is difficult to adapt as the agreement is already final.

3. **Mobility as a Service:** A third party service provider acts like a taxi service, providing rides as needed to employees while keeping the vehicles with themselves. Companies are usually charged depending on a range of factors such as kilometers travelled, number of trips, peak or off-peak travel, etc. This is the most widely adopted form of employee transport and involves the vendor bearing such expenses like staff training, parking, etc. which would be overheads for a company. In this model, companies do not need to worry about forecasting demand, and can call for transport as and when needed.

The employee transport industry and especially Mobility as a Service has been selected as a priority business case for the following reasons-

Utilization	Predictability	Visibility
• Multiple pickups and drop-offs throughout the day ensure that the vehicle travels enough to meet the utilization thresholds for passenger 4-wheelers.	• While exact routes may vary day-to-day, the number of customers and their destinations are known which allows advanced planning of charge and duty cycles.	• Digitally enabled, silent, and clean electric vehicles are appealing to employees and give off a modern, high-tech impression.

• Very high fuel savings of over INR 100,000 a year can be achieved with even a utilization of 100km/workday compared to a petrol vehicle. • These savings can cover the excess up-front within 2-3 years, depending on the model used. • The longevity of 4-wheeler batteries ensures that replacements are only necessary after 6-8 years. • The service providers' costs such as hiring, paying, and training staff for EVs can be covered these savings. • Passenger 4-wheelers have larger, long-lasting batteries capable of covering 200km per charge, although during peak demand periods the vehicle may need to stop and charge once a day.	• Advanced bookings with a limited number of slots for unplanned rides can control the level of unpredictability in routing. • Advanced telematics built into EVs, and app-based tracking allows companies to easily monitor the performance of these vehicles and whether they are providing a satisfactory level of service • Chargers for these vehicles can be installed in the same parking spaces that are currently used for ICE vehicles, in partnerships with Charging Point Operators.	• Zero emission vehicles enhance a company's environmentally friendly image and contribute to CSR and environmental commitments. • Corporate employees interested in eventually buying their own vehicles would be able to experience the benefits of EVs firsthand, increasing the likelihood of buying one themselves.

In addition to these, relying on electric vehicles for employee transport will improve the AQI around offices and reduce the heat island affect cause by the large number of ICE vehicles concentrated in small, commercial areas.

Electric Compact SUV

Steps for Electrification

Mobility as a Service is a model that is well-suited for the deployment of electric vehicles. The service provider handles expenses such as staff training, charging, parking, IT, etc. that would be overheads for a company. Operating an electric vehicle fleet is a specialized activity that involves intensive planning and monitoring of vehicle operations, that may not be feasible for a company to do in-house for its owned or leased vehicles.

Software solutions for trip planning, charging schedules, and performance measurements require scale and expertise to get the maximum benefits from. Therefore, a large service provider serving multiple companies at once is much more efficient than each company handling their own small set of vehicles and can ensure high levels of utilization for each vehicle. The lower cost of operations means that these service providers can offer rides at lower costs compared to their ICE counterparts.

The government can promote these EV service providers in the following ways-

Table 16 : Steps to be taken for the implementation of EVs in Corporate Employee Transport

Heading	Steps to be Taken
Financing and Investment	• Further increase the limit on the number of vehicles for which a fleet owner can avail subsidy, as EV fleets function better at scale. • Help EV entrepreneurs access funds by guiding and publicizing them through InvestUP, through a dedicated team and helpline. • Further publicize state owned banks' EV loan schemes, that provide loans concessionary rates for electric 4-wheelers.
Availability of Skilled Workforce	• Develop a range of skilling programs, certifications, courses, institutes, etc. to meet the coming demand of trained personnel from this sector, so that growth is not stifled due to lack of recruits.
Parking and Access	• Reserved parking spaces complete with EV charging points at government-owned parking throughout the city, to increase access and operational range of vehicles. Potential locations, business models, types of chargers are covered in-depth in the chapter on Public Charging Infrastructure along with other measures. • Exemption from toll tax and parking fees in locations like CCS airport, Charbagh railway station, etc. along with government parking spaces. As corporate taxis frequent these places, this will act as a significant incentive.

The government can give a significant boost to this business case, but the ultimate drivers would be the client companies, service providers, and other stakeholders in the EV ecosystem. For them, certain additional steps can be-

Table 17 : Additional steps for companies to take to implement EVs in Corporate Employee Transport

Stakeholder	Steps to Take
OEMs	• Further marketing to EV service providers, showing off the possible savings in high-utilization roles along with the digitally enabled systems that come installed in electric vehicles. • Designing vehicles software to support a healthy ecosystem of apps and data.
Service Providers	• Identify clients with regular demand for transportation, in high-utilization areas such as commercial hubs to reach out to for trials. • Identify suppliers for bulk procurement of vehicles once proof of concept is successful, for example EESL. • Providing training in-house or enrolling staff in certification courses on EV operation and EV management software, as described in the chapter on Skilling and Awareness. • Preparing marketing material that address companies' interests and actively championing the cause of transitioning to electric vehicles.
Charging Point Operators	• Partner with EV service providers to set up charging infrastructure in their land and parking spaces. Likewise, reach out to companies to set up chargers in the spaces they have available, to increase the reach of EV transport vehicles and even serve those personally owned by employees. • Provide access to their charger networks and do joint planning of charge cycles with EV service providers for efficient and uninterrupted operations.
Fleet Management Software Companies	• Companies with existing fleet management software that are used to track ICE fleets need to adapt to meet the requirements of electric vehicle fleets and create software that takes advantage of their in-built telematics systems. • Ensure that fleet management software is compatible with charging related applications such that performance monitoring and charging management occurs seamlessly.

Company Departments- Finance	• Study the economics of EV operations and develop a clear understanding of the kind of savings that can be achieved without compromising the reliability of transport. • Present the benefits to senior decision makers, act as champions for the switch to electric vehicles.
Company Departments- Legal	• Draw up robust contracts that assure the company of quality services while also giving EV service providers confidence on receiving a steady level of business from the company. • Longer term contracts to help service providers justify their initially large investments in fleet creation and expansion.
Company Departments- HR and CSR	• Appoint an 'EV Champion' to maintain momentum in the adoption of clean transport solutions, and also present the benefits of EVs to employees interested in purchasing one for personal use. • Take advantage of the company's use of zero-emissions to enhance its public image and market it as environmentally responsible and technically savvy. • Leverage the transport services provided by the company to market to potential new hires and retain existing talent.

A company's timeline for hiring an EV service provider and reaching wide scale adoption can be as follows-

Table 18 : Possible timeline for hiring EV service provider for employee transport

3 to 5 Months	1. Develop an understanding of the technology and cost economics
	2. Calculate potential savings by examining current transport usage
	3. Reach out to EV service provider for trials on select routes.
	4. Monitor performance, check real savings vs. expected, obtain user feedback.
	5. Consider trial results and potential improvements in brand image of company.
	6. Draw up agreement with service provider and scale up use of EVs.

Lithium Urban Transport, India's first zero emissions transport services operational in 7 cities

"Lithium Urban Transport has pioneered EV as a service in India, and now runs a fleet of 850+ vehicles across 7 cities. They run more than 10,000 trips a day serving 23,000 passengers. Their operations are supported by 500+ slow and fast chargers across different cities. They have achieved highly efficient operations with a suite of analytical software plugged into the telematics systems of their vehicles. They have significant presence in Bangalore, Delhi, Hyderabad, Pune, and Manipal. Initially, they faced a lack of skilled drivers for their EVs, so now their drivers undergo in-house training and receive defensive driving certifications to ensure the highest level of safety. Their clients include Google and Wipro, who have also installed captive chargers within their campuses to support EV use."

Investment, Savings, and Emissions Reduction

Table 19 : Investment and savings for EVs in Corporate Employee Transport

S. No.	Heading	Value
1	Number of Commercial 4-wheelers expected to be on-road in Lucknow by 2030	25,500
2	Per Vehicle additional Up-front Cost for EV vs. ICE (CNG) Vehicle	INR 270,000

3	Lifetime Operational Savings per Vehicle (vs. CNG Vehicle)	INR 480,000	
4	Total Additional Investment	INR 688.5 Cr.	USD 82.6 Million
5	Total Operational Savings, at a utilization of 130km/day	INR 1224 Cr.	USD 146.9 Million
6	**Monetary Benefits**	**INR 535.5 Cr.**	**USD 64.3 Million**

In terms of emission savings, the calculation is as follows-

Table 20 : Emission savings for EVs in Corporate Employee Transport

S. No.	Heading	Value
1	Number of Commercial 4-wheelers expected to be on-road in Lucknow by 2030	25,500
2	Production and Maintenance related emissions (including battery production for EVs) per vehicle	ICE: 7.3 tons CO_2 Equivalent
		EV: 8.1 tons CO_2 Equivalent
3	Fuel related emissions per vehicle	ICE: 66.3 tons CO_2 Equivalent
		EV: 41.8 tons CO_2 Equivalent
4	Emissions savings per EV	23.7 tons CO_2 Equivalent
5	**Total Emission savings**	**604 thousand tons CO_2 Equivalent**

4.7. Use of Electric Vehicles in Urban Freight

Vehicle Segments- 2-wheelers, cargo 3-wheelers, mini-trucks

Urban populations have increasingly come to rely on e-commerce giants such as Amazon for shopping for accessories, furniture, clothes, etc. Combined with perishable delivery such as online food ordering and groceries, almost every item can reach a customer's doorstep quickly and without hassle. The backbone for this entire ecosystem is urban freight, with an enormous fleet of 2-wheeler, 3-wheelers, and Small Commercial Vehicles (SCVs) working through the day. The businesses that require delivery services cover three broad categories-

E-commerce last mile delivery: Involves the delivery of a wide range of semi- and non-perishable items that do not require refrigeration. The industry in India is expected to grow to USD 350 billion by 2030 and it is estimated that e-commerce will require a combined 160,000 new vehicles of all types in the coming decade. Urban freight and last-mile delivery also constitute most of an e-commerce company's emissions. 100% adoption by 2030 could prevent the consumption of approximately 32 billion liters of fuel and 76 million tons of CO_2 emissions a year. Examples include Flipkart and Amazon.

Perishable Delivery- Food orders and Groceries: Involves the delivery of perishables such as cooked food and groceries, which may be refrigerated or delivered with ice packs if required. These can range from fully prepared meals to simple ingredients such as flour. These businesses may take the form of grocery stores and restaurants or even rely entirely on delivery for sales, running warehouses and cloud kitchens. There is some overlap with e-commerce in terms of semi-perishables such as bottled syrups and jams. The e-grocery market had reached nearly $4 billion in FY2021 and is growing at an extremely fast CAGR of 33% as the convenience appeals to Indian households. Examples include Zomato, Zepto, Dunzo, and Swiggy.

Specialized Delivery- Pharmaceuticals: Involves the delivery of medication, medical aids such as bandages, and devices such as thermometers. While many medical products can be delivered through any means, certain medications like vaccines require a properly refrigerated vehicle and specialized handling and storage. While this involves lower utilization, the low-volume high-value nature of these goods make delivery lucrative. The e-pharmacy market reached nearly $350 million in 2021 and is experiencing surging growth due to internet penetration and increase in spending on medicines. Examples include 1mg and Apollo Pharmacy.

There are three modes of delivery that are used to fulfill businesses' delivery requirements, individually or in a mix-

1. **Business Owned-** In which the vehicles are purchased and operated directly by the delivery platform, store, or e-commerce company. This is an asset-heavy approach with a high up-front cost, viable for those who face consistent demand and can guarantee high rates of utilization for each vehicle. If there is a mismatch in the number of vehicles and actual demand, the business must bear the burden of keeping unused vehicles on its balance sheet. Both operational costs and capital costs are borne by the business itself, making this model a serious commitment. As the number of vehicles rises, the complexity of planning their operations grows rapidly as well.
    a. Grocery stores and restaurants with a consistent customer base keep 2- and 3-wheelers for local deliveries.
    b. Larger E-commerce companies keep a fleet of 3-wheelers, vans, and mini trucks for deliveries in areas of high and consistent demand, along with internal transport from warehouse to warehouse.

2. **Service Contracts-** In which vehicles are owned by service providers contracted to delivery products. This is an asset light approach with larger continuous payments which may be time or performance based. This model can be followed by both small and large businesses alike since they can leave the handling of operational complexities to the service provider and adjust the use of these services according to actual demand.
    a. Large scale grocery chains and app-based delivery services partner with fleet operators to serve a larger number of customers.
    b. E-commerce platforms largely rely on these service providers as their expertise in large-scale logistics is needed to meet the requirements of companies such as Amazon and Flipkart.
    c. Specialized services such as refrigerated transport of medicine can be availed from dedicated service providers as needed.

3. **Driver Owned-** In which vehicles are owned and maintained by drivers themselves, who are hired on by businesses. This model mostly covers smaller vehicles, as private ownership of LCVs and delivery vans is rare. These are often gig workers with no long-term contracts with the business, affording the maximum flexibility to match demand. This is another asset light model for the business itself but requires significant investment and risk by the drivers- wear and tear, increased insurance costs, and accident risk are some of the main concerns. These drivers may also be untrained and unable to provide the kind of operational efficiency needed for delivery services. The businesses itself must provide guidance such as route planning to operate efficiently.
    a. Instead of buying their own vehicle, local stores and restaurants may hire drivers that bring their own 2-wheelers. Similarly, App-based food and grocery delivery services like Swiggy, Zomato, Dunzo, Blinkit, and Zepto rely on gig workers with their own vehicle.

Overall, deliveries and other logistics represent a major cost center for these businesses, who are always looking for ways to increase utilization and reduce operational costs. Therefore, urban freight is one of the strongest business cases for e-mobility-

Utilization	Predictability	Visibility
• Urban freight involves some of the highest utilization rates for vehicles out of all possible roles. For all vehicle segments, utilization is much higher than the threshold for cost parity with ICE vehicles. • At a 100km/day, possible fuel savings in different segments are as follows-	• Businesses servings local customers have a known and limited area of operation, making EV use simple. • Larger scale delivery operations already involve intensive route planning and logistics, which can be adapted for EVs related planning.	• Digitally enabled, silent, and clean electric vehicles are appealing to both drivers and customers. • The use of electric vehicles in such demanding roles shows off their reliability to the public. • Businesses can become brand leader in the zero-

• For 2-wheelers, INR 60,000 per year • For 3-wheelers, INR 85,000 per year • For mini trucks, INR 120,000 per year • These savings easily cover the extra up-front cost of these vehicles within 1-2 years. • Businesses can invest in higher-end models with longer lasting batteries to further reduce lifetime costs. • The additional costs such as hiring, paying, and training staff for EVs can be covered these savings as well. • The high utilization of delivery vehicles comes with an accordingly higher insurance cost, but once the safety record of such vehicles is established and visible to insurers, insurance costs will also reduce.	• Advanced telematics built into EVs, and app-based tracking allows businesses to easily monitor the performance of these vehicles and whether they are achieving high operational standards. • Within their depots and warehouses, companies also possess sufficient space to set up charging infrastructure, in addition to partnerships with charging point operators.	emission delivery space, and significantly reduce their carbon footprint. • Zero emission vehicles enhance a business' environmentally friendly image and contribute to CSR and environmental commitments.

The lesser maintenance requirements and fewer breakdowns reduce the vehicles' down time, which is an important metric for a delivery network that functions round-the-clock. The sheer number of vehicles involved in urban freight will also help establish a robust second-hand market for electric vehicles, making them easier to access for smaller businesses and even individuals.

The lingering barriers to their adoption specific to this industry are as follows-

1. Higher up-front cost remains a challenge for many companies and EV service providers to shoulder, requiring large amounts of capital investment. While their financial analysis may show EVs to be the superior option over time, they may lack the initial cash to bring them into operation.

2. Businesses concerns regarding range and reliability of these vehicles, slowing down adoption. Meanwhile, fleet owners and service providers are uncertain about receiving enough demand to achieve high utilization and related savings.

3. Lack of expertise in operation, maintenance, and software analytics related to electric vehicles. The potential of electric vehicles requires skilled staff to unlock. Currently, many EV service providers are new to the market and face a shortage of this skilled staff. They are not able to provide the levels of performance demanded by companies like Amazon and Flipkart.

4. Fragmented nature of electric vehicle service providers across the country. Companies with operations stretching across the nation generally work with large scale logistical partners who have a pan-India or pan-region presence. However, EV service providers are currently small scale and are restricted to only certain areas of operation.

Steps for Electrification

Driver and business owned models can be adapted easily for 2- and 3-wheelers, as these vehicles can easily be charged at home and do not require much parking space. The subsidies on electric 2-wheelers make them highly accessible for private ownerships, and gig-based delivery provides more

than enough utilization to generate immense savings. 3-wheelers, whether owned or leased from fleet owners can also be operated simply.

However, the true potential of electric vehicles is unlocked by proper route planning and charge scheduling. The array of built-in telematics and specialized EV fleet management software allow for excellent operational planning and accurate performance monitoring. However, this requires scale and expertise both, which are best available among specialized EV Service Providers. With charging infrastructure throughout the city mapped on government EV portals and private charging network apps, vehicles' operations can be planned across multiple shifts.

For all the above models, the aforementioned barriers need to be to overcome this sector's immense potential. Certain steps that can be taken are-

1. **Up-front cost and Access to Funds-** Regarding up-front cost, subsidies and other incentives linked to schemes like FAME II and the draft UP EV Policy (2022) are a helpful leg-up for companies and EV service providers. Awareness on the available benefits and how to apply, as well as streamlining of the application process are two helpful steps for this purpose. Financial institutions, who have been hesitant to provide loans for new technologies, need to be briefed on the proven operational benefits of electric vehicles and encouraged by the government to provide automotive loans. Publicly owned banks can take the lead by providing specialized financial support for electric vehicle purchase.

2. **Range and Reliability-** Business needs to analyze their delivery patterns and identify areas of high utilization where EVs can be first rolled out so that they can see their reliability first-hand. EV service providers need to aggressively market their capabilities and be ready to provide vehicles on a trial basis. Contracting with EV service providers should include minimum payment guarantees so that during unforeseen periods of low utilization the vehicle owners are not badly affected. However, since EVs provide maximum savings in high-utilization roles, there is an incentive for businesses to make the need for this does not arise.

3. **Lack of Skilled Staff-** The government needs to expand enrollment in EV skilling, setting up courses in technical institutes along with other capacity building exercises like workshops and apprenticeships. Alongside, EV service providers and companies running their own EVs need to invest time and money into training their drivers and unlocking the potential of their vehicles. This would include route planning and charge management software training as well. This is covered in detail in the chapter on EV Skilling.

4. **Fragmented Nature of Services-** In time, EV service providers will grow larger in scale. To accelerate this growth, businesses should form deeper partnerships with their service providers and help them grow via investments and long-term contracting. This would cultivate large service providers that are well-versed in the specific requirements of their partner companies and are able to seamlessly provide the needed level of service even while expanding to new areas. This would also enable businesses to be brand leaders in zero-emission delivery and achieve economies of scale faster.

Amazon India deploys Mahindra's electric vehicles in its delivery network

"Under the partnership, Amazon India has deployed close to hundred Mahindra Treo Zor EVs in seven major cities, the companies said in a joint statement. The cities where the electric three-wheeler, Mahindra Treo Zor have been deployed so far include Bengaluru, New Delhi, Hyderabad, Ahmedabad, Bhopal, Indore and Lucknow. Other delivery platforms using such EVs include Flipkart and Big Basket,"

Zypp Electric provides IoT enabled fully electric scooters to all from local merchants to e-commerce giants

"The company currently delivers groceries, medicines, food, e-commerce packages from point A to point B through their advanced IoT and AI-enabled scooters which are low on maintenance and high on performance. It has over 7000 electric 2-wheelers in operation"

Domino's ties up with Revolt Motors to convert petrol Bike Fleet into EVs

"Following a successful pilot, Jubilant Foodworks in 2021 procured Revolt's entire inventory of RV300 electric bikes to be customized for its use, with more to follow as production increases. According to RattanIndia Enterprises (who acquired Revolt Motors in 2022) Business Chairman, Anjali Rattan, this partnership makes sense not just environmentally, but also offer great cost savings for the company."

Investment, Savings, and Emissions Reduction

Summary as follows-

Table 21 : Investment and savings for EVs in Urban Freight

S. No.	Heading	Value	
1	Number of Electric Light Goods Vehicles (4-wheeler) expected to be on-road in Lucknow by 2030	17,500	
2	Number of Electric 3-wheeler Cargo Vehicles expected to be on-road in Lucknow by 2030	10,700	
3	Per Vehicle additional Up-front Cost for EV vs. ICE (CNG) Vehicle	Mini-trucks- INR 110,000	
		3W Cargo- INR 90,000	
4	Lifetime Operational Savings per Vehicle, at a utilization of 100 km/day	Mini-trucks- INR 1,200,000	
		3W Cargo- INR 850,000	
5	Total Additional Investment	INR 288.8 Cr.	USD 34.7 Million
6	Total Operational Savings	INR 3009.5 Cr.	USD 361.2 Million
7	**Monetary Benefits**	**INR 2720.7 Cr.**	**USD 326.5 Million**

In terms of emission savings, the calculation is as follows-

Table 22 : Emission savings for EVs in Urban Freight

S. No.	Heading	Value
1	Number of Electric 3-wheeler Cargo Vehicles expected to be on-road in Lucknow by 2030	10,700
2	Number of Electric Light Goods Vehicles (4-wheeler) expected to be on-road in Lucknow by 2030	17,500
3	Production and Maintenance related emissions (including battery production for EVs) per vehicle	ICE 3-wheeler: 2.8 tons CO_2 Equivalent
		EV 3-wheeler: 4.1 tons CO_2 Equivalent
		ICE Mini-Truck: 9.9 tons CO_2 Equivalent
		EV Mini-Truck: 11.1 tons CO_2 Equivalent
4	Fuel related emissions per vehicle	ICE 3-wheeler: 30.8 tons CO_2 Equivalent
		EV 3-wheeler: 23.7 tons CO_2 Equivalent
		ICE Mini-Truck: 79.4 tons CO_2 Equivalent
		EV Mini-Truck: 55.8 tons CO_2 Equivalent

5	Emissions savings per EV	3-wheeler: 5.8 tons CO_2 Equivalent
		Mini-Truck: 22.5 tons CO_2 Equivalent
6	**Total Emission savings**	**456 thousand tons CO_2 Equivalent**

4.8. Summary of Recommended Initiatives

Table 23: Summary of Recommended Initiatives over the short, medium, and long term

Areas of Focus	Probable Solutions	Action Timeline	Investment by 2030 and Savings
Government Fleets- Passenger 4Ws for Official Use and Patrolling (4W Sedans, Hatchbacks, and compact SUVs.)	○ Make future purchases electric, target older, less efficient vehicles for replacement. ○ Partner with charging network providers to support new EVs ○ Train staff for the operation and lifelong maintenance of electric vehicles ○ Create guidelines for EV procurement, covering technical details and available models for easier tendering	Short Term	Number of Vehicles: 60,000 Additional Expense: INR 1320 Crore or USD 158 Million Total Operational Savings: INR 2250 Crore or USD 270 Million
	○ Adoption mandate to replace ICE passenger vehicles for each department, at 10% a year. ○ Perform demand aggregation exercises across department to bring down cost of procurement ○ Install charging points on office premises and maintain a database of all such chargers to share the network across all state agencies	Medium Term	
	○ Update EV procurement guidelines as new models enter the market	Long Term	
Municipal Solid Waste Collection: Replace door-to-door collection fleet of nearly 1,500 vehicles with EVs (3W & Mini-Trucks)	○ Conduct a pilot project with a small number of EVs in one or more Zones of the city, note results and collect driver feedback	Short Term	Number of Vehicles: 1400 Additional Expense: INR 6.61 Crore or USD 0.8 Million Total Operational Savings: INR 17.67 Crore or USD 2.1 Million
	○ Conduct capacity building of officials on economics and technical details obtained through pilot, to scale up EV procurement for the whole fleet. ○ Order vehicles in bulk to reduce price post successful pilot, train workers in optimal operating methods, and install	Medium Term	

	chargers in LMC workshops and parking spaces.		
	○ As newer EV models with increased carrying capacity come out, investigate possibility their use as water sprinkler and road cleaning vehicles.	Long Term	
Promote EVs for Personal Use: 2-Wheelers	○ Promote awareness regarding fuel savings and ease of domestic charging ○ Releases guidelines on safe home charging, covering installation and fire safety	Short Term	Number of Vehicles: 258,000 Additional Expense: INR 412.8 Crore or USD 49.5 Million Total Operational Savings: 6,708 Core or USD 780 Million
	○ Promote existing concessionary EV loans from public banks such as SBI and Union Bank, and encourage more such schemes ○ Provide interest free motor vehicle advances to government employees, or advantageous EMIs through bulk purchase	Medium Term	
Corporate Employee Transport (4W cabs)	○ Promote and guide EV entrepreneurship through Invest UP ○ Develop sufficient skilling programs and courses to meet rising demand of employees ○ Provide reserved parking for EVs in public parking spaces, exemptions from toll tax and parking fees to improve ease of use	Short Term	Number of Vehicles: 25,500 Additional Expense: INR 688.5 Crore or USD 82.6 Million Total Operational Savings: INR 1224 Crore or USD 146.9 Million
	○ Increase policy limit on number of vehicles fleet operators can avail subsidy on, as EVs operate better with scale	Medium Term	
	○ Begin limiting use of CNG taxis once the EV transport services market matures	Long Term	
Urban Freight (2W, 3W Cargo, Mini Trucks)	○ Promote and guide EV entrepreneurs in the logistics field	Short Term	Number of Vehicles: 28,200

	○ Increase limit on number of vehicles a business can avail subsidy on ○ Prioritize installation of charging infrastructure in high use areas such as Transport Nagar and other hubs. This would be conditional on companies' commitment towards EV use	Medium Term	Additional Expense: INR 288.8 Crore or USD 34.7 Million Total Operational Savings: INR 3009.5 Crore or USD 361.2 Million
	○ Develop fast-charging infrastructure along highways to enable future models of EV trucks to operate intercity freight.	Long Term	

05

Planning for EV Charging Infrastructure

5. Planning for EV Charging Infrastructure

5.1. Introduction

An accessible and robust network of electric vehicle (EV) charging infrastructure is an essential pre-requisite for our ambitious transition to clean mobility. A holistic and well-developed EV charging infrastructure network includes charging points at residential buildings, office locations, and public places. Local and state governments have an important role to play in planning and implementation of public charging infrastructure, as well as enabling the development of charging infrastructure in residential, office and commercial buildings.

Uttar Pradesh Electric Vehicle Manufacturing and Mobility Policy 2022 [8] proposes a range of support incentives and policies to facilitate charging infrastructure implementation. The state's Infrastructure and Industrial Development Department (IIDD) is the assigned state nodal agency (SNA) for the implementation of its EV policy.

Lucknow's charging infrastructure network is at a nascent stage, with about 11 public charging points currently operating in the city. This chapter provides an overview of the considerations for planning and implementation of a robust EV charging infrastructure network in the city.

5.2. Policy Initiatives

As part of the Uttar Pradesh EV Policy 2022, the state government aims to catalyze the development of public and private charging infrastructure.

The policy aims to attract investments for setting up at least 20 charging stations and five swapping stations per district during the policy period (5 years). Besides providing land at subsidized rates, the following incentives will be provided by the government:

Capital subsidy to service providers

- Charging service providers shall be provided with a one-time 20% capital subsidy on eligible fixed capital investment, capped at Rs. 10 lakh/unit for the first 2,000 charging stations.
- Swapping service providers shall be provided with a one-time 20% capital subsidy on eligible fixed capital investment, up to Rs. 5 lakh/unit for the first 1,000 swapping stations in the state.

The incentive shall be provided after the commencement of the commercial operation of the charging/swapping stations. Any individual investor/enterprise/company/ institution can be provided the subsidy for installing up to 100 charging/swapping stations. Subsidies shall be awarded on a first-come-first-serve basis to projects with a sanction letter for incentives issued by the state government.

Additional measures

Besides the financial incentives, Uttar Pradesh aims to promote development of charging infrastructure as a commercially viable business venture in the state. To this end, the government will-

- Promote creation of charging/swapping infrastructure in a grid of 3km X 3km in cities and urban conglomerates as per the guidelines of Ministry of Housing & Urban Affairs.

Development of charging infrastructure shall be promoted every 25kms along expressways/highways.

- Promote creation of charging/swapping facilities in public parking spaces, metro stations, bus depots/terminals, petrol pumps, government and corporate buildings, educational and health institutes, shopping malls and other commercial places, group housing societies and Residents Welfare Associations (RWAs), Gram Sabha land, etc. The State Urban Development Department, Transport Department, Housing Department and Panchayati Raj Department shall facilitate the identification of such locations and development of charging/swapping facilities.
- Facilitate land availability to service providers for setting up charging facilities in the state.
    - Land on lease shall be provided to government entities for 10 years with a revenue sharing model @INR 1/kWh as per the Ministry of Power (MoP) guidelines. Lease period, revenue sharing rate and other prescribed parameters shall be updated from time to time as per MoP guidelines.
    - Land on lease shall be provided to private entities for 10 years with a revenue sharing model @INR 1/kWh. Selection will be through a tender process (managed by respective local body/government agency) based on the bidding parameters of minimum service charges, so that the consumers may avail of charging at low costs.
- The urban local bodies shall take up parking policy reforms in cities for developing public charging/swapping facilities in such spaces. In the short term, local authorities may identify spaces for reserved EV charging in public parking.
- Uttar Pradesh Electricity Regulatory Commission (UPERC) has already notified a special tariff category for EV charging. The state government shall regularly coordinate with UPERC for rationalizing the EV charging tariff rate from time to time.
- Distribution Companies (DISCOMs) shall ensure fast-track electricity connections to EV battery charging/ swapping service providers and implement the EV tariff established by State Electricity Regulatory Commissions (SERC) DISCOMS shall also ensure that these facilities operate properly, prevent improper use of EV connections, manage the distribution network, and undertake grid upgrades. In this context, the guidelines issued by GoI/ NITI Aayog from time to time shall be followed.
- The state government shall allow open access at charging/swapping stations or kiosks with contract cumulative demand of at least 1 MW.
- The state government shall establish a working group to fast track the development of charging infrastructure under Urban Development Department with representatives from Housing Department, DISCOMs, chief town and country planner, Transport and Industry Departments, among others. The working group shall ensure smooth implementation of the model byelaws and regulate the strategy and implementation of charging/swapping infrastructure development.

Governance Mechanisms

- Invest UP (the investment promotion and facilitation agency of the state of UP) shall provide a single platform for facilitation and ensure inter-departmental coordination for processing applications for incentives and necessary approvals and clearances. It will also work closely with the working group to report issues and share developments. Invest UP shall also coordinate with departments for regularly monitoring and updating status of charging/swapping stations. It will also facilitate dashboarding of the information on Bureau of Energy Efficiency (BEE) portal for charging facilities.

5.3. Initiatives Undertaken for EV Charging

The Government of Uttar Pradesh, with support from the Government of India, has already taken several steps to promote charging infrastructure development. Some of the key measures taken towards charging infrastructure development are highlighted below.

Charging networks in Lucknow

There are currently about 11 EV charging points being operated by private operators in Lucknow, with additional charging points being set up by MG Motor India, Tata Power, and Indian Oil Corporation. Additionally, 37 charging stations have been sanctioned under Faster Adoption and Manufacturing of

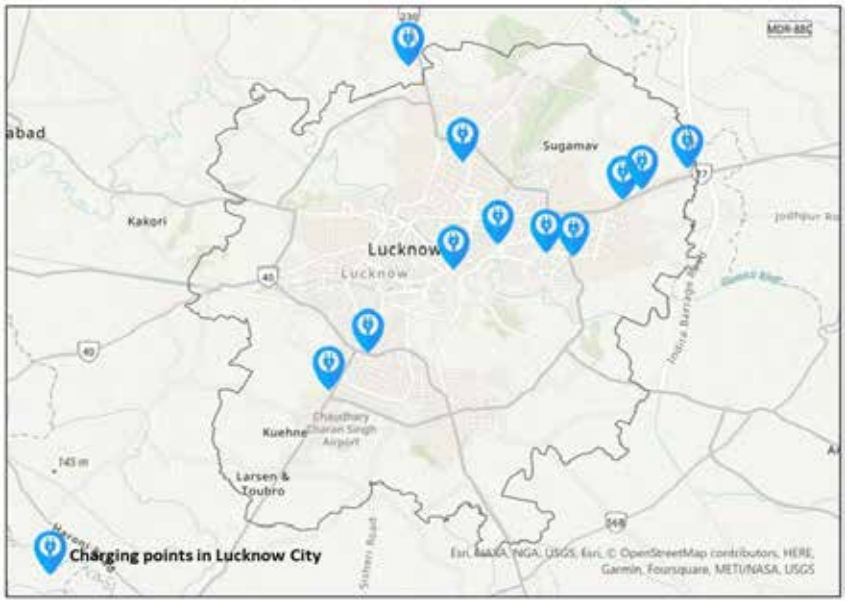
Electric and Hybrid Vehicles in India-II (FAME-II), including 10 slow and 27 fast charging stations. Rajasthan Electronics and Instruments Ltd. (REIL) has been selected to set up these charging stations, for which land will be provided by the local authorities. Another 40 charging stations have been sanctioned for the Agra-Lucknow Expressway under highway charging infrastructure allocations under FAME-II.

Table 24: List of charging points with type

S. No.	Charging station	Charger type
1.	IOCL Indra Auto	CCS/SAE, CHAdeMO[9]
2.	Taj Mahal Lucknow Wall Charger	Wall (BS1363)
3.	TML SRM Motors-Tata FC (30kw)	CCS/SAE
4.	One Awadh Centre-Tata Power (25kw)	CCS/SAE, Type 2, CHAdeMO
5.	SAS Hyundai (7.2kw)	Type 2
6.	Tata Motors Puneet Workshop (25kw)	CCS/SAE
7.	MG Motors - Tata Power (50kw)	CCS/SAE
8.	Speed Motorwagen	CCS/SAE
9.	Novotel Hotel Gomti Nagar Tata Power FC	CCS/SAE, Type 2
10.	Revanta Wall Charger	Wall (BS1363)
11.	goEgo Garmenti 4 Wall Charger	Wall (BS1363)

Source: Plug share website[10]

Figure 12 : Location of charging points in Lucknow city



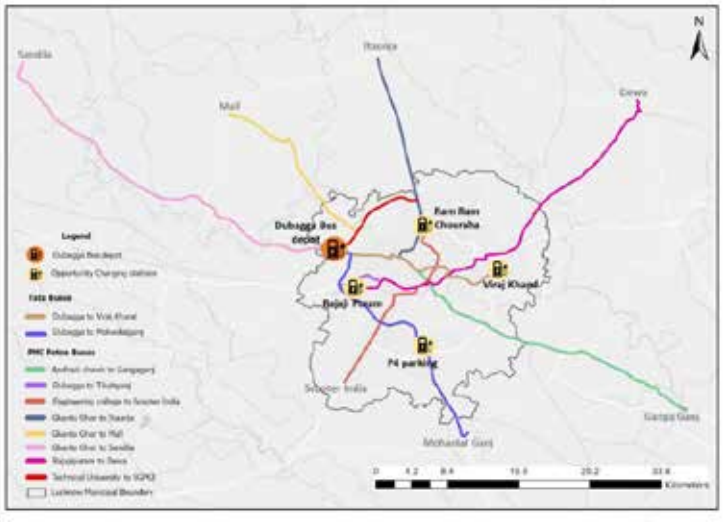
(Source : https://www.plugshare.com/)

E-bus charging network

Lucknow City Transport Service Ltd (LCTSL), a special purpose vehicle set up under the Directorate of Urban Transport, operates e-buses in the city. Under FAME-I and FAME-II, Lucknow purchased 140 e-buses which operate from Dubagga bus depot on ten routes.

[9] Society of Automotive Engineers (SAE) certified Combined Charging System (CCS) and CHArge de MOve (CHAdeMO), name for a DC charging standard.
[10] https://www.plugshare.com/

Figure 13: E-bus routes and charging stations in Lucknow



(Source: Dubagga Depot, LCTSL)

Under FAME-I, 40 e-buses (TATA e-buses with outright purchase) have been operational since 2018. Lucknow City Transport Service is responsible for the operation and maintenance of buses and charging infrastructure set up under FAME-I. There are 12 EV chargers (120 kW DC chargers) set up at the depot which are used for both overnight and opportunity charging.

Under FAME-II, 100 e-buses (PMI Foton e-buses with wet lease purchase) were procured, of which 95 have been operational since 2021. PMI Foton is responsible for their operation and maintenance. There are eight chargers (180 kW DC chargers) for overnight charging at the depot and opportunity charging has been set up at four locations (see Figure 2).

The number and types of e-bus chargers in Lucknow are shown in the table below.

Table 25: Number and types of e-bus chargers in Lucknow

	Locations	Charger Capacity	No. Of Chargers
Overnight Charging	Dubagga depot	120 kW	12
		180 kW	8
Opportunity Charging	Rajaji Puram	180 kW	2
	Ram Ram Chouraha	180 kW	2
	P4 Parking	180 kW	3
	Viraj Khand	180 kW	4

(Source: Dubagga Bus Depot, LCTSL)

Amended building byelaws

In 2019, the Ministry of Housing and Urban Affairs (MoHUA) amended its Model Building Byelaws to include an additional section on EV charging infrastructure, which covers independent residences as well as other residential and commercial buildings. In addition, the MoP charging infrastructure guidelines provide minimum limits for the number of public charging stations to be provided in urban areas and along highways.

The Uttar Pradesh Expressways Industrial Development Authority (UPEIDA) adopted the suggested building byelaw amendments by MoHUA and public charging provision targets by MoP through a separate chapter on provision of EV charging infrastructure in the Land Development & Building Regulations 2021.[11]

According to the UPEIDA Land Development & Building Regulations 2021:

[11] UPEIDA Land and Building Regulation 2021

- 20% of parking spaces in upcoming big housing and commercial projects must be equipped with EV charging.
- At least one public charging station should be available in a grid of 3km x 3km
- One public charging station must be set up every 25kms on both sides of highways/roads.

5.4. Planning for Public Charging Infrastructure

Multiple state and local government bodies are responsible for the successful rollout of public charging infrastructure. At the local level, urban local bodies (ULBs) such as municipal corporations play an important role in the planning and implementation of EV charging infrastructure. They are responsible, alongside Urban Development Authorities (UDAs), for establishing public charging rollout plans, enforcing building byelaws, providing access to public land parcels for setting up EV charging, managing public-private partnerships for charging infrastructure implementation, and integrating EV charging in planning and parking policies.

Lucknow Nagar Nigam, with support from the state nodal department, will establish the public charging rollout plan for the city. The first step in planning an accessible and safe public charging network in Lucknow is to assess the charging infrastructure requirement. This is followed by charging infrastructure location planning, using a geospatial analysis approach for ensuring a sufficient distribution and density of public chargers across different parts of the city. Finally, site selection and planning guidelines help identify appropriate sites in each location and minimize adverse impacts on traffic.

Number and Type of Public Chargers Required

By 2025, more than 94,489 number of EVs are expected to be plying on the roads of Lucknow, rising to 4,12,118 EVs by 2030. The public charging infrastructure network for the city must ensure that an adequate number of compatible chargers are available on the roads.

Figure 14: Forecasted EV sales- 2025 and 2030

A demand-based approach is used to estimate the number and types of public chargers required in Lucknow on a year-on-year basis, which are then established as annual targets for public charging infrastructure implementation. Public charging estimation is based on EV penetration rates, EV battery capacities, number of electric kilometers driven and assumed public charger utilization rates for different vehicle segments.

Steps for public charger estimation:

1. Considering EV penetration rates for different vehicle segments and target penetration, the number of EVs on road by 2025 and 2030 is estimated.
2. The daily kilometers driven by both private and commercial segment EVs, and the current and future battery capacities for e-2W, e-3W and e-4Ws are considered.
3. The energy consumption per km is calculated and a Y-o-Y decrease in energy consumption levels is considered.

4. The daily energy needs for charging EVs is calculated and the share of charging to be fulfilled through public charging infrastructure is assigned.
5. Considering a Y-o-Y charger utilization rate and maximum power drawn by an EV (based on battery capacity and C-rate) , the power delivered by chargers per day is estimated.
6. From steps 4 and 5, the cumulative number of chargers needed to support charging needs of EVs in the city is calculated.

The detailed methology is provided in Appendix 3. For further information, refer to the Handbook of Electric Vehicle Charging Infrastructure Implementation by NITI Aayog, MoP, Department of Science and Technology (DST) and WRI India[12].

Based on this methodology, it is estimated that a total number of 4,039 public chargers will be required by 2025 to serve the public charging needs of EVs in Lucknow. Of these, 3.3 kW chargers are expected to comprise majority of the public charging requirement, serving e-2Ws, e-3Ws and e-rickshaws. This is followed by 15kW chargers for commercial e-4Ws, and a small number of 50kW chargers for private e-4Ws. Table 6 provides the year-on-year requirements for public charging up to 2025 in the city.

	2021	2022	2023	2024	2025
Number of public chargers needed	1656	2861	3200	3809	4039
3.3kW chargers	1634	2787	3073	3604	3768
15kW chargers	18	63	111	178	237
50kW chargers	3	11	15	26	34
No. of EVs on road	7891	19526	36843	61543	94489

Table 26: Public charger number projections and total EVs on road in 2025

In the immediate future i.e., by 2023, 3,200 chargers need to be deployed in Lucknow city. Under FAME II, 37-charging stations will be installed; with the capital expenditure requirement for the fast chargers being largely offset through FAME-II funding. For the remaining requirements, the urban local body can set up public charging stations on identified accessible lands through a tendering process or incentivize private operators to set up charging stations on privately-owned sites.

Public charging requirements by 2030: Almost 7,000 public charging points are estimated to be required by 2030 – consisting of 5,513 3.3kW chargers, 1,281 15kW chargers and 115 50kW chargers. However, the number and types of required chargers may vary significantly, depending on changes in EV models and charger specifications. Hence, the public charger requirement for 2030 will need to be reviewed later, based on the emerging changes in the dynamic EV market.

Potential Investment Required to Set up Chargers

The charging infrastrucuture deployment in Lucknow will require cumulative investment of INR 153 crore.

Table 27: Estimated Cost of EV Charging Infrastructure in India

No.	Type of Charger	Number of Chargers Required Until 2030 in Lucknow	Unit Price (INR)	Cost
1.	3.3kW	5513	100,500	INR 55.4 Crore or USD 6.65 Million
2.	15kW	1281	323,700	INR 41.5 Crore or USD 5 million
3.	50kW	115	3,029,450	INR 35 Crore or USD 4.2 Million

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

4.	50kW along highway	71	3,029,450	INR 22 Crore or USD 2.6 Million

Note: In order to calculate the above figures, the following aspects were considered:

1. The number of units of chargers required until 2030 is based on the preceding analysis.
2. The cost of an average EV charging unit takes into account the capital expenditure required for setting up an AC charging equipment compliant with Bharat EV Charger standards.[13]
3. Cost of EV and EV charging units is expected to reduce considerably in the near future due to market maturity and technological advancements.

The cost of an individual unit of each type of charger is calculated as follows-

Table 28: Estimated Cost of EV Charging Infrastructure in India

Cost of chargers	AC-001 (in INR)	DC-001 (in INR)	C-122 (in INR)
EVSE unit	50000	175000	1400000
Civil Work	0	0	0
Installation Cost	1000	8500	50000
Transportation Cost	1200	1750	10000
Earthing	0	10000	0
AMC (4%)	2000	7000	56000
Total EVSE Cost	**54200**	**202250**	**1516000**
Meter Box + Meter	5000	5000	10000
Canopy and Barricading Cost	0	45000	45000
Cost of CMS	0	0	0
Transformer + Substation cost	0	0	1000000
Charger Cost	**59200**	**252250**	**2571000**
Contingency charges	0	0	0
GST (subject to change)	0	0	0
PMC charges (3%)	1760	7550	77150
Service Connection charges (Subject to change based on location)	24000	40000	280000
Security Deposit Charges (Refundable)	54000	90000	630000
Annual charges for Security Deposit	540	900	6300
One-time Service Line Cum Development (SLD) charges (Subject to change based on location)	9000	13000	25000
Processing charges	6000	10000	70000
Other costs	0	0	0
Total Cost per Unit	**100,500**	**323,700**	**3,029,450**

Introducing Battery Swapping Infrastructure

Battery swapping infrastructure will allow EV owners to exchange discharged batteries with charged ones at various swapping stations. To create a reliable and standardized battery swapping ecosystem, NITI Aayog released the draft battery swapping policy[14] in April 2022 for e-2Ws and e-3Ws. Battery swapping is still nascent in India but has been gaining ground rapidly, especially for commercial and fleet operations. Presently, there are only a few battery swapping service providers that have been engaging with original equipment manufacturers (OEMs), individual/commercial users, and other relevant stakeholders, to develop an ecosystem of swapping services with compatible components (batteries, vehicles, chargers, etc.).

13 India Smart Grid Forum, 2018

14 Draft Battery swapping policy 2022

Number of battery swapping stations required:

Considering 10% of e-2Ws and 20% of e-3Ws will have swappable batteries by 2025, the number of EVs with swappable batteries are expected to be nearly 3410 in the year 2025. Swappable battery stations must ensure an adequate number and type of batteries for e-2w and e-3w segments. 2 kWh batteries for e-2W and 4kWh batteries for e-3W are considered

The number of swapping stations for Lucknow is estimated considering the demand and available swappable model specifications in the market. The estimate of swappable batteries and swapping stations are based on EV battery capacities, number of electric kilometers driven, number of battery swaps per day. A total of 170 swapping stations will be required by 2025 which would require 4,844 2kW batteries for e-2Ws and 271 4kW batteries for e-3Ws. A swap station consists of one or more charging kiosks, each kiosk can have about 12 to 15 batteries.[15]

The detailed methology is provided in Appendix 4.

EV Charging for Municipal Fleets

Lucknow Nagar Nigam plans to electrify its municipal fleet, with a focus on solid waste collection vehicles. It is expected that approximately 10-20 electric waste collection vehicles will be piloted in the city by 2023. The land for setting up charging infrastructure for the municipal fleet has been identified at the municipal workshop area (shown in Figure 4). The number and type of chargers required will depend on the vehicle specifications and number of vehicles acquired. Chargers can be acquired along with vehicles from the supplier, who will also be responsible for the maintenance of the vehicle fleet and chargers.

Figure 15: Land for charging infrastructure of municipal vehicle fleets

Source: Lucknow Nagar Nigam

Expanding the e-Bus Charging Network

Lucknow is expected to continue expanding its e-bus expansion fleet in the future. The city's four opportunity charging stations are located strategically for easy accessibility. Therefore, for expansion or addition of e-buses in the city, it is expected that existing depot charging stations and opportunity charging stations with additional number of chargers will be sufficient in the near-term. For longer routes beyond the city limits, additional opportunity charging stations will be required. These could be located at regional bus stations through which e-bus routes pass, if land is available. Alternately, opportunity chargers may also be installed along highways, at rest stops, adjacent to fuel stations or

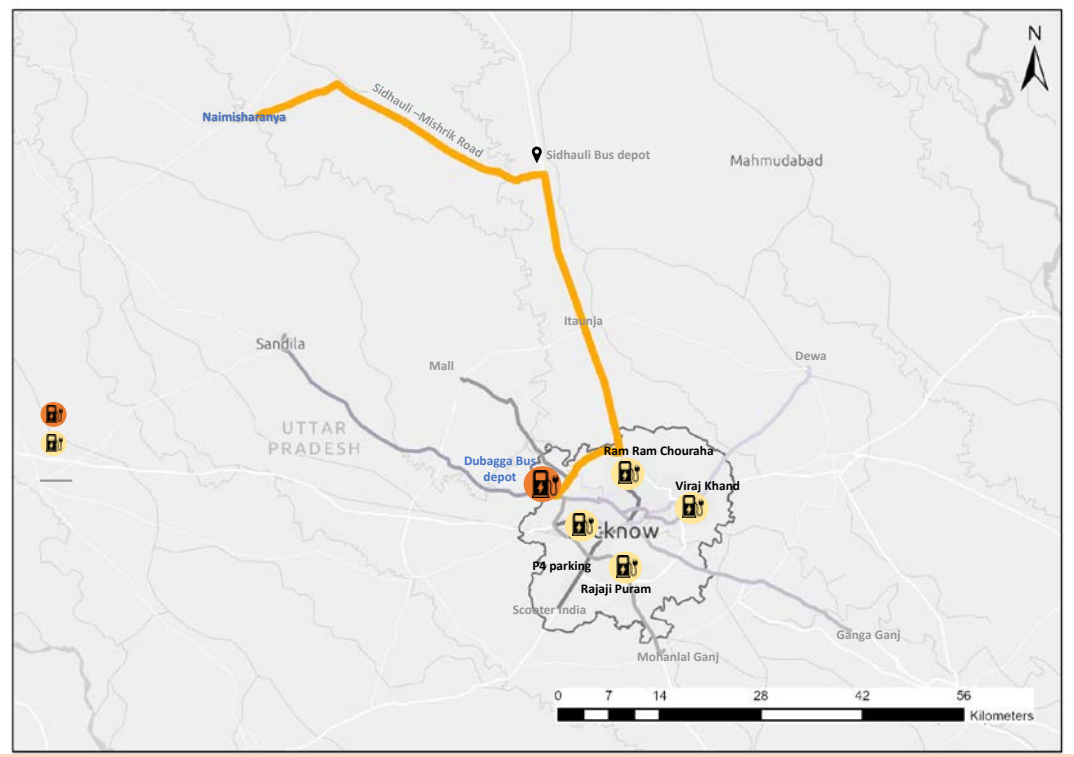
[15] https://www.niti.gov.in/sites/default/files/2022-05/Battery_swapping_report_09052022.pdf

on available land parcels at the peripheries of existing settlements- sites with access to electrical grid infrastructure, which can be strengthened as required.

Highway Charging Infrastructure Requirements

Example: Additional Charging Requirements for e-Bus Route Electrification

Electrification of longer bus routes by the LCTSL, such as the Lucknow-Naimisharanya route with a route length of about 91 km, will require additional charging infrastructure for opportunity charging. For this route, buses could depart from the Dubagga depot and use the opportunity charging station at Ram Ram Chouraha. Considering the longer route length, additional opportunity charging will be required which could be located at the Sidhauli bus depot en route. Available land parcels near rest stops and fuel stations on the Sidhauli- Misrikh road are other options for locating the charging infrastructure for opportunity charging.



Highway charging infrastructure is another important component of the EV charging infrastructure network to facilitate inter-city, personal, shared, and freight vehicle movements. Under FAME-II, 40 EV charging stations have been sanctioned along the Agra-Lucknow Expressway.

Additionally, Lucknow is well connected to other major cities like Kanpur, Prayagraj, Varanasi, Ayodhya, Gorakhpur, Sitapur, and Azamgarh through expressways and national highways. As per the UP EV Policy 2022, at least one charging station is to be set up every 25km on both sides of highways/roads.

The estimated number of chargers required along key highways connecting Lucknow and other cities are given in Table 7.

Table 29: Number of chargers required along highways

Name of Highways / Expressways	Connecting city	Length in km	No. of charging stations required
Purvanchal expressway	Lucknow- Azamgarh	240	19

NH 30	Lucknow-Sitapur-Bareilly	241	19
NH 27	Lucknow- Ayodhya	121	10
NH 30	Lucknow- Prayagraj	192	16
NH 27	Lucknow- Kanpur	88	7

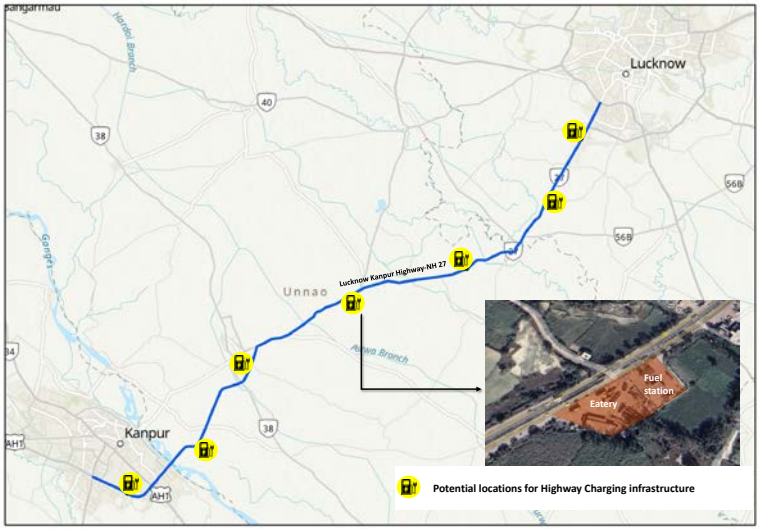
Considering the higher proportion of e-4W on the highways, these charging stations will mainly comprise of 50 to 100 kW DC chargers. As more cars enter the EV market with higher battery specifications, 150kW chargers can also be considered. A smaller number of 3.3 kW and 7kW charger can be accommodated at the charging stations for serving the minimal share of e-2Ws and e-3Ws plying on the highways.

Additionally, fast chargers for intercity e-buses can also be part of highway charging infrastructure with 180 kW DC chargers. Installation of EV charging stations along expressways and national highways will significantly aid the EV transition of intercity and freight vehicles.

Highway charging infrastructure can be integrated with petrol pumps, highway food plazas, rest stops or other available land parcels along highways with adequate parking space and access to electricity with potential for grid strengthening as required.

Example: Charging Infrastructure Planning on Lucknow- Kanpur Highway

The Lucknow-Kanpur highway, which is about 88 km long, is one of the busiest inter-city roadways in Uttar Pradesh. Connecting two major cities in U.P, it is important to ensure the availability of charging infrastructure along this critical highway. The below map shows the potential locations for highway charging infrastructure along Lucknow- Kanpur Highway. These locations include petrol pumps, CNG pumps, highway dhabas/ eateries etc. identified at 25km distance along the highway on both sides.

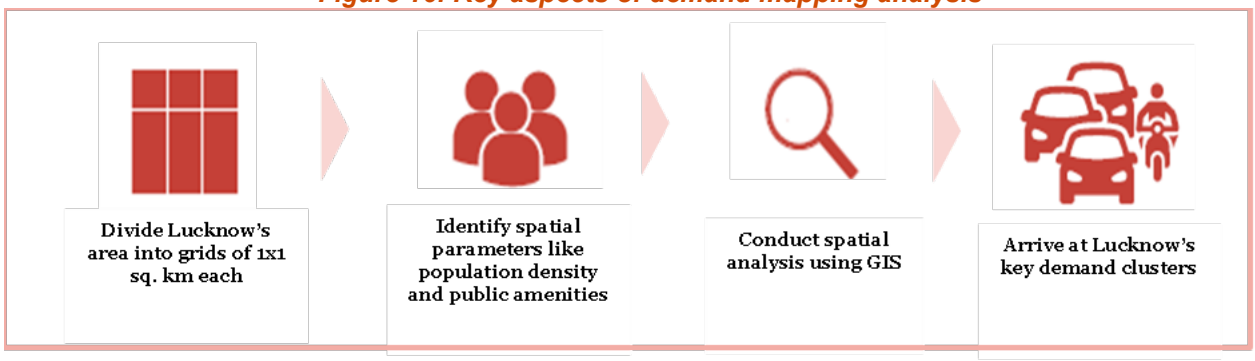


5.5. Location Planning of Public Charging Networks

For public charging, it is necessary to plan a charging network that is conveniently located and well-distributed across the city. As local authorities look for available land parcels for EV charging stations, they must also compare the relative accessibility and charging demand at each location to select the best sites. Therefore, a spatial analysis is critical for site selection of capital-intensive EV charging stations to ensure availability and effective utilization.

Spatial planning for public charging infrastructure is based mainly on considerations of accessibility and potential EV charging demand. Geospatial analysis is undertaken using Geographic Information System (GIS) software to estimate relative levels of public EV charging demand by mapping and assessing the impact of various spatial parameters. This is then used to distribute public charging infrastructure in different areas, in proportion to the charging demand.

Figure 16: Key aspects of demand mapping analysis



For the geospatial analysis, the city is divided into grids of one square kilometer. Spatialized parameters are mapped to these grids, including population density, density of commercial establishments, locations of trip generators such as educational institutes, shopping malls, parks and hospitals. Existing transport infrastructure such as road networks, fuel stations and transit stations are also mapped and the parameters that indicate potential charging demand are identified and collated spatially. Weightages are assigned to each parameter based on their impact on potential charging demand, with charging demand scores calculated for each grid cell. The grid cell values are then used to distribute the total number of public chargers required for the city.

A detailed methodology of the spatial analysis is provided in Appendix 5. For further information, refer to the Handbook of Electric Vehicle Charging Infrastructure Implementation[16].

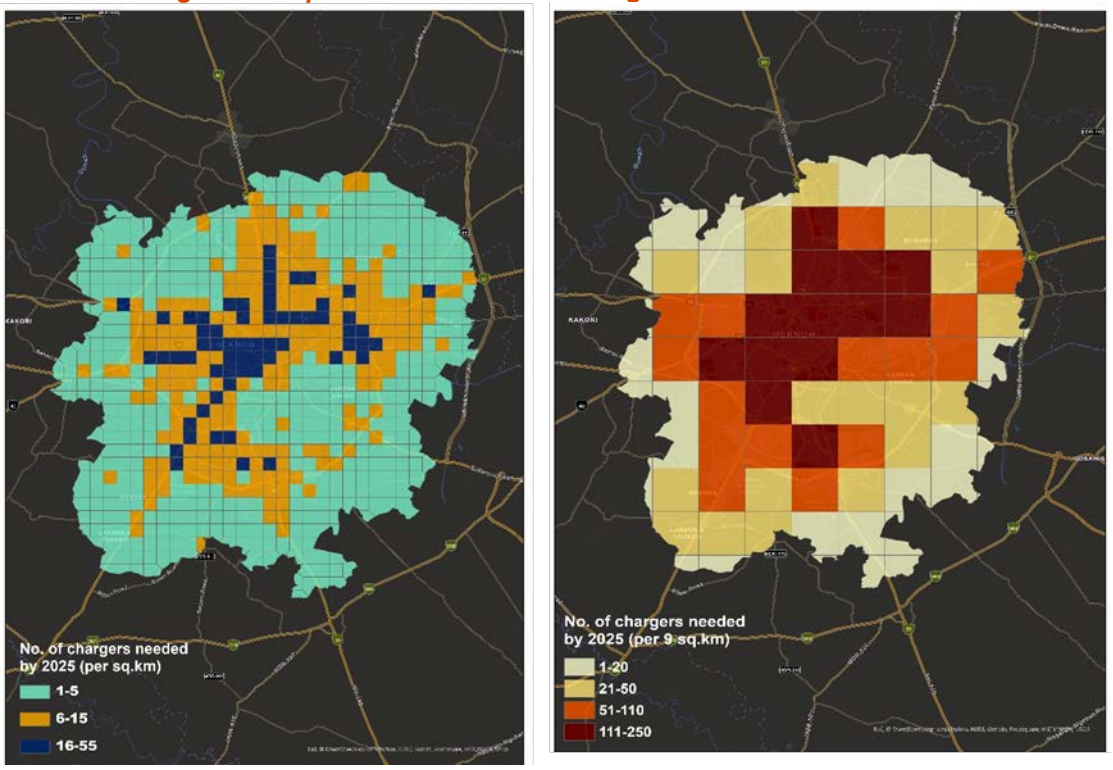
While the spatial analysis is only an indicative tool to be used in the absence of charging station utilization data, it can help cities with decision making on how to distribute the first set of public chargers. As the EV ecosystem develops, more robust data parameters such as the density of EV registrations, EV fleet patterns and utilization rates of public charging infrastructure can be used to determine additional demand and allocate more chargers.

Spatial distribution of public chargers:

Based on the charging demand for each cell, the required number of charging points in a cell as a proportionate share of the total number of public charging points for Lucknow city is calculated and represented spatially in grids of 1 sq.km and 9 sq.km as shown in the maps below.

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

Figure 17: Spatial distribution of chargers based on estimated demand in 2025



In one square kilometer, the charging requirement in Lucknow varies from 1 to 55 charging points, with a maximum of 15-55 chargers per grid. When calculated as a 3*3km grid (9 sq.km.), in line with the MoP guidelines, the charging requirement varies from 1 to 250 chargers, with a maximum of 111-250 chargers per grid.

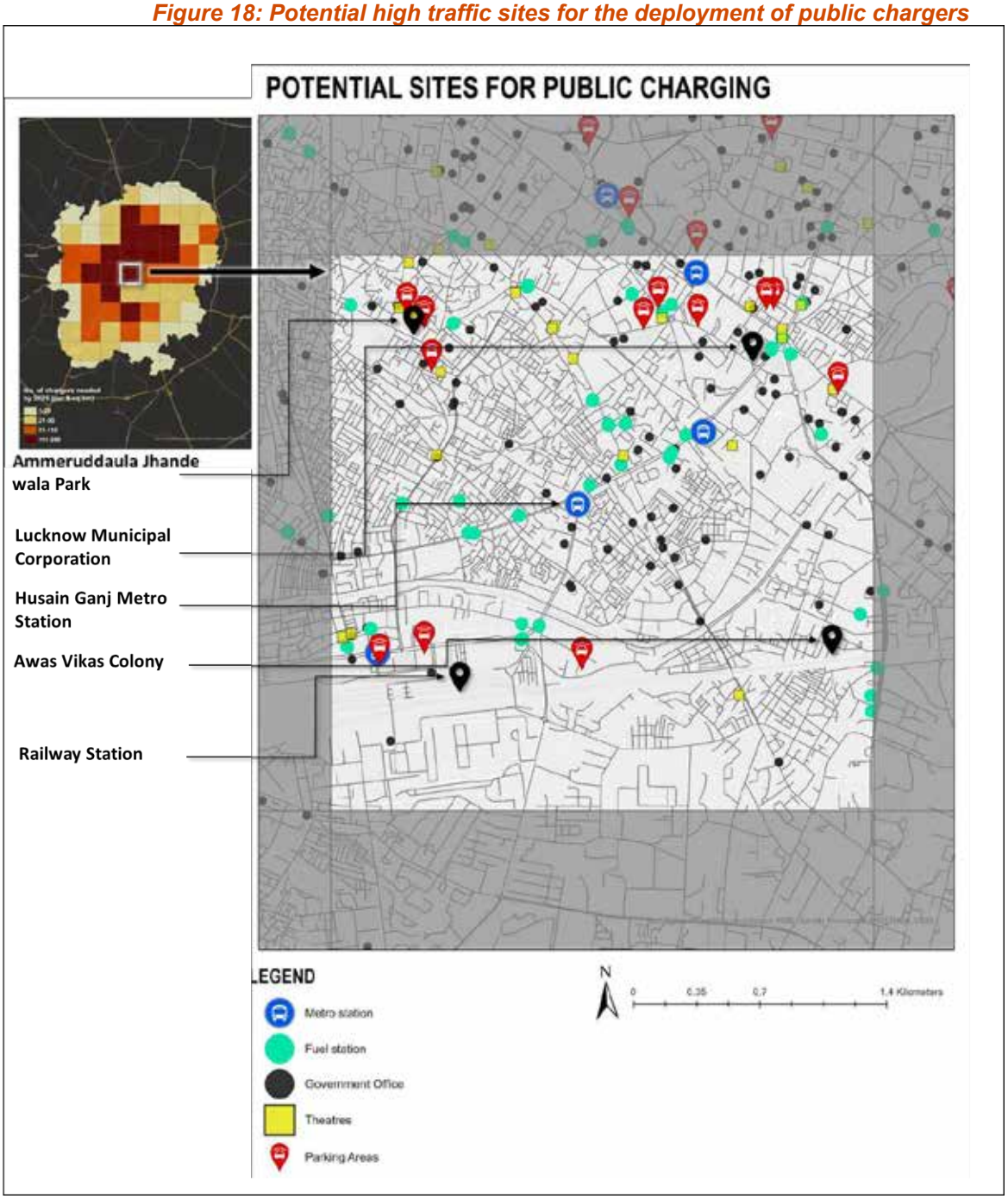
Site Selection and Planning for Public Charging

Once the spatial distribution of EV charging infrastructure across Lucknow is determined, it is important to undertake a robust site selection and planning process. Sites for installing EV charging need to be located in such a way that it is accessible and has low impact on traffic circulation. The sites should have adequate space and availability of power to set up EV charging infrastructure. Site planning needs to account for circulation and safety requirements to ensure ease of vehicular movement and adherence to safety norms.

Site Selection for Charging Infrastructure Installation

Site selection involves identifying and selecting appropriate sites for installing charging infrastructure within a given area. Depending on the number and size of available sites, public charging infrastructure within an area may be concentrated at a few big charging stations or may be distributed across multiple smaller charging stations. The figure below shows potential locations for setting up public charging in Nazarbagh area in central Lucknow, one of the areas with highest charging demand across the city. Identified locations include municipal parking areas, fuel stations, government offices, movie theatres, and transit stations, which are typically sites that are government-owned or sites with access to ample parking.

Figure 18: Potential high traffic sites for the deployment of public chargers



From the potential sites identified, it is important to select sites that can maximize accessibility and utility, while minimizing costs of installation. A local authority or charge point operator (CPO) can use the following steps for site selection for setting up public charging stations.[17]

1) Carry out a preliminary site feasibility check.

Potential sites identified for setting up public charging infrastructure in a given area must be assessed in terms of their accessibility. Ease of access is critical for installing public chargers for EV users.

Identified sites should be assessed on whether they meet the following conditions:

i. Is the site located on a major road, and is it clearly visible from the road?

[17] NRDC Report on: How to Siting EV Charging Stations In Indian Cities

ii. Are there well-defined ingress and egress points that allow vehicles to enter and exit the site without hampering traffic
iii. Is the site open to all EV users? Is it accessible 24 hours a day?
iv. Is the site area level with clear space and minimum obstructions?
v. Is there an electricity grid connection available at or near the site?

These parameters help shortlist sites that are accessible and easy to use as locations for EV charging stations.

2) Determine the use cases and charging infrastructure requirements

Once appropriate sites are shortlisted, they can be categorized for different use cases. Consider a site for whether it is 1) along a travel corridor; 2) in the city/urban center, or on the outskirts; 3) in a commercial area or a residential area; or 4) a major trip origin or destination point. Then, assess the site surroundings to understand vehicle counts for different segments (two-wheelers, three-wheelers, cars, others) and the parking patterns in the area.

Based on these parameters, the types of chargers required at a given site may be determined. For sites which see a predominance of four-wheelers and high-powered vehicles, with short parking times, DC fast chargers may be provided for opportunity charging. Alternately, for sites with mixed traffic and longer parking times (such as at metro stations or shopping malls), a mix of AC slow chargers and DC fast chargers may be used.

Number of chargers to be installed can be determined based on the available space on site and an assessment of potential demand through surveys.

3) Determine the feasibility of power distribution (including the lowest cost option for energizing the site).

Accessible, reliable, and affordable electricity is a prerequisite for adequate charging infrastructure provision. The charging requirement (type and number of chargers) at each site determines what kind of electricity load and connection are required to power the site. To determine its feasibility, following parameters should be considered.

- Determine the power load availability at the nearest distributional transformer.
- Measure the distance from site to pole, from site to transformer to pole, and from pole to pole.
- Measure the cable length distance from the nearest transformer.
- Estimate the cost of laying power cable from transformer to charger point.
- Estimate the cost of upstream power infrastructure at various levels of electricity load (160kVA, 100 kVA, 63 kVA, 25 kVA).

4) Review for safety and threats

The site should then be assessed from an environmental and user safety perspective. Site safety considerations for the end user should also be considered.

- Confirm if the legal owner of the property possesses the right to allow you to build on it.
- Note the security of the location. Are there lights, security cameras? Is there anything nearby such as a wall or bushes that an assailant could hide behind? Obtain the crime report for the property.
- Is there a permanent security guard in the location/near the charging equipment?

5) Develop a detailed site plan

Site layout planning is an important component in setting up public EV charging infrastructure. Depending on the type of parking area and the number and type of EV charge points, wall or pedestal mounted charging equipment can be considered. For instance, normal power chargers can be wall mounted, which is a less expensive and more space efficient option. For high-powered chargers in public off-street parking lots having space constraints, pedestal-mounted charging equipment permits better maneuverability and can host multiple charging points in a single charge point.

For site planning of EV charging infrastructure, the following planning guidelines need to be considered[18]:

- Public charging stations should be easily accessible and clearly visible from the site entrance.
- Select charging locations that minimize civil work and wiring requirements.
- Select locations that follow safety provisions for EV charging as defined by the CEA.
- Proper signages and markings must be present at parking spaces reserved for EV charging.
- Provide ample space for vehicles to enter and exit the charging bays.

Indicative station layout plans both for off and on-street public parking are depicted in Figures 8 and 9.

Figure 19: Off street perpendicular parking with wall mounted sockets

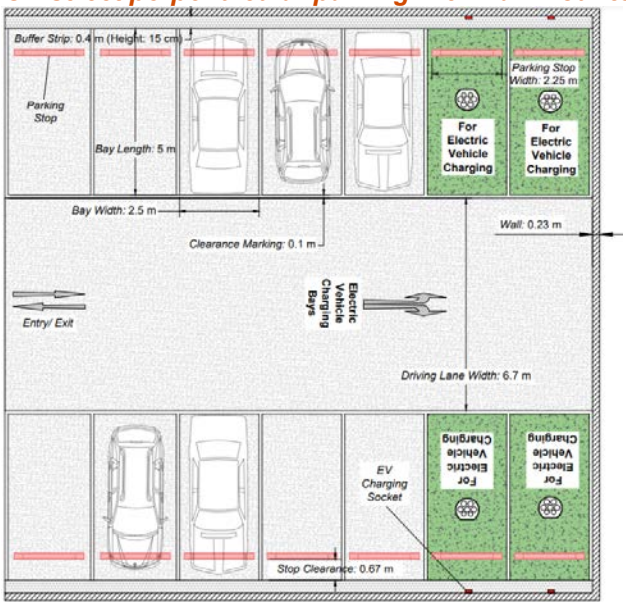
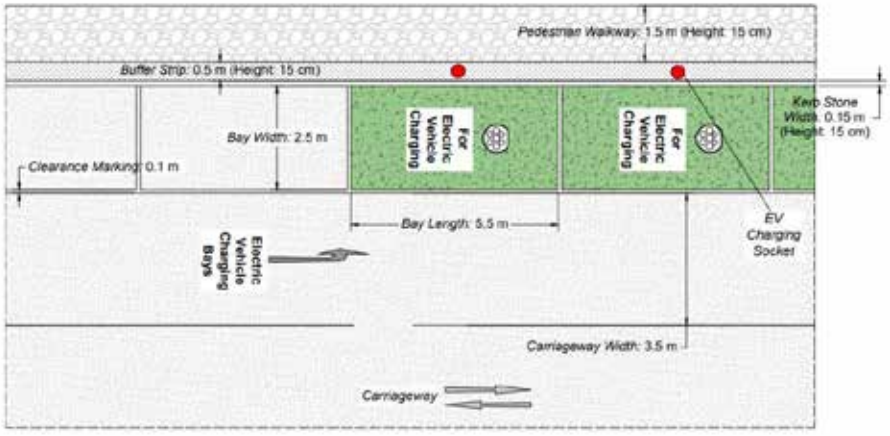


Figure 20: On street linear parking with pedestrian walkway and floor mounted sockets



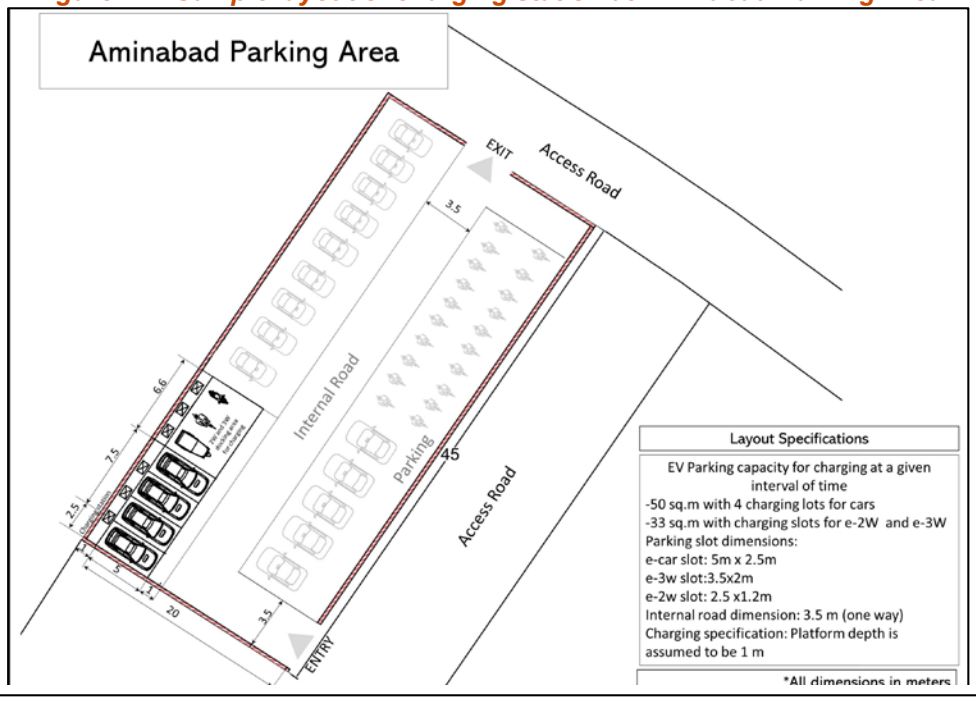
[18] https://www.niti.gov.in/sites/default/files/2021-08/HandbookforEVChargingInfrastructureImplementation081221.pdf

The layouts shown above can be adapted with necessary modifications based on the requirement.

Example: Layout template of EV Charging site- Aminabad Parking area

The figure below shows a sample layout of the EV charging station at Aminabad municipal parking located in Nazarbagh area. The site is in central Lucknow and has access from two arterial roads. Considering its locational importance, four charging points for e-4Ws and three charging points for e-2Ws or e-3Ws are provided.

Figure 21: Sample layout of charging station at Aminabad Parking Area



5.6. Integration of EV Charging in Built Environment

In the medium- to long-term, it is essential to integrate EV charging in planning policies and regulations to ensure its continued development. Urban planning and parking policies and building byelaws must be amended, and governance processes established, for creating a future-proof charging infrastructure network in Lucknow. Measures for integrating EV charging infrastructure in the city's planning policies and governance mechanisms are highlighted below.

Public Charging

For the successful rollout of public charging infrastructure, inclusion of public charging into the current policies, urban planning processes and additions in governance mechanisms is required.

Parking policy reforms

Parking spaces being the prime location for public charging, integrating them into parking policies is essential to ensure that all existing and future public parking spaces have reserved EV charging spots. The parking policies can have reforms on:

- Setting up charging points at on-street parking spots.
- Setting up charging points in public parking places.
- Setting up charging points in transit station parking areas.

Urban planning process

Integration of public EV charging in the urban planning processes like land pooling and town planning schemes will support a rapid scale up of public charging infrastructure.

Governance mechanisms

- Identifying land to set up public charging stations by the local government. This land can be tendered to private entities at concessional lease rates.
- Single window system for efficient approvals for charging infrastructure businesses.
- Common database for ease of locating, pre-booking, paying for charging services.

Private Charging

While the government doesn't have a major role in setting up private charging facilities, it can create an enabling policy and regulatory framework to facilitate the process. Below are a few suggestions that the state and local governments may incorporate for faster uptake of EV charging in buildings.

New Buildings

- Amendments to Lucknow building byelaws for new multi-unit buildings, including residential buildings; 20% of all parking spaces to be equipped with EV charging as per the amended Model Building Byelaws by the Ministry of Housing and Urban Affairs (MoHUA).
- Subsidies for installing private charging at residences and in other buildings.

Existing Buildings

Safety

- To address EV charging barriers in existing residential buildings, guidelines can be set for installation of private EV chargers in residential areas. These guidelines can be enforced by cooperative societies.

Regulations

- Residential welfare associations/cooperative housing societies can provide no objection certificates (NOCs) to individuals meeting the safety guidelines criteria.
- Property tax rebates can be considered for residential units setting up EV charging points.
- Existing commercial and institutional buildings with a parking capacity of more than 100 vehicles shall set aside 5% of their parking spaces for EV charging. This can include shopping malls, hospitals, hotels, offices, educational institutions, movie theatres, etc. The Delhi Government established such a mandate to support public charging infrastructure provision in their region.
- All institutional and commercial establishments shall convert at least 25% of parking to make them EV-ready by 2023.

Governance

- MVVNL can undertake a DISCOM-led program to empanel EV charging vendors to set up EV chargers in buildings, with installation and EV charger costs recovered as part of the electricity bill. Reputed charging vendors with compliant and tested EV charging infrastructure should be selected for empanelment, to ensure quality and safety of charging equipment.

5.7. Business Models for Charging Infrastructure Implementation

Once the planning for EV charging infrastructure is complete, the installation and operation of public charging networks requires viable implementation models. Different types of implementation models may be used to set up and scale public charging infrastructure in Lucknow. A typical charging infrastructure implementation model comprises of multiple components, including the capital expenditure for charging equipment, provision of land, supply of electricity, and the day-to-day operations and maintenance of facilities and services. Implementation models for EV charging

services can be broadly classified into three types- the energy provider model, the public-private-partnership model, and the private service provider model.

Energy Provider Model

Public or private electricity utility companies and oil & gas (O&G) companies are well-positioned to enter the charging infrastructure space. DISCOMs, in addition to their control over electricity distribution infrastructure, also often have land assets within cities which can be leveraged to set up charging infrastructure. Similarly, O&G companies have fuel pumps where fast charging guns or battery swapping stations can be set up.

DISCOMs or O&G companies in Lucknow, such as MVVNL and IOCL, can take an active role in setting up charging infrastructure in the city, through one of the following models:

- Partner with EV charger manufacturers/service providers to install EV charging stations through a turnkey engineering-procurement-construction (EPC) contract, after which the DISCOM or O&G company owns and operates the charging stations themselves, OR
- Partner with charge point operators (CPOs) by providing land (and in the case of DISCOMs, access to electricity), through build-own-operate (BOO) or build-own-operate-transfer (BOOT) contracts in which the CPO designs, installs, and operates the charging stations at their own cost while providing a fixed monthly fee or share of revenues to the DISCOM/ O&G company.

This model of charging infrastructure implementation is expected to account for a small yet significant share of public charging infrastructure, as DISCOMs and O&G companies often have land in strategic locations to contribute to accessible charging networks. In the case of public DISCOMs, if they choose to work with CPOs for operating charging infrastructure, this model will closely resemble the public private partnership model that is defined next.

Case study: BESCOM's Electric Vehicle Charging Infrastructure Deployment

In line with Electric Vehicle and Energy Storage Policy of Government of Karnataka, the state power utility BESCOM has created EV charging infrastructure across the state, especially in Bengaluru city. BESCOM – the state nodal agency for the state of Karnataka – is responsible for setting up EV charging infrastructure across the state and implementing the charging infrastructure component of FAME II scheme. So far, BESCOM has installed 136 charging units at 70 locations and plans to add another 140 public charging stations – with each station having at least four charging units. BESCOM has one of the biggest networks of charging stations among the electricity supply corporations in the country.

The utility is actively partnering with potential investors through the following implementation models:

- BESCOM enters an EPC contract with a private OEM of EVSE.
- CPO sets up charging stations on BESCOM/government land under a lease agreement.

In the first case, BESCOM is the owner while the private implementing agency/partner sets up and maintains the EV charging station under an EPC contract for a designated time period. The charging stations can be accessed via an app and users can book the slot in advance to avoid queues. The payment is through a prepaid system wherein the user pays an advance amount. Once the car is charged fully or when the driver decides to unplug, the billing amount is sent to the user via the app.

In the second model, BESCOM examines opportunities with entities who are ready to plan, design, develop, invest, operate and maintain the EV charging stations in BESCOM-owned locations or other government land on a land rental basis. The selected agency signs a contract with BESCOM and pays the land rent annually on a pre-paid basis. The private agency is also responsible for investing in upstream electrical infrastructure and timely payment of the monthly electricity bill of the EV charging station.

Public-Private-Partnership Model

In this model, the public or the quasi-public agencies drive the partnership with private entities to accelerate EV charging infrastructure development. Here, the public agency aggregates land parcels for setting up public charging stations, and a private CPO is selected to procure, install, operate and maintain the charging infrastructure and provide charging services at these sites.

Contracting is typically done through a tender process, in which the most competitive bidder or bidders are selected. The selected CPOs are responsible for the entire capital and operational expenditure for setting up and operating the charging stations, which are then recovered over the contract period through service fees for charging services. Land is provided by the public agency on a revenue-sharing basis, at a fixed cost per kWh of power sold by the operator. Electricity connections are provided by the DISCOM- the connection may be provided at market cost or with subsidized/ exempted costs up to a certain limit, depending on the tender conditions.

At the end of the contract period, the concessionaire may choose to take up ownership of the charging infrastructure assets after clearance by the land-owning agency and DISCOMs.

The PPP model of implementing public charging infrastructure has several advantages, as highlighted below:

i. It allows local authorities to ensure that public charging facilities are operated and maintained at an optimal level.
ii. It enables ease of access and interoperability through standard specifications for charging equipment and operating protocols.
iii. It minimizes the use of public finances by attracting private investments.
iv. It helps discover the business case for EV charging infrastructure and supports ease of scalability through multiple private operators.

In Lucknow, local authorities such as the Lucknow Municipal Corporation, the Lucknow Development Authority or the Lucknow Metro Rail Corporation can contract private operators to set up and operate public charging infrastructure in the city. One nodal agency may also pool land parcels from different public agencies and create a combined tender for the city, which would enable better planning and distribution of charging infrastructure. Contracting authorities must ensure that the business case for public charging infrastructure is attractive to private operators, by designing the tender to ensure financial viability of the project.

Case Study: Delhi's EV Charging and Battery Swapping Station Tender – Delhi Transco Limited

Delhi Transco Ltd (DTL) – the state nodal agency for Delhi – is responsible for improving the EV charging infrastructure across the state. They had issued a tender recently to invite bids from private agencies to set up and operate public charging stations (PCS) across the city through a PPP model.

In this model, the company offering the lowest service charge was preferred for the award of tender and the concessionaires who won the bidding were given the responsibility to set up public charging stations on a revenue sharing model. Land for setting up charging stations was provided by the government, with land parcels aggregated from various public and quasi-public agencies like Delhi Metro Rail Corporation, Delhi Transport Corporation, Delhi State Industrial and Infrastructure Development Corporation Limited etc. Land has been provided on a revenue-sharing basis and the concessionaires will pay a fixed rate of INR 0.70/kWh of power sold to the site-owning agency for the duration of the contract period (60 months).

The private concessionaries/CPOs who were awarded the tender are responsible for obtaining EV metered connections from the DISCOMs and pay for the consumed electricity. The concerned DISCOMs are mandated to provide electricity connections up to 100 kW sanctioned load for the public charging facilities. Regulatory support in the form of seamless approvals, quality checks, site feasibility etc. is being provided to the private entity by the SNA. At the end of the lease period, the concessionaires may choose to take up ownership of the charging infrastructure assets after clearance by the land-owning agency and DISCOMs.

This is a typical example of a public-private partnership for EV charging implementation. SNAs in other states are also considering similar models for implementation.

Private Service Provider Model

In the private service provider model, any individual private entity like a charge point operator can plan, install and operate the charging station, either on their own land or on land owned by other private entities. In this model, the private entities drive the EV charging provision for public and semi-public charging.

The private service provider takes the onus of procuring the EVSE from EVSE manufacturers, who are also responsible for its installation and annual maintenance. Apart from charging operations, the private entity (through a third-party service provider) can also provide additional charging services like digital payment. The power connection and support infrastructure are provided by the power distribution utility (under a contract with the private service provider) and the private entity pays for the energy consumption and necessary upstream electrical infrastructure.

At present, a few of the EV charging points in Lucknow are set up under this model, by stakeholders including EV manufacturers like Tata Motors and MG Motors, EVSE manufacturers like Delta Electronics, and CPOs like Quench Chargers and Mass Tech, on their own properties or on other private properties. This model can be used to scale up public charging infrastructure in response to growing demand, and can help increase the stock of public charging in a city. The Lucknow Municipal Corporation, MVVNL and other relevant local authorities should create a single-window mechanism

for easing the process of procuring permits, approvals, and certifications needed to set up public charging infrastructure.

Battery Swapping Business Models

Case study: Kirana Charzer's Electrification Drive

Amidst the rapid pace of 2-W and 3-W electrification in India, Kirana Charzers – a Bengaluru-based startup – is leveraging the market through its collaboration with small commercial establishment (Kirana) owners. Kirana Charzer is a low cost, compact and accessible plug-n-play solution which is made available to kirana owners and other establishments like restaurants, retail shops and gyms for direct purchases and it allows the owners to earn an additional source of income. Till date, it has installed about 150 charge points across the country, with one lakh additional charge points being planned for the next two years.

There are two types of 3.3 kW type 1 AC chargers available, costing INR 10,000 and INR 15,000 respectively. The difference between the two is in the communications protocol. There is no annual maintenance cost (AMC) or other fixed costs attached to the purchase. The charger works on single-phase electricity connection and can be installed without upgrading existing grid connections. However, a quality check of the electrical connection is done and if found below the required quality, Charzer uses its own wiring for the installation at the owner's expense. Required load for a charger is around 4kW – available in most small establishments. The only limitation here is that these establishment owners need to have their own designated space for docking the vehicle for charging.

Once an establishment owner procures the charging unit, this IoT enabled device is listed on the Charzer app. EV owners can locate them, reserve a charging slot in advance and pay for it through the app. For any transaction that happens through the app, the revenue share on charging in the Charzer network is 80% for establishment owners and 20% for Charzer. The establishment owners have been given the flexibility to decide the price for the charging services. The pricing is fixed on the basis of time – wherein an EV owner will pay about INR 25/hour to charge their vehicles. Moreover, these establishment owners are given additional flexibility to charge a 10% premium if the shop is in a dense commercial area. An energy meter is placed inside the charger itself and through the application, the establishment owners can get the real-time report of power consumed, along with the number of bookings and earnings.

This is a typical model of how different establishment owners like kiranas, restaurants, retail shops etc. can potentially scale up the EV charging network.

Battery swapping is a mechanism that involves replacing discharged batteries with charged ones. This provides the flexibility to charge them separately by de-linking charging and battery usage – keeping the vehicle in operational mode with negligible downtime. It also reduces the upfront cost for the EV owners, as they do not have to purchase the battery upfront along with the vehicle.

Battery swapping is a form of a Battery-as-a-Service model, where the batteries are leased from the battery swapping operator and the end user pays for the battery on a pay-per-use basis. The battery swapping business model is being adopted in the following ways:

- The battery manufacturer acts as a network operator and offers battery swapping services to the customers.
- The EV manufacturer (after having procured batteries from battery manufacturers) acts as a network operator and offers battery swapping services to customers.
- The network operator contracts with battery (for purchase or leasing of batteries) and EV manufacturers and offers swapping services.

In this model, the vehicle owner can subscribe to any relevant battery swapping operator and pay for each swap. The battery swapping stations can be set up on their own land, land owned by other private entities (through a leasing arrangement with the battery swapping operator) or any government/quasi-government owned land on a revenue-sharing basis. The state or local authorities

can also provide concessional land parcels for battery swapping services. The operator ties up with the power utilities to acquire the required power connections and infrastructure.

Any battery manufacturer (like Volt up or Drone power currently functioning in Lucknow), EV manufacturer or network operator can set up battery swapping stations in Lucknow either on their own land, other privately owned land or government lands through a leasing agreement. The necessary electricity supply to be provided by MVVNL and regulatory support to be provided by IIDC or any other body designated by IIDC.

Case study: SUN Mobility's Battery Swapping Service

SUN Mobility is an energy infrastructure and service provider with a vision to create a universal network of interoperable energy infrastructure to accelerate mass adoption of electric mobility. The approach of separating batteries from vehicles through the battery swapping model addresses the key issues facing electric vehicles – their high upfront cost and range anxiety. They operate under energy-as-a-service model wherein they provide standard batteries and charging infrastructure which are bundled as a service.

SUN Mobility has collaborated with vehicle manufacturers and battery cell technology providers, power utilities (TATA-DDL), fleet operators/aggregators (Uber, SmartE, Metro Ride, Zyngo Mobility), oil marketing companies (IOCL) and cities across the ecosystem to enable quicker adoption of its solutions, thereby accelerating mass EV transition.

The operating model involves the establishment of individual swapping facilities (Quick Interchange Stations - QIS) that can charge and dispense batteries and is primarily used for e-2W and e-3W segments. The batteries are standardized for enabling easy operations, with a typical battery having a 1.5 kWh capacity. While an e-2W requires only one battery, the e-3Ws may need 2-3 batteries, depending on the type of vehicle and the built requirement. The QIS is designed to dispense fully charged batteries every hour. While some of the stations avail of EV charging tariffs, many are charged for electricity at commercial rates for the energy required to charge the batteries inside the QIS. The company ties up with power utilities to acquire the required connections and infrastructure. A typical QIS with battery charging (AC) and monitoring equipment has a connected load of 28 kVA. While a single QIS will require only an LT electricity connection, a multiple QIS system will require an HT connection along with associated electrical equipment.

This innovative model supplements the scale up of EV charging network in the country.

5.8. Grid connection and safety requirements for EV charging

Whenever a new customer (i.e charging station load) connects itself with the electric distribution system, the customer's electrical installation must comply with statutory regulatory prerequisites like grid connection and safety requirements. The Chief Electrical Inspector or any other competing authority will then inspect the site installation and verify the incorporation of statutory regulatory requirements and approve the site installation for a connection with MVVNL.

Grid Connection Requirements of EV Charging Stations

The requirements for grid connection of charging stations are provided in the regulation 11A of the Central Electricity Authority (Technical standards for Connectivity of the Distributed Generation Resources), Amendment Regulations, 2019[19]. Any charging station developer or charge point operator seeking connectivity for their charging station at a voltage level below 33 kV shall follow the technical requirements provided in this document.

These standards provide the technical requirements for grid connection for any generating company, charging station, and prosumers seeking connectivity to the electricity system at a voltage level below 33 kV. The requirements are:

[19] https://cea.nic.in/old/reports/others/god/gm/notified_regulations.pdf

- The charging station shall have a reliable protection system to detect various faults and abnormal conditions and provide an appropriate means to isolate the faulty equipment or system automatically.
- The appropriate licensee shall carry out an adequacy and stability study of the network before permitting connection with its electricity system.
- The limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement, and other such matters, shall be in accordance with the IEEE 519-2014 standards, as amended, from time to time.
- The measuring and metering of harmonics shall be a continuous process with power quality meters complying with the provisions of IEC 61000-4-30 Class A.
- The charging station seeking connectivity at 11 kV or above shall install power quality meters and share the recorded data with the distribution licensee with such periodicity as may be specified by the appropriate electricity regulatory commission.

The Chief Electrical Inspector is responsible for approving any charging station and its technical compliance with the CEA standards before its connection with MVVNL. MVVNL is responsible for conducting a power quality analysis at site to check the compliance of power quality parameters of the EV charging station connection, such as harmonics within the prescribed limits. In case harmonics are exceeding the limits, MVVNL must issue the notice to the charging station developers or CPOs to mitigate the harmonic injection into the grid. Only after these checks are conducted can the connection be energized.

Safety Requirements for EV Charging Stations

Safety is one of the important points to consider for EV charging infrastructure. Safety of charging stations is a combined effort of various stakeholders involved in the charging station development, operation, and maintenance. Chapter XI, "Safety Provisions for Electric Vehicle Charging Stations" of Central Electricity Authority (Measures relating to Safety and Electric Supply), (Amendment) Regulations, 2019[20] provides the technical requirements of a charging station, from the perspective of safety. Clauses related to the design of EV charging stations include:

- Clause. 117 – General safety requirement for electric vehicle charging stations,
- Clause. 118 – Earth protection system for charging stations, and
- Clause. 119 – Requirement to prevent fire for electric vehicle charging stations.

The design engineer has to consider the safety of the person involved in charging as well as the safety of equipment while designing the charging station.

For testing the installed equipment, the testing engineer must perform the minimum tests as per Clause. 120 – Testing of charging stations. The Chief Electrical Inspector or a certified electrical safety engineer is responsible for inspecting and testing the charging station and its technical compliance before connecting it to the MVVNL grid.

The owner of the charging station shall ensure that tests and inspections of the charging station are carried out every year for the first three years after the energization of the charging station, and every four years thereafter. The owner of the charging station shall establish and implement a safety assessment program for regular periodic assessment of the electrical safety of the charging station.

Apart from the CEA regulations, guidelines may also be issued by state authorities to streamline and standardize safety procedures for the design, installation and operation of EV charging stations. The office of Chief Electrical Inspector of the Industry, Energy & Labour Department of Maharashtra issued specific guidelines for "Safety and standard operating procedure for EV charging stations in Multistorey Buildings (residential, commercial premises / hotels / Hospitals / Malls / Car parks / Places of public gatherings) for Two / Three / Four Wheelers across Maharashtra"[21]. Similarly, the

[20] https://cea.nic.in/old/reports/regulation/measures_safety_2019.pdf
[21] 283_CEI_ Safety Advisory_ Standard Operating Procedure for EV Charging Stations (EVCS) across Maharashtra_organized.pdf (ceimah.in)

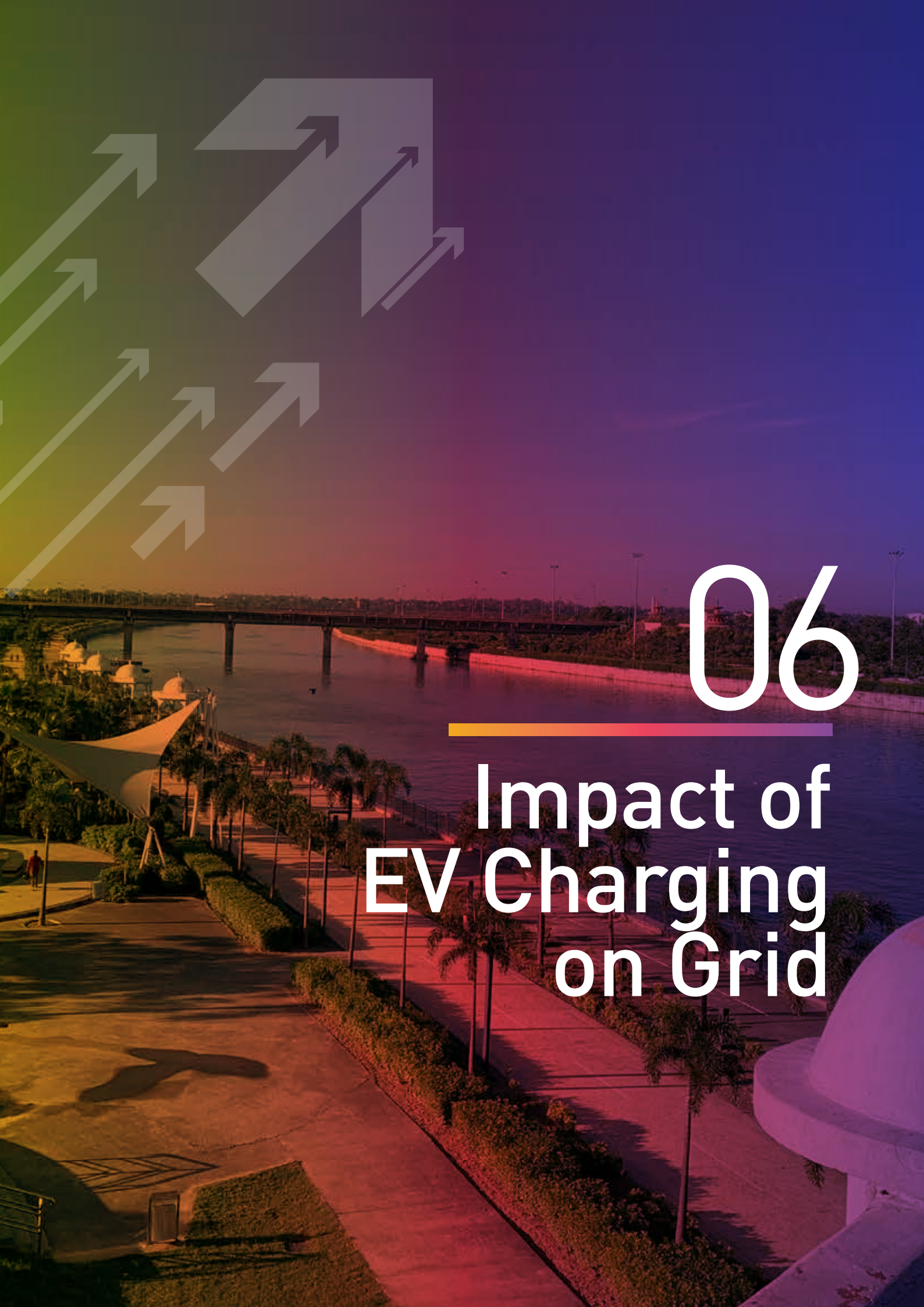
Government of Uttar Pradesh may issue specific guidelines for safety and standard operating procedure for developing and operating charging stations across the state.

5.9. Summary of Recommended Initiatives

Table 30: Summary of Recommended Initiatives over the short, medium, and long term

Area of focus	Probable Solutions	Action Timeline	Major stakeholders
Public charging infrastructure network planning and implementation	Create and establish roadmap for development of public charging infrastructure for Lucknow, with annual targets of charging points.	Short Term	Infrastructure and Industrial Development Department, Invest UP, Lucknow Municipal Corporation
	Identify available public sites for installing charging stations, based on spatial analysis of EV charging demand in different parts of the city.		Infrastructure and Industrial Development Department, Invest UP, Lucknow Municipal corporation, Lucknow Development Authority
	Implement tender(s) for public charging infrastructure through PPP mode, with appropriate terms and conditions to ensure viability of charging as a business.		Infrastructure and Industrial Development Department, Invest UP, Lucknow Municipal corporation, Lucknow Development Authority
	Create single-window mechanisms for enabling ease of public charging infrastructure implementation by private sector.	Medium Term	Infrastructure and Industrial Development Department, Invest UP, Lucknow Municipal Corporation, Madhyanchal Vidyut Vitran Nigam Ltd. (MVVNL)
	Develop standards and guidelines for communication protocols and smart charging equipment for public charging infrastructure		Infrastructure and Industrial Development Department, Invest UP, Lucknow Municipal Corporation, Lucknow Smart City.
Policy and regulatory measures for	Amend Lucknow building byelaws to require 20% of all parking spaces in new buildings to be equipped with EV charging as per	Short Term	Town and Country Planning Department UP, Lucknow Department Authority

EV charging infrastructure	the amended Model Building Byelaws.		
	Create a mandate for existing commercial and institutional buildings with a parking capacity of more than 100 vehicles to set aside 5% of their parking spaces for EV charging.		Town and Country Planning Department UP, Lucknow Department Authority, Lucknow Municipal Corporation
	Notify safety regulations and guidelines to be followed for installation of charging infrastructure		Madhyanchal Vidyut Vitran Nigam Ltd. (MVVNL), Chief Electrical Inspector,
	Mandate the provision of no-objection certificates (NOC) for installation of EV charging that adheres to all planning and safety guidelines		Lucknow Development Authority, Lucknow Municipal Corporation, Madhyanchal Vidyut Vitran Nigam Ltd. (MVVNL), residents welfare associations (RWA),cooperative housing societies
	Integrate EV charging requirement in parking policies and urban planning policies for setting up charging points at on-street parking spots, public parking places and transit station parking areas.	Medium Term	Town and Country Planning Department UP, Lucknow Municipal Corporation, Lucknow Smart City, Lucknow Development Authority



06

Impact of EV Charging on Grid

6. Impact of EV Charging on Grid

6.1. Introduction

Lucknow is served by Madhyanchal Vidyut Vitran Nigam Limited (MVVNL) which is one of the distribution companies under Uttar Pradesh Power Corporation Limited (UPPCL)[22]. UPPCL is a managed utility company supplying reliable and cost efficient electricity to the state of Uttar Pradesh.

According to the Central Electricity Authority's 20th Electric Power Survey, the peak demand in Lucknow is currently around 1580 MW and is expected to see a CAGR of 6.15% up to 2024-25 and will reach 1955 MW. It will then reach 2579 MW in 2029-30 with a CAGR of 5.70% after 2024-25. The electrification of transport will create additional demand in the coming years, with the deployment of charging infrastructure throughout the city. This chapter provides an overview of the imact of EV charging on the grid as well as the power scenario in Lucknow, and going forward what are the kind of measures and investment required to keep up with this added demand.

6.2. Energy Supply and Demand

For the Year 2021-22, the overall energy requirement was not met based on the available energy summed over the year. However, There was deficit for eight months from Apr to Nov in 2021. Also, the peak demand did not meet the peak availability. There was a deficit of 0.7 % in peak demand as shown in the table below.[23] For the Year 2022-23, it is anticipated that the overall energy requirement will be met based on the available energy. However, the peak availability is expected to not meet the peak demand.

Table 31: Annual Power Supply Position in UP for 2021-2023

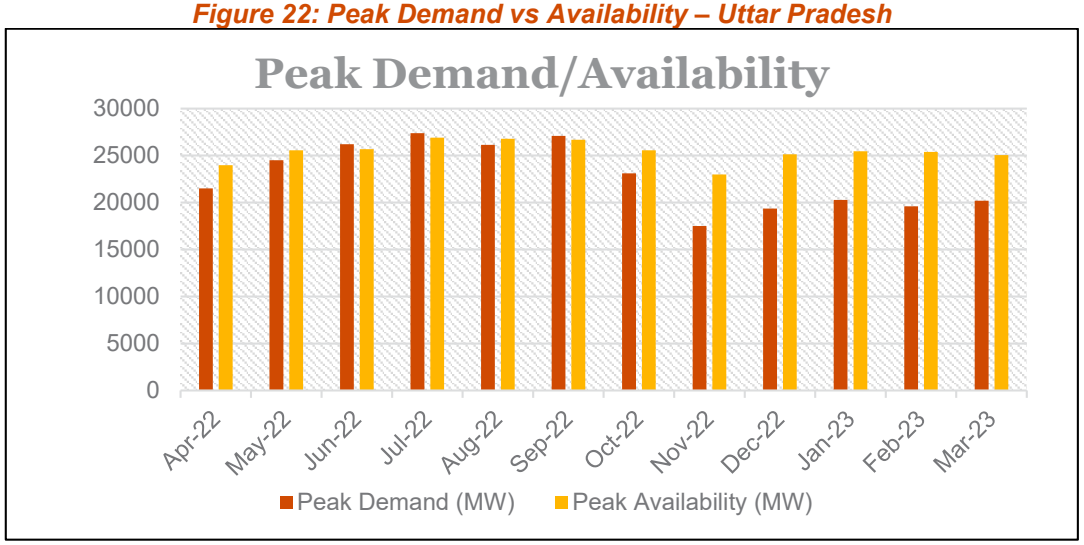
	2021-22	Anticipated 2022-23
Energy Requirement (MU)	128,611	147,390
Energy Availability (MU)	127,516	151,050
Surplus	-0.90%	2.50%
Peak Demand (MW)	24,965	27,380
Peak Availability (MW)	24,795	26,900
Deficit	-0.7%	-1.80%

Source: LGBR Report, CEA

The peak demand during the summer months does not meet the peak availability. Same is true for energy requirement during the summer months. Based on the figure below, in summer months there is a deficit in peak demand as well as the energy requirement. However, during the winter months, the energy availability as well as the peak availability is surplus in the state of UP as shown in the figure below. With the increase in EV penetration, this will lead to more energy requirement which will need power infrastructure upgrade. The peak demand from EV charging can be regulated based on the time of the day tariff imposed by DISCOMs.

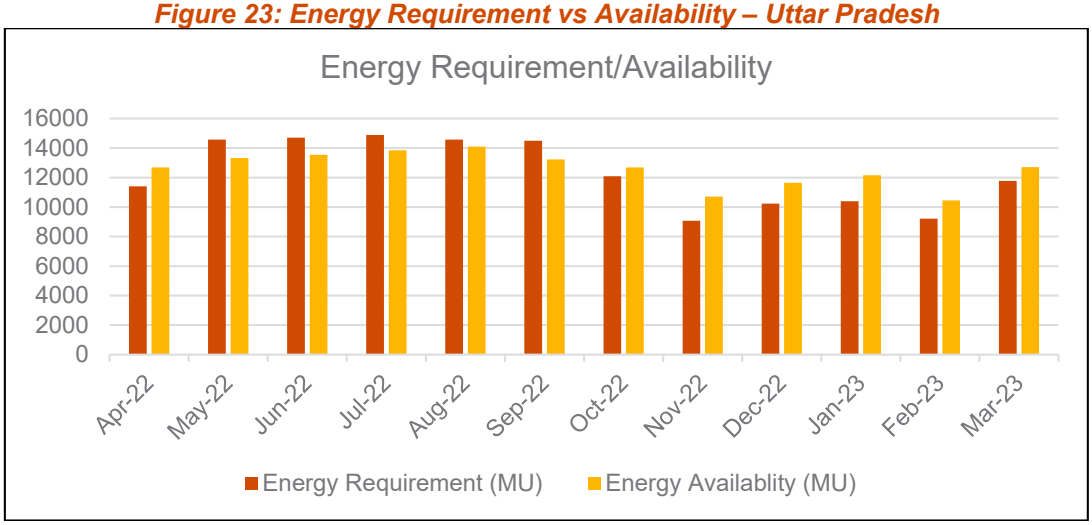
[22] http://www.indiaenvironmentportal.org.in/files/file/Report-On-Nineteenth-Electric-Power-survey-Of-India-Mega-Cities.pdf
[23] https://cea.nic.in/l-g-b-r-report/?lang=en

Figure 22: Peak Demand vs Availability – Uttar Pradesh



Source: LGBR Report, CEA

Figure 23: Energy Requirement vs Availability – Uttar Pradesh



Source: LGBR Report, CEA

Power Consumption based on time of day

Based on the load curve, the power consumption in Lucknow can be observed during different time of the day. The peak hours are between evening 6 PM to night 10 PM. During this time, the power consumption is more than the supply which causes power shortage, During the off-peak hours in commercial and residential area, there is enough power in surplus to feed the demand. The power demand recorded by MVVNL for Lucknow is mentioned in the subsequent sub-section.

6.3. EV Charging and the Electricity Grid

EV charging is a new type of electricity load that is expected to be connected with the electric distribution systems across the country. Its high proliferation into the distribution system will increase the peak load demand and increase the energy requirements of the DISCOMs (i.e MVVNL). Grid impact analysis provides information about the urban peak load demand and energy requirements for EV charging. The analysis can be used by DISCOMs to assess grid upgradation requirements and the need for greater energy generation or purchase.

EV Charging Tariffs

The Ministry of Power's guidelines on EV charging infrastructure requires states to provide a concessional tariff for public EV and battery charging stations until 31st March 2025. This comes with a caveat that the concessional tariff should not exceed the average cost of supply. According to the

revised MoP charging infrastructure guidelines, public charging stations should also have Time of Day (ToD) tariffs and discounts for hours with high solar energy generation.

Uttar Pradesh introduced a multi-part EV charging tariff for various consumer segments in 2019. The Uttar Pradesh Electricity Regulatory Commission (UPERC) tariff order specified separate EV tariffs for public charging stations under Low Tension (LT) and High Tension (HT) connections and the suspension of demand charges in order to boost EV adoption. ToD tariffs (surcharge during peak hours and rebate during off-peak hours) are also included in the tariff order.

The EV tariffs for different consumer categories, including public charging stations, are given below:

1. **Domestic consumers (LMV-1):** All metered residential consumers under LMV-1 (Low Medium Voltage-1) category will be allowed to charge at their residences if the EV charging load does not exceed the contracted load for that residence. Tariffs that are applicable as per the rate schedule will be applicable for EV charging as well.

2. **Multi Storey Buildings (covered under LMV-1b & HV-1b of the Rate Schedule):**

Table 32: EV charging tariff for multi-storey buildings

Category	Demand Charge	Energy Charge
Multi Storey Buildings (Covered under LMV-1b)	Nil	Rs. 6.20 / kWh
Multi Storey Buildings (Covered under HV-1b)	Nil	Rs. 5.90 / kWh

3. **Public charging stations (LMV-11):** The tariff applicable for public charging stations is as follows:

Table 33: EV charging tariff for public charging stations

Category	Demand Charge	Energy Charge
Public Charging Station (LT)	Nil	Rs. 7.70 / kWh
Public Charging Station (HT)	Nil	Rs. 7.30 / kWh

(Source: UPERC Tariff order 2021-22)

Time of Day (ToD) tariff for public charging stations:

The advantage of LMV-11 tariff structure (rate schedule category considered for consumers having EV charging station) electric vehicle charging is Time of the Day (ToD) rates. EV users can schedule their EV charging as per the ToD timings and get additional benefits of lower energy costs. Madhyanchal Vidyut Vitaran Nigam Ltd. (MVVNL) has two different ToD rates for the summer months (April to September) and winter months (October to March), as shown in Table 4.

Table 34: Time of day tariff for public charging stations

Hours	% Of energy charges (Summer Months – April to September)	% Of energy charges (Winter Months – October to March)
05:00 hrs – 11:00 hrs	(-) 15%	0%
11:00 hrs – 17:00 hrs	0%	0%
17:00 hrs – 23:00 hrs	(+) 15%	(+) 15%
23:00 hrs – 05:00 hrs	0%	(-) 15%

In summer months, EV users get a 15% reduction on energy charges if they charge their EVs between 05:00 and 11:00 hours in the morning. If users charge their EVs between 17:00 and 23:00 hours in the evening, they must pay an additional 15% surcharge on the EV tariff.

In winter months, EV users get a 15% reduction on energy charges if they charge their EVs between 23:00 hours in the night to 05:00 hours the next morning. If users charge their EVs between 17:00 and 23:00 hours in the evening, they must pay a 15% surcharge.

4. **Other consumers** (metered consumers of LMV-2(a), LMV2(c), LMV-4, LMV6, LMV-7, LMV-8 (Metered), LMV-9 (Metered), HV-1, HV-2, HV-3 and HV-4)

Consumers of other categories (Non-domestic, public and private institutions, public water works, commercial, etc.) that are not covered above, will be charged as per the tariff applicable for their respective category.

UP EV Policy 2022 Special Tariff Support

Uttar Pradesh Electricity Regulatory Commission (UPERC) has already notified Special Tariff category for EV Charging. The State Government shall regularly coordinate with UPERC for rationalising the tariff rate from time to time for EV charging in the State.

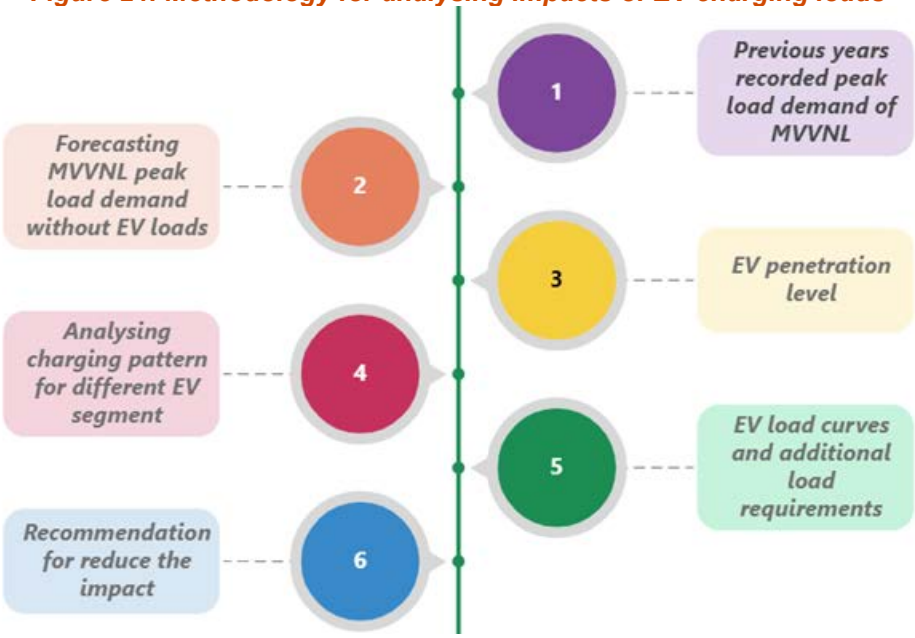
Peak Energy Demand Due to EV Charging

The power and energy demand analyses highlight the additional energy requirements that MVVNL must procure for EV charging loads, and the impact of EV charging loads on the existing electricity distribution grid. The following assumptions have been considered in the estimation of power and energy demand from EV charging loads in Lucknow:

- Commercial e-4Ws in a city will be charged at the charging hub and public charging station daily.
- Non-commercial e-4Ws in a city will be charged at home, workplace charging, and public charging station once in three days.
- Commercial e-3Ws (e-autos) in a city will be charged at the charging hub and public charging station daily.
- Commercial e-3Ws (e-rikshaws) in a city will be charged at the charging hub and public charging station daily.
- All EV 2-wheelers in a city will be charged at home once in three days.
- All e-buses in a city will be charged at the bus depot and opportunity charging stations dedicated for e-buses only.
- At the time of plug in, the State of Charge (SoC) of the battery is evenly distributed at 25%, 30%, and 40% for all EVs (except e-buses).
- The distribution system loss is considered as 19.19%.

The detailed assumptions considered for the analysis are available in Appendix 6. Note: details of the e-bus fleet are not available for the years 2025 and 2030. Hence, charging loads for e-buses are not considered for these years. The methodology used to analyze the urban peak load demand due to EV charging loads and the additional energy requirements is shown as follows.

Figure 24: Methodology for analysing impacts of EV charging loads

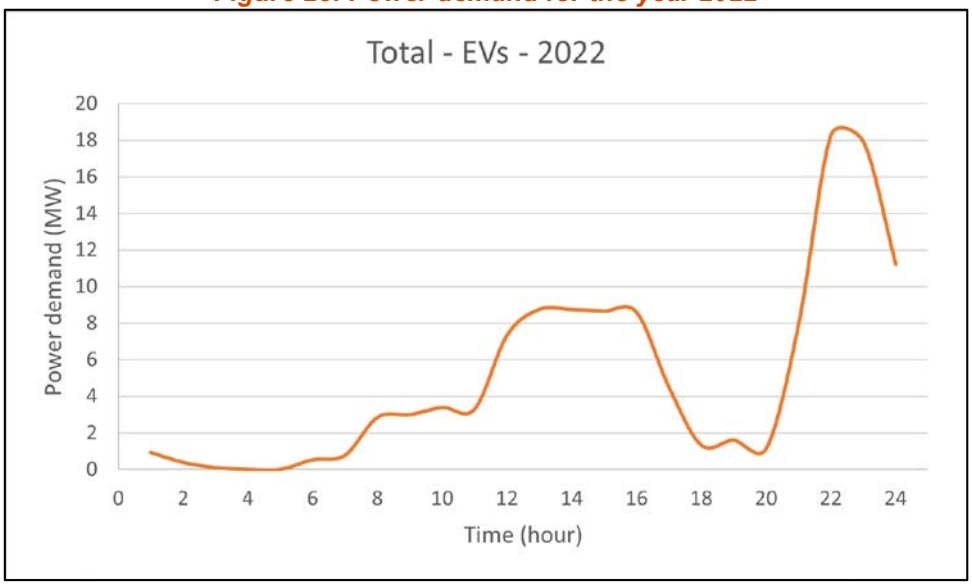


- **Step 1:** Input data collection (peak load demand of the city recorded in the previous years, 24-hour load curves of the city for each month of the year)
- **Step 2:** Forecast the peak load demand of MVVNL for horizon years (2025 and 2030) without EV loads
- **Step 3:** Estimate EV penetration levels in the city by vehicle segment and their specifications
- **Step 4:** Analyze the charging demand and charging patterns for different EV segments in the city
- **Step 5:** Determine the EV load curves for individual vehicle segments and assess the additional peak load requirements
- **Step 6:** Provide recommendations for tariff structures and other incentives to reduce peak load requirements.

To assess the impact of EV charging loads on Lucknow's peak power demand, the load curves of EV charging in the city are estimated for the years 2022, 2025, and 2030.

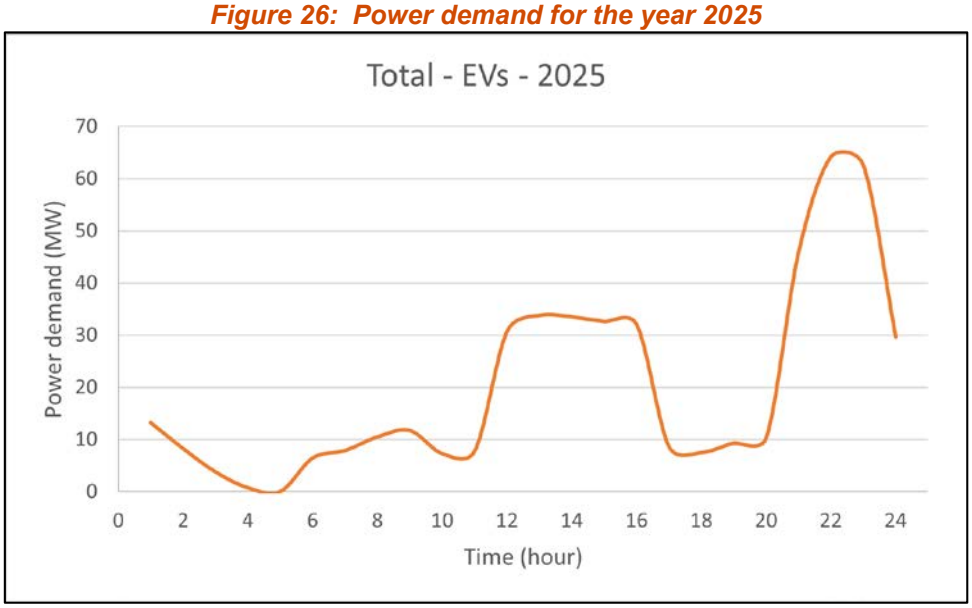
The EV charging power demand for the year 2022 is shown in as follows. The maximum power demand required for EV charging in the daytime is 8.8 MW at 13:00 hours and 18.3 MW at 22:00 hours.

Figure 25: Power demand for the year 2022



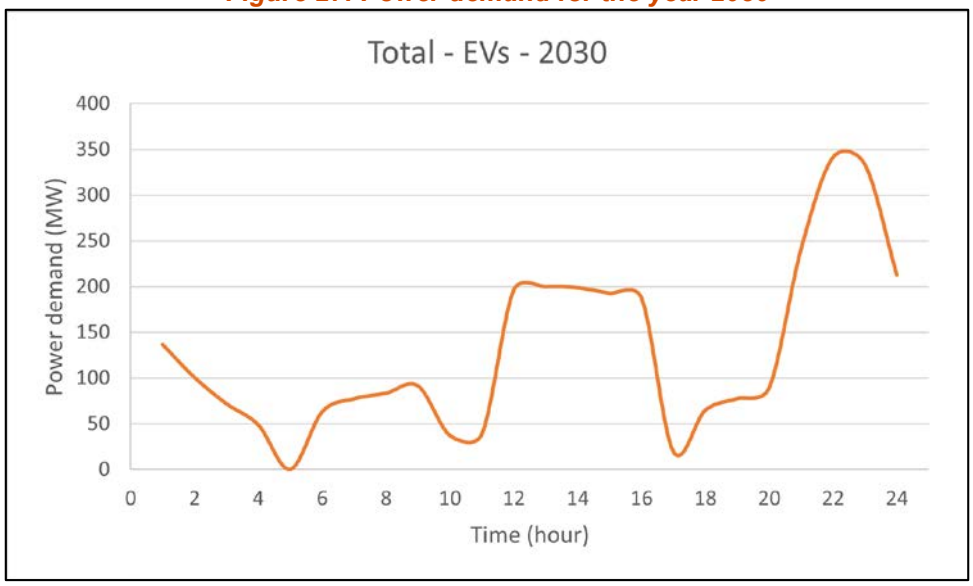
The EV charging power demand in Lucknow for the year 2025 is shown as follows. The maximum power demand required for EV charging in the daytime is 33.8 MW at 13:00 hours and 64.2 MW at 22:00 hours. Compared with 2022, the maximum power demand for 2025 is expected to increase by almost 3.8 times in the daytime and 3.5 times at night.

Figure 26: Power demand for the year 2025



The EV charging power demand in Lucknow for the year 2030 is shown as follows. The maximum power demand required for EV charging in the daytime is 199.8 MW at 13:00 hours, and in the nighttime, it is 341.4 MW at 22:00 hours. Compared to 2025, the maximum power demand for the year 2030 is expected to increase by almost 5.9 times in the daytime and 5.3 times at night.

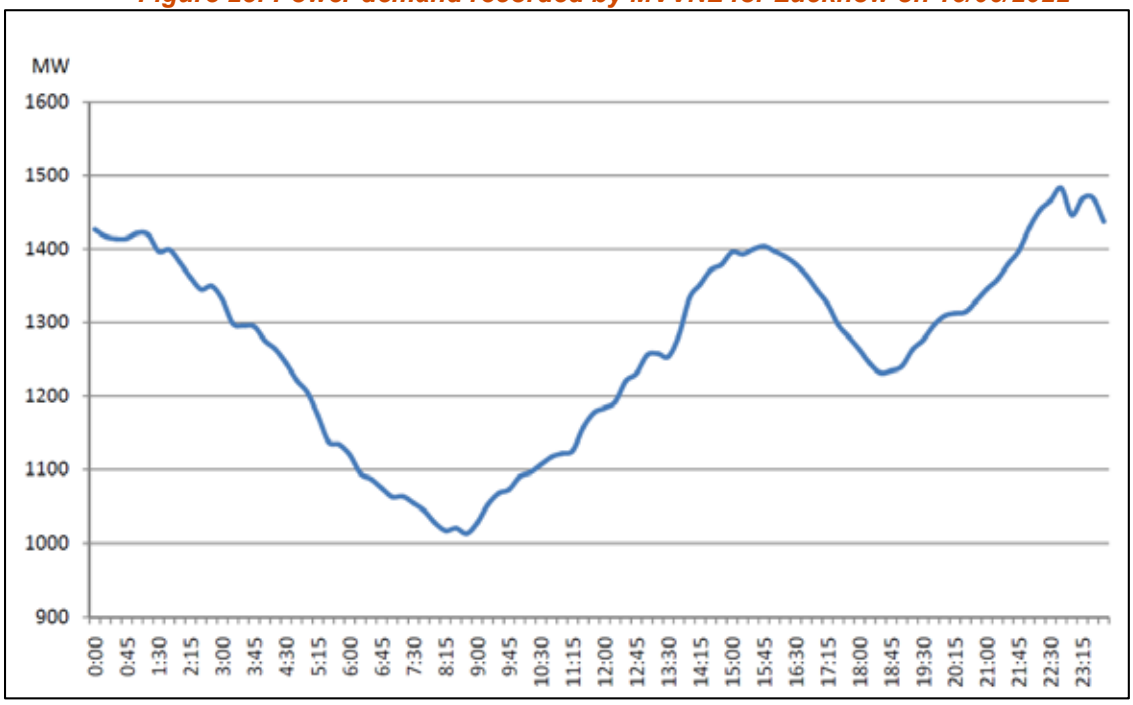
Figure 27: Power demand for the year 2030



The EV charging power demand for individual EV segments for Lucknow, for the years 2022, 2025, and 2030 is detailed in Appendix 7.

The EV charging load curves are then compared with Lucknow's load curve for overall electricity demand. The maximum power demand recorded by MVVNL for Lucknow is approximately 1600 MW. A typical 24-hour load curve (recorded on 15.06.2022) for the city is shown in Figure 13, with a daytime peak load of 1,400 MW at 16:00 hours and a night-time peak of 1,500 MW at 22:00 hours.

Figure 28: Power demand recorded by MVVNL for Lucknow on 15/06/2022



Therefore, for the year 2022, the peak EV charging load of 18.3 MW (at 22:00 hrs) is expected to account for only about 1% of the overall peak load of the city. Furthermore, the EV charging loads will be connected across the MVVL distribution grid, and not concentrated at any one point.

For 2025, the projected peak load for the city is 1,955 MW at 22:00 hours. The peak EV charging load of 64.2 MW at the same time accounts for 3.3% of the total power demand in the city. Therefore, EV charging loads are not expected to significantly impact the MVVNL distribution grid in the short term.

For 2030, the projected peak load for the city is 2,579 MW at 22:00 hrs (not considering EV charging loads). The peak EV charging load for 2030, of 341 MW at 22:00 hrs, accounts for an additional 13.2% of Lucknow's peak power demand. Therefore, in the medium-term, MVVNL must plan for this growing type of demand, and strengthen its distribution grid infrastructure accordingly.

Total Energy Demand for EV Charging

The total energy requirements in MWh to cater to Lucknow's EV charging loads for the present and horizon years are given in Table 8.

Table 35: Total energy requirements for the years 2022, 2025 and 2030

S. No	Year	Total daily energy requirements (kWh)	Total yearly energy requirements (kWh)	Total yearly energy requirements (MU)
1	2022	116612	42563414	43
2	2025	427526	156047036	156
3	2030	2513549	917445533	917

Note: MU – Million Units. 1 MU is equal to 10,00,000 units or 10,00,000 kWh.[24]

For 2022, the energy requirement for EV charging is estimated to be 43 MU, which is 0.18% of the expected energy requirement of MVVNL (24,265 MU)[25]. It is important to note that a significant share of EV charging loads will be covered under other consumer tariff categories, and not just under the EV tariff category[26].

In 2025, the energy requirement for EV charging loads is projected to be 156 MU, 3.6 times higher than 2022, and accounting for 0.56% of MVVNL's projected energy requirements (27,946 MU).

By 2030, the energy requirement for EV charging is expected to grow to 917 MU, representing a 5.8 times jump over the 2025 requirement, and accounting for 2.3% of MVVNL's total projected energy needs (39,946 MU). While not significant, energy requirements for EV charging are growing at a faster rate than the overall energy requirement in the city. MVVNL may consider adding energy requirements of EV charging based on EV registrations in the city, to calculate their total energy requirements year-on-year.

6.4. Accounting for Additional Load on Distribution Network

Overall, interventions on the energy supply side are not necessary, considering the low fraction of EV charging in total energy requirements. However, distribution networks need to be upgraded to handle additional peak demand of 13% generated by EV charging. As identified in the chapter on planning public charging infrastructure, charging stations are likely to be located in areas of high population density and commercial activity. Transformers located in these areas are likelier to be at capacity, and would need upgrading to deal with the additional demand.

Certain measures that can be taken to reduce the upgrades required, and the possible scope and investment required for distribution transformers are as follows-

[24] https://qa.answers.com/Q/How_do_you_convert_MU_million_units_of_power_to_KWH
[25] http://www.indiaenvironmentportal.org.in/files/file/report%20of%20the%20electric%20power%20survey%20of%20india.pdf
[26] https://www.dvvnl.org/UploadFiles/DETAILED%20up%20tariff%20order%202022-23.pdf. As per table 5-26: category-wise revised sale of MVVNL for FY 2021-22 (MU) of Uttar Pradesh Electricity Regularity Commission Lucknow, annual performance report, the energy consumed by EVs for charging purposes across the MVVNL distribution boundary limits is 3.58 MU. However, this accounts for only the energy consumed by users of the EV tariff connections, and not for the EV charging loads under domestic or other consumer categories.

Smart Charging

Smart charging involves adapting the charging cycle of EVs based on the conditions of the power system and the needs of the users. It facilitates an optimized integration of EVs with the electrical grid while also meeting the mobility requirements of EV users. Smart charging is enabled through communication between an EV, the charger, a backend platform for charging management, and the electricity grid management system. Depending on the specifications of the different components and the level of communication between them, smart charging can enable different functions and benefits.

i. **Charging monitoring and management:** At the local level, smart charging can help balance and manage EV charging loads so as not to exceed beyond the connection limit. For multiple chargers on a single electrical connection, load balancing helps distribute the available power across the total number of chargers, thereby allowing public charging CPOs or other users (office buildings, apartment buildings, fleet charging hubs) to optimally size their required electrical connections. Further, smart charging can also manage EV charging loads to not exceed the maximum available capacity, by reducing energy consumption or even pausing charging sessions as needed until enough power is available.

ii. **Dynamic energy management:** Energy management helps control EV charging loads at the grid level, by optimizing energy consumption in response to grid constraints, energy pricing, renewable energy availability, locally stored energy, preconfigured EV owner preferences, and driver needs . This allows EV chargers to provide power based on static or dynamic time-of-day (ToD) or time-of-use (ToU) chargers, and helps manage peak loads at the city level.

Smart charging systems can play a significant role in managing EV charging loads in cities, and can help reduce or delay the need for grid infrastructure upgradation. Especially for public and semi-public charging hubs, they can result in significant cost savings while also optimizing electrical connections for EV charging infrastructure.

The development of smart charging infrastructure can be supported by government policies, incentives, and guidelines. In Lucknow, subsidies for charging stations delivered as part of the Uttar Pradesh EV Policy should mandate the installation of smart chargers using standardized communication protocols. Similarly, any tenders for public charging infrastructure rolled out by local authorities should include a requirement for the use of smart chargers.

Rules or guidelines may be issued by MVVNL or other competent authority such as the CEI, mandating standardization of communication protocols and the specifications of smart chargers to be used in all public and semi-public charging stations. At the same time, DISCOMs such as MVVNL must work with CPOs to aggregate EV charging loads and enable management measures such as dynamic pricing for more optimal EV charging management.

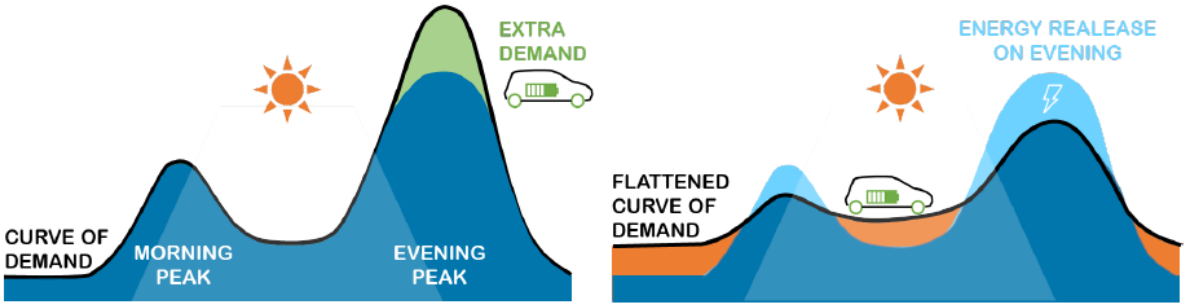
These measures can lay the groundwork for the development of smart charging systems that minimize the impact of EV charging loads on the electricity grid, both at the individual connection level as well as the urban level.

Adopting V2X applications

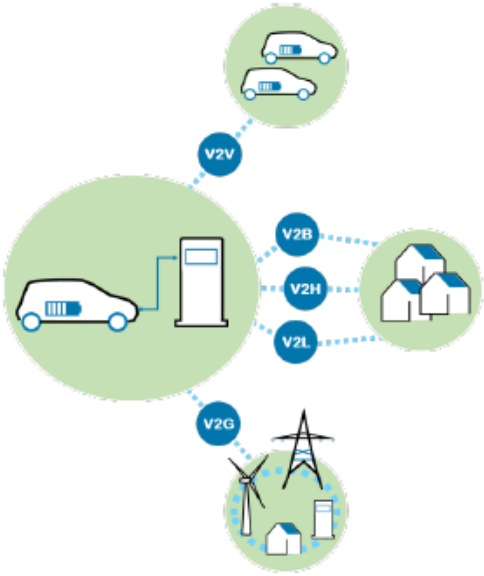
Vehicle-to-everything (V2X) is defined as the bidirectional electricity transfer between the onboard battery of an EV and the system it is connected to. By enabling vehicles to control their charging behavior and supply power, V2X technology aims to offer services to homes, buildings, electricity grids and other electrical system, whilst simultaneously minimizing battery degradation and inconvenience to EV users.

By dynamically controlling vehicle charging and enabling EV batteries to feed electricity back into the grid, EVs could one day provide flexibility and capacity at the system, distribution and building level. It is anticipated that the need for such flexibility in the power system will rise in the future, as penetration levels of variable renewable energy sources such as wind and solar increase. EVs could therefore help shape the future load curve to match renewable energy supply and provide frequency regulation services to improve grid security and stability

Figure 29: Load Curve without (left) and with (right) V2G (Source: IEA V2X Roadmap Study, 2019)



V2X requires additional electrical equipment compared with standard or smart charging, such as an bidirectional inverter to convert the DC power output from the on-board battery to AC for both charging and discharging the EV battery. This conversion equipment is normally integrated into EVSE. Control units are also required for efficient, reliable and safe battery charging and discharging, along with upstream communication protocols to manage these interactions with the electrical systems where the vehicle is connected.



V2X technology can be used for a number of different applications. Probably the most important is vehicle-to-grid (V2G) where the EV is connected the distribution network and provides services to different actors in the power system. V2G services include congestion management services to the Distribution System Operator (DSO), balancing services to the Transmission System Operator (TSO) and energy trading with Balancing Responsible Parties (BRPs). In order to deliver a sufficiently large and reliable response to the grid, V2G services require the aggregation of multiple EVSE, leading to the new “aggregator” role to emerge in the power system.

The other major application is vehicle-to-home (V2H) or vehicle-to-building (V2B). These applications are similar to V2G in terms of electrical connection, services are instead provided to the home or building user where the vehicle is connected. The final applications are vehicle-to-load (V2L) and vehicle-to-vehicle (V2V), characterized by power flows to islanded system that are not normally connected to the distribution network.

Figure 30: V2X Applications (Source: IEA V2X Roadmap Study, 2019)

Case study: V2G frequency response in Commercial fleet, Denmark

In greater Copenhagen, where a fleet of vehicles used for service and maintenance assignments, provide frequency regulation on market terms. Nissan eNV200 electric vans are used and Enel have developed the DC charging infrastructure used by the project. CHAdeMO allows for the use of series-produced, un-modified, vehicles supporting V2G. By controlling the vehicles bidirectional active power set-point, according to the system frequency, NUVVE and SEAS acts in the market as to receive a capacity payment

Upgrading network of Distribution Transformers

The typical Distribution Transformers owned by MVVNL have capacities of 10, 16, 25, 63, and 100 kW. In order to accommodate various types of charging stations, as well as charging points spread across neighbourhoods, new transformers of different capacities need to be deployed. In order to estimate the additional transformers needed and the total investment required, the following process was followed-

1. A set of typical charging stations are taken, with their configuration of chargers, peak demand, and likelihood of creating the need for an additional transformer.
2. The number of such stations according to the projected demand for EV charging is then calculated, along with the number of additional transformers required.

3. The cost of installation of the 25kW, 63kW, and 100kW transformers accounting for various inputs such as transformer cost, poles, fuses, and labor cost, based on other grid strengthening project costs.

4. Assuming 15% labor and transport charge over material cost and 30% additional cost for the installation of LT and HT lines connecting transformers to the grid and to the charging stations.

Results

Table 36: Additional Transformers needed to Accommodate Peak Charging Demand

S. No.	Charger Configuration	Peak Energy Demand	Number of Stations	Proportion requiring additional DT	Number and type of additional Transformers
1	3 Bharat AC-001 charging guns of 3.3 kW each 1 Bharat DC-001 charging gun of 15kW 1 Fast Charger gun of 50kW	75 kW	186	100%	100kW Transformers- 186 Nos.
2	3* Bharat AC-001 charging guns of 3.3 kW each 2* Bharat DC-001 charging gun of 15kW each	50 kW	1095	80%	63kW Transformers- 876 Nos.

3	6* Bharat AC-001 charging guns of 3.3 kW each	20 kW	644	20%	25kW Transformers- 129 Nos.

* These may be present in singular locations such as mall parking lots or distributed across an area like a residential neighbourhood.

Table 37: Cost of Installation and Total Investment Required by 2030[27]

S. No.	Cost Head	25kW Transformer (INR)	63kW Transformer (INR)	100kW Transformer (INR)
1	PSC Poles	3,000	3,000	3,000
2	Steel Structuring to Support Components	7,000	7,000	7,000
3	11 KV Horn Gap Fuses	4,000	4,000	4,000
4	Lighting Arrestor	2,400	2,400	2,400
5	Concreting of Base	1,500	1,500	1,500
6	Guy-wire set for stability			4,500
7	Earthing	1,600	1,600	1,600
8	Transformer	51,000	98,000	1,26,000
9	11kV Ring Main Unit		235,000	235,000
10	HT Metering Cubicle		140,000	140,000
11	Total Material Cost	70,500	492,500	525,000
12	Labor & Transport Charge @ 15% of Materials	10,500	74,000	79,000
13	LT/HT Cable Cost @ 30% of Materials	21,100	148,000	157,500
14	**Total Cost per Unit**	**102,100**	**714,500**	**761,000**
15	**Total Investment Required**	**19,000,000**	**625,900,000**	**98,200,000**
16	**In USD**	**$228,000**	**$7,511,000**	**$1,178,000**

The total investment required turns out to be around INR 74.3 Crore or USD 8.92 Million. This expense needs to be met urgently to ensure the move towards electric mobility is not stifled by the limits of the power distribution network of the city. They would be borne in part by DISCOMs, the charging point operators, and land owners for the charging station. These upgrades can be incorporated in a phased manner into the regular grid infrastructure expansions carried out by DISCOMs, and would focus first on areas of the city anticipating high charging demand.

These upstream infrastructure costs have been the biggest obstacle in setting up charging stations so far, as they often exceed the cost of installing the chargers themselves. In order to help meet these costs, the central govenrment has made a provision under the Revamped Distribution Sector Scheme (RDSS) through which DISCOMs can submit proposals to upgrade upstream infrastructure for charging stations, and receive funding. The charging infrastructure guidelines issued by the Ministry of Power also recommend availing funds through this scheme. In the past, it has been successfully used by the Kolkata government to support the rollout of charging infrastructure.

6.5. Summary of Recommended Initiatives

Table 38 : Summary of recommended initiatives over the short- medium- and long-term

Area of Focus	Possible Recommendations	Timeline
Smart Charging	○ DISCOMs need to tie up with existing charging network providers to receive real time data of charging demand	Short Term

[27] As per approved costing of PGVCL for a grid strengthening project and BESCOM estimates

	○ Implementing two-way communication between the charger, DISCOMs, and the charging network provider to allow dynamic Time of Use pricing and subscription models.	Medium Term
Adopting V2X Applications-vehicle-to-grid (V2G) and vehicle-to-building (V2B)	○ Creating data linkages between EVSE and DISCOMs to support future V2X deployment ○ Begin piloting V2G in locations with strong power grid infrastructure with the installation of bi-directional inverters and other monitoring technology ○ Begin piloting V2B solutions similarly in large building such as offices and malls.	Medium Term
	○ Develop the V2X market as deployment increases, including congestion management services to the Distribution System Operator (DSO), balancing services to the Transmission System Operator (TSO) and energy trading with Balancing Responsible Parties (BRPs). ○ Introduce role of V2G aggregators that organize returning power to grid on a scale that can meet its requirements.	Long Term
Upgrading Network of Distribution Transformers	○ Review the geospatial mapping of future charging demand, and partner with current and prospective charging operators for Lucknow to determine the initial areas where charging demand is high. ○ Identify missing or overloaded transformers in these areas, and upgrade them.	Short Term
	○ As charging demand and associated peak load will rise quickly post-2025, a large scale upgrade program will need to be carried out to meet the following years' demand. Bulk purchasing for this purpose can be done to bring down costs.	Medium Term
	○ Using the wealth of data generated by EVSE and provided by charging point operators, create models to predict upcoming charging demand and upgrade transformers accordingly.	Long Term

07

Renewable Energy Integration in Grid

7. Renewable Energy Integration in Grid

7.1. Introduction

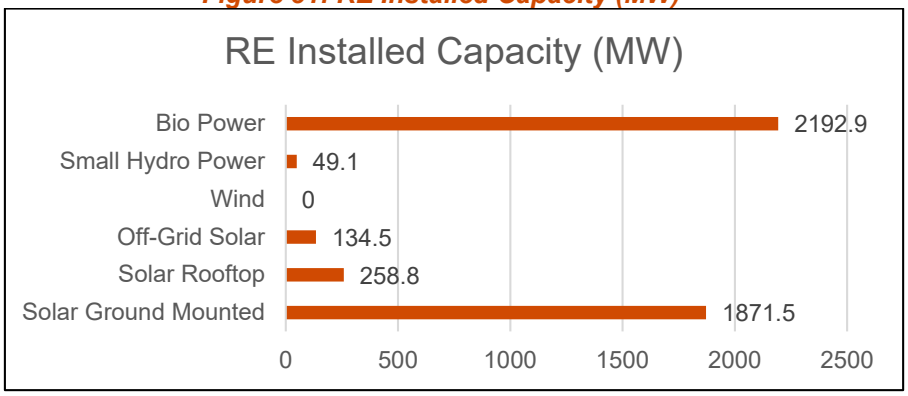
An important aspect of the move towards e-mobility is the switch to electricity as a power source, and how that impacts GHG emissions. The increasing share of EVs in the transport sector and the overall vehicle stocks can help reduce GHG emission significantly. However, with the introduction of e-mobility the major share of emissions from vehicles shift from tailpipe emissions to emissions associated with energy production. EVs do not have any tailpipe emissions, so by replacing conventional ICE vehicles with EVs, the pollution on road is reduced. However, these EVs do require power for charging. So in order to evaluate whether introducing EVs actually reduce the pollution or shifts the pollution from road to power production plants, further analysis needs to be done from the perspective of power supply. As a result, the emissions from EVs depend on the emission factor of the power supply used. That is, electric vehicles are only as clean as the power grid itself. Uttar Pradesh is one the most thermal power dependent states, with one of the highest contributions to the emission factor of India's power grid.

In this context, the use of renewable energy (RE) becomes even more important. The increase in proportion of RE integration in Grid will have a direct effect on the grid emission factor. This will supplement the emission reduction caused due to EV penetration. The increase in EV coupled with the increased RE source of power generation will show significant GHG emission reduction over a period of time. This chapter covers the current state of renewable energy in Uttar Pradesh, the benefits of a increased renewable energy mix, and how Lucknow can further integrate it into EV charging through smart solutions and rooftop solar.

7.2. Renewable Power in UP

The state of UP has total solar power generation installation of 2264.8 MW as per State-wise installed capacity of Renewable Power as on 30.09.2022.[28] The total RE installed capcity including solar, hydro and bio power is 4.5 GW as shown in the figure below. UP has no presence of wind power generation. There is a good potential in generating electricity from huge water reservoirs and canals and harnessing solar power. UP has over 75,000-km-long flowing canals, 33,800 government tubewells, 92 huge water reservoirs and 281 lift-irrigation canals.[29]

Figure 31: RE Installed Capacity (MW) [30]



[28] https://mnre.gov.in/the-ministry/physical-progress
[29] https://www.dailypioneer.com/2022/state-editions/up-looking-towards--renewable-energy-to--meet-power-demand.html
[30] https://mnre.gov.in/the-ministry/physical-progress

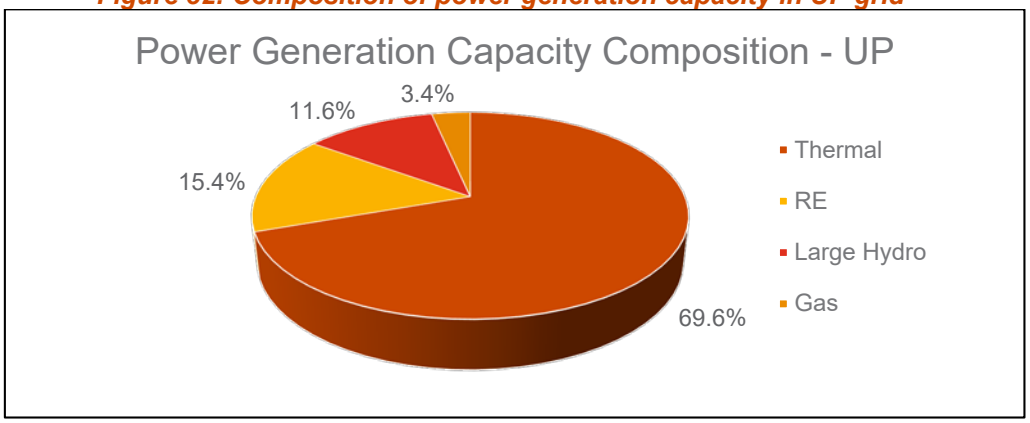
The PM-KUSUM scheme has innovative solutions such as the building of solar power plants on barren land, installation of solar pumps for farmers, and solarisation of existing pumps with the overall goal of ensuring energy security for the agricultural sector. In order to achieve the higher goal of reducing GHG emissions and move towards developing a net-zero-carbon transport system, the promotion of renewable energy as an energy source for EVs is necessary.

Grid mix and renewable integration – GHG Emissions

The overall GHG emission from vehicles comprises of both vehicle life cycle (cradle to grave) and fuel life cycle (well to wheel) emissions. The vehicle lifecycle emission considers the emission from production of different components along with their maintenance throughout the life of the vehicle, whereas fuel life cycle emissions are calculated based on the emission produced during production, transportation (well to tank) and consumption of the fuel (tank to wheel) for the vehicle's operation throughout life. The emission factor for all the associated activities is cascaded to give the overall lifecycle emission factors in gCO_2eq per km. These activities include glider and powertrain, battery prodction, maintennce, and fuel life cycle.

The state of UP has an overall generation capacity of 29.7 GW largely dominated by thermal power which accounts for approximately 70% share whereas, Renewable Energy (RE) generation capacity accounts for 15%. Due to the low utlilization of renewable energy, the actual power generation by RE stands at merely 4.3%. The plot below shows the current share of different generation types in the UP grid. With the current EV penetration and RE grid mix, the well to wheel emsision saving is negative. This effectively suggests that introducing EVs shift emissions from urban area to location where thermal power plants are situated.

Figure 32: Composition of power generation capacity in UP grid [31]



The installed generation capacity of the Indian grid[32] mix constitutes a share of 25% generation from renewable sources, increasing this share with time can complement towards the overall GHG reduction from transport sector. As India now follows the one-grid one-frequency system, increase in RE in any region benefits the entire country. Increasing the share of renewables in the current generation mix can significantly reduce emissions as the grid emission reduction efficiency increases. Currently, the emission factor for the power sector in India is considered to be 0.79 kg CO_2eq/kWh[33]. Using the emission factor for Indian grid and the EV penetration numbers considered, the emission savings comes out to be negative till 2025. The savings become positive as the number of EVs increases further after 2025. The negative savings in emissions is due to increased number of e-rickshaws; the e-rickshaws are replacing manual rickshaws, which have no emissions at all.

The model to estimate the well to wheel emission savings due to EV penetration based on the RE grid mix is used to predict the level of RE share in the grid at which there will be emission reduction. Increasing the share of renewables in the current generation mix can significantly reduce emissions as the grid emission reduction efficiency increases.

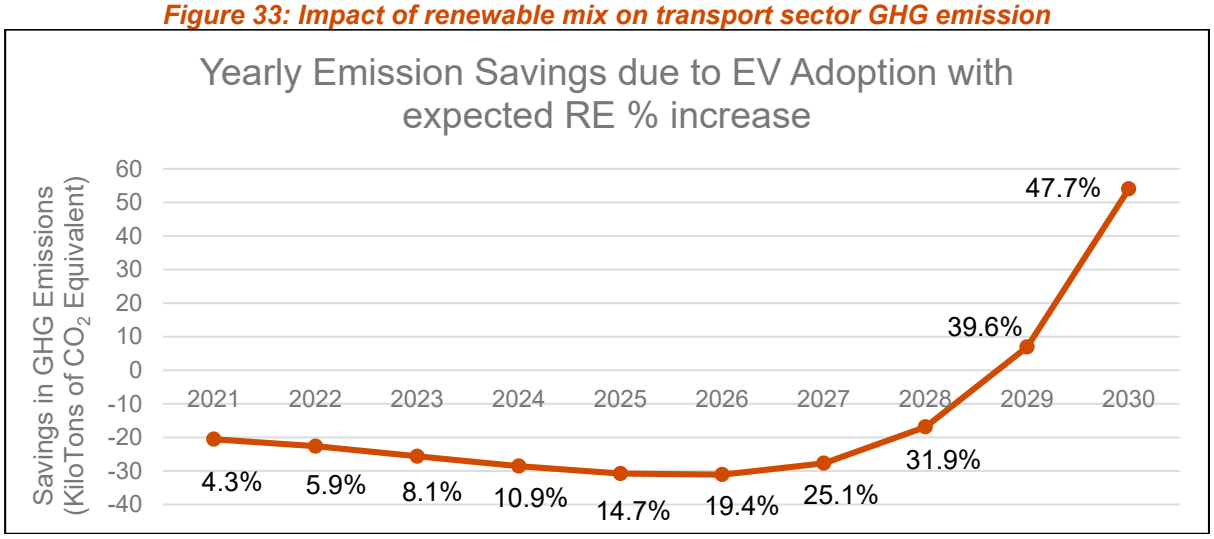
[31] https://cea.nic.in/installed-capacity-report/?lang=en
[32] Source: *MoP*
[33] Source: cea 2021

Benefits of Increasing Renewable Energy Share

The overall well to wheel emissions of an EV are influenced drastically with increase in share of renewables in the grid mix. The emission factor of UP is high due to high mix of thermal power generation in the grid. The effects of increase in share of renewable generation can be observed clearly on the overall GHG emission from the transport sector. With increasing share of renewables in the grid mix the transport sector emission reduces. However, the effects are more prominent with increase in share of EVs in the total number of vehicles on-road. Based on the EV penetration values and overall projected number of EVs and ICE vehicles between 2021 to 2030, it can be observed that significant reduction in GHG emissions is observed after 2028 when the Renewable energy share in the grid increases above 32%. The state of UP has a target of 47.7% renewable energy generation by 2030[34]. Based on the calculation of emissions saving, it is estimated that with 32% of renewable energy generation, there will be positive savings in emission because of EV as compared to traditional ICE vehicles.

The figure below shows the relationship between the percentage of renewable energy and the magnitude of GHG benefits in using EVs. The RE % increases from 4.3% to the set target of 47.7% in 2030. These results indicate that under current conditions, EVs does not reduce, but shifts the GHG emissions from urban area to thermal power plants, as the savings are negative. The emissions saving starts increasing as the EV penetration increases and renewable energy share in the grid mix increases or in other words, as the grid becomes greener. Once the renewable energy mix is above 32%, the positive results in emission savings can be observed.

Figure 33: Impact of renewable mix on transport sector GHG emission



7.3. Renewable energy integration for EV charging

If an EV charging station is powered by renewable energy sources, its dependency on conventional energy sources for charging is significantly reduced. The use of renewable energy sources for EV charging stations can be maximized in three ways:

1. Revising the MVVNL ToD rates to coincide with the peak renewable energy generation.
2. Installing renewable energy systems at charging stations.
3. Purchasing renewable energy from the open-access market.

Another major intervention is the use of battery storage solutions to store renewable energy during peak generation hours, for use during peak demand hours. A detailed study on this topic is given in the following chapter.

[34] https://ieefa.org/wp-content/uploads/2021/12/Uttar-Pradesh_A-State-Critical-for-Indias-Energy-Transition_December-2021.pdf

Revision of MVVNL TOD rates

Solar power is currently one of the most reliable renewable energy resources for UP. These solar PV systems generate the maximum power and energy between 11:00 hours to 15:00 hours in the daytime. The present ToD tariff structure of MVVNL does not offer any rate benefits between 11:00 to 15:00 hours. To increase the share of renewable energy resources in meeting EV charging demand, MVVNL must provide the ToD rate benefits during the solar PV system's maximum generation time (i.e 11:00 hours to 15:00 hours). This will increase the amount of renewable energy used for charging EVs in Lucknow.

Installing the renewable energy systems locally at charging stations or multi-storey buildings

The installation and use of Renewable energy systems for public EV charging at charging stations or for public and semi-public charging points in buildings can be enabled by means of mandates (30% of charging station demand must be met through renewable energy) or by providing subsidies or tax benefits to developers. Charging station developers or charge point operators can install renewable energy systems locally on-site and use the generated renewable energy for charging EVs. In case the generated energy is not being stored or used to charge any vehicles, it can be exported back to the grid with net metering. Not only does the use of on-site renewable generation reduce electricity costs for a CPO, it also reduces expenditure on upstream electrical grid infrastructure and saves energy losses in the distribution system.

Solar PV systems can be installed using the AC or DC interconnection methods.

i. AC interconnection method: AC interconnection method can be used for the locations where most of the existing loads are AC like residential apartments/multistorey buildings, any fuel stations, any office premises, etc. Solar PV string inverters are suitable for most of the locations free from shadow due to nearby buildings or trees and solar PV micro inverters are suitable for the location with shadow impacts in which string inverters are not suitable.

ii. DC interconnection method: DC interconnection method can be used for any new charging stations. In this method, the DC output from the solar PV system can be directly used to charge the EVs and it reduces the energy losses in DC-AC and AC-DC conversion process.

Any charging station developer or CPO can install solar PV systems alongside the charging infrastructure installation. The additional cost incurred can be offset by revenues from two streams:

i. Energy used to charge the electric vehicles: The user of the charging station pays for the generated renewable energy consumed by the EV for charging.
ii. Exporting the excess energy to the grid: MVVNL pays for the energy supplied to their network by the charging station, as per net metering regulations.

Alternately, a renewable power developer can install a solar PV system using a build-own-operate-transfer (BOOT) model, either at an EV charging station or at a building site which contains EV charging infrastructure. Here, CPOs or building owners can purchase renewable energy from the developer without incurring additional capital expenditure and can take ownership of the solar PV system after the contract period.

In cases where charging stations have sufficient space available on rooftops (including parking sheds, and buildings), the solar PV system can be installed at the charging station. Solar modules can be installed on the rooftop of any Reinforced Cement Concrete (RCC) buildings and sheds in the shadow-free area. The solar PV modules are available up to 550 Wp in polycrystalline or mono-facial/mono-PERC. As a rule of thumb, 10 sq. meter shadow-free area is required for installing a 1 kW solar PV module.

Suitability of on-site generation of renewable energy for EV charging is based on the available roof space at a given site. E-bus charging stations at bus depots and charging stations located within large, covered parking lots are good use cases for on-site renewable energy generation.

Solar-powered charging infrastructure for e-buses:

Solar-powered e-bus charging can support the operations of electric public transport networks in Lucknow using clean energy. Bus depots often have a substantial amount of roof area for installing solar PV systems for local generation and use. At the Dubagga bus depot, shadow-free space is available on the rooftops of the e-bus charging sheds and office buildings for the installation of solar PV modules. Figure 15 shows the charging shed for PMI Foton e-buses at Dubagga bus depot, which can be used for installing solar PV modules for electricity generation. The total area available on the rooftop is approx. 5,921 square meters (including 4,014 square meters on the shed and 1,907 square meters on the buildings); therefore, approximately 550 kW - 580 kW solar PV panels can be installed in Dubagga depot.

Figure 34: Solar Shed for PMI Buses

The approximate cost of implementing a 550kW solar PV system is approx. INR 2.4 to 2.6 crores, including taxes (see Appendix 7 for details). Considering that 1 kW of solar PV system produces 4 kWh of energy per day, the 550-kW solar PV system can produce an estimated 8,03,000 kWh of energy per year. As per the present MVVNL tariff structure, the energy cost for consumption of electric energy from MVVNL is INR 7.3 / KWh. For 8,03,000 kWh energy, the energy cost per year is INR 58.61 Lakh. The return on investment for the installation of a 550-kW solar PV system will therefore take about 4.4 years.

The energy consumption for e-bus charging (of both TATA and PMI buses) was 65,25,749 kWh between November 2021 and October 2022. The energy (i.e 8,03,000 kWh) from the 550-kW solar PV system therefore provides 12.3% of the e-bus charging energy requirements of the Dubagga bus depot. The energy from the solar PV system can be used to charge the e-buses as well as other loads in the depot. Whenever any e-buses are not charged during the daytime, the excess energy can be exported to the grid. If the LCTSL wants to utilize 100% energy from the solar PV system for e-bus charging, then battery energy storage system can be used to store the energy whenever the e-bus charging demand is less and deliver the energy later.

Case Study: E Bus charging using rooftop solar in Shanghai

In order to achieve 100% emission-free transport, the local bus transport company introduced electric buses into service and developed a solar-powered bus depot in Shanghai in China. It has 195 kW of roof top solar PV system installed on nearly 2,000 sq.m. area on the rooftop and the expected annual energy generation is up to 20 MWh. The installation of solar PV panels on the rooftop of the bus depot is shown in figure 15. The local bus company has 70 e-buses in services and the installed rooftop solar PV system can charge 6 e-buses at the same time, and it provides

electricity for other loads in the bus depot. The typical travel distance of these e-buses are 100 to 120 KM/day and it consumes 220 to 230 kWh energy. Any excess energy produced by the solar PV system is exported to the grid. Also, it reduced the emission of 6 tons of oxynitride and 160 tons of carbon dioxide.

Figure 35: Solar PV Powered Bus Depot in Shanghai

Case Study: On-site electricity generation on parking lot

In many locations like office premises and residential buildings, and public parking lots, vehicles are parked outside the building in a parking shed. Electricity can be produced by installing solar panels on the rooftop of the parking shed, and the same can be used for charging. A typical solar PV powered parking shed is shown in the Figure. Any excess energy produced by the solar PV system can be used by other loads in the building/system or exported to the grid.

Figure 36: Solar Shed for Parked Cars

Courtesy: https://www.automotiveworld.com/articles/driving-on-sunshine-ev-charging-goes-green/

Purchase of renewable energy for charging stations

For locations where adequate space is not available to install a solar PV system, renewable energy can be purchased from the competitive energy market. EV charging station developers or charge point operators can buy clean power from a competitive open access energy market like Indian

Energy Exchange (IEX) or through Power Purchase Agreements (PPAs) with renewable power developers. By using RE directly, EVs can produce emission savings faster without waiting for the entire grid mix of RE to change.

The MoP has significantly reformed renewable energy through open access, with its recently published (June 2022) regulations "Promoting Renewable Energy through Green Energy Open Access". This regulation states that any customer who has a power demand of at least 100 kW can buy green energy from the green open access market through open access portal. This allows charging station developers or service providers to avail of concessions on cross-subsidy surcharges, wheeling charges, transmission charges, and standby charges, thereby significantly reducing the cost of accessing renewable energy through the grid.

Any charging stations with demand of at least 100 kW demand can therefore directly purchase renewable energy through the competitive energy market like IEX, while availing the benefits of open access[35].

7.4. Summary of Recommended Initiatives

Table 39: Summary of recommended initiatives over the short-, medium-, and long-term

Area of Focus	Possible Recommendations	Timeline
Revision of MVVNL Time of Day Tariffs	○ Use Time of Day tariffs to direct EV charging demand to hours of maximum RE generation (i.e., 11:00 to 15:00)	Short Term
Installing the renewable energy systems locally at charging stations or multi-storey buildings	○ Install solar panels on electric bus depot in Dubagga to supplement EV charging with solar power. A 550 kW solar installation at the depot would cost INR 2.4-2.6 Crore or USD 288,000-312,000. Considering energy costs, the payback period would be 4.4 years.	
	○ Identify other large shadow-free spaces such as parking lots and building terraces for solar installation, install smart meters.	Medium Term
Purchase of renewable energy for charging stations	○ Create a single-window platform for charging point operators to avail green energy from the green open access market Identify missing or overloaded transformers in these areas, and upgrade them.	
	○ Upgrading renewable energy generation and transmission capacity in the state.	Long Term

[35] https://greenopenaccess.in/landing

08

Energy Storage Solutions

8. Energy Storage Solutions

The energy storage sector is poised to play an integral role in state level energy planning, given the ambitions plans for low carbon transition in electrification and mobility segments. The proposed trajectory for high level penetration of renewables- '16 GW solar by 2027', in conjunction with the large-scale propogation of electric vehicles by 2030, articulates the need for mainstreaming energy storage in Uttar Pradesh. In addition, the present challenges of managing the peak demand situation in the state, further supports a strong business case for adoption of battery storage.

At the same time, to bridge the demand side, supply side measures also need to be reinforced. To support the rising battery storage demand, local capacities in the form of battery and cell manufacturing also need to be developed. The manufacturing setup has to be backed by adequate R&D infrastructure, capacity building and innovation measures, incentives and financing, collaboration opportunities and strategic tie-ups.

Strengthening both demand side and supply side measures for energy storage will be a critical element for implementation of the envisaged CEMP.

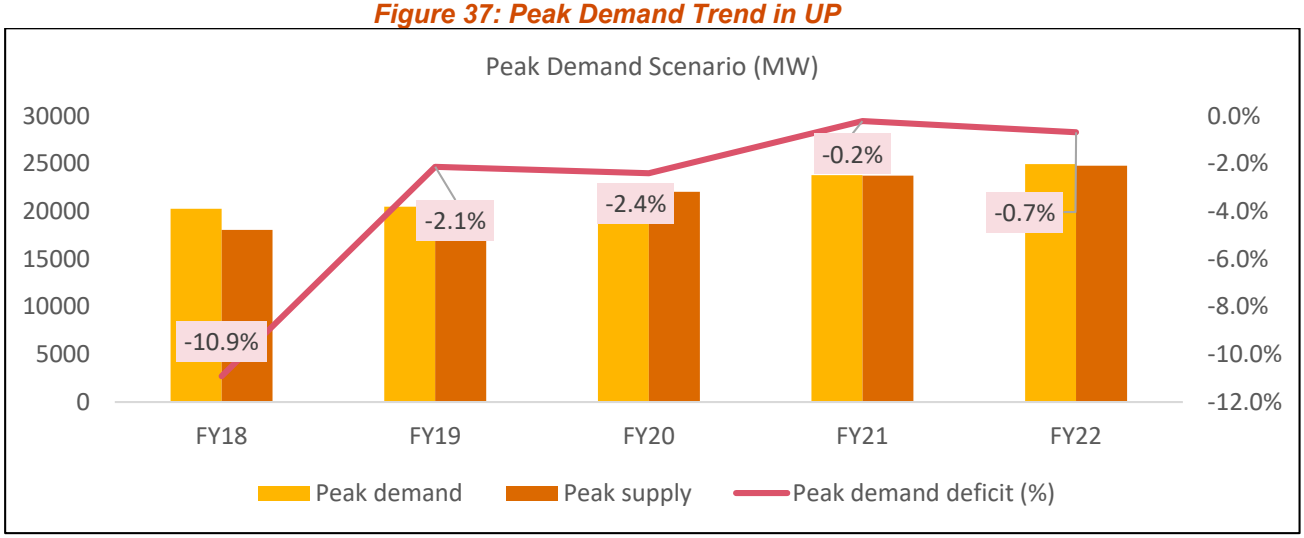
8.1. Key demand side avenues for energy storage

As aforementioned, energy storage demand in UP is expected to be shaped by the envisaged high volume of EV penetration, and ambitious renewable energy plans. These key application segments for battery energy storage have been analysed in subsequent sections.

8.2. Energy storage in managing peak demand and RE grid integration

Over the last 5 years, the peak demand in the state has been rising at a CAGR of 5.3%, with deficit ranging from 0.2% to as high as 10.9%. The state has an overall generation capacity of 29.7 GW[36] largely dominated by thermal (20.4 GW), followed by RE (4.5 GW), large hydro (3.4 GW), and gas (1 GW) based sources.

Figure 37: Peak Demand Trend in UP



However, with even close to 30 GW capacity, the state has faced 2.5-3 GW[37] deficit during peak hours. In September 2022, the peak demand created an all-time high of 26.5 GW. As per the 20th

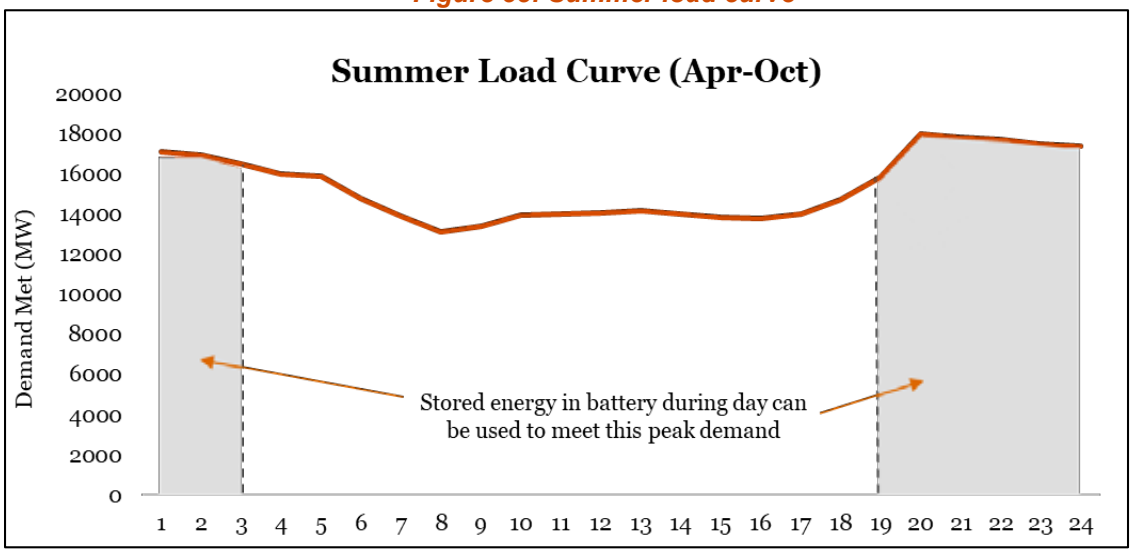
[36] CEA-Installed Capacity Report
[37] UPPCL petition

EPS, the peak demand in the state is expected to rise to 55.5 GW by 2037, at a CAGR of 5.5%. Hence, accordingly, generation side planning measures need to be undertaken.

In this context, battery-based energy storage can be targeted as an effective tool for managing peak demand and at the same time provide multiple benefits for state T&D utilities. BESS can be deployed to store excess energy from different sources during off-peak times (day) and discharged during peak time (evening hours) to meet the consumer demand. Both summer and winter load curves of the state point to evening level peaks (common peak during **19:00 to 23:00 hours**) as elucidated in the graphs below[38].

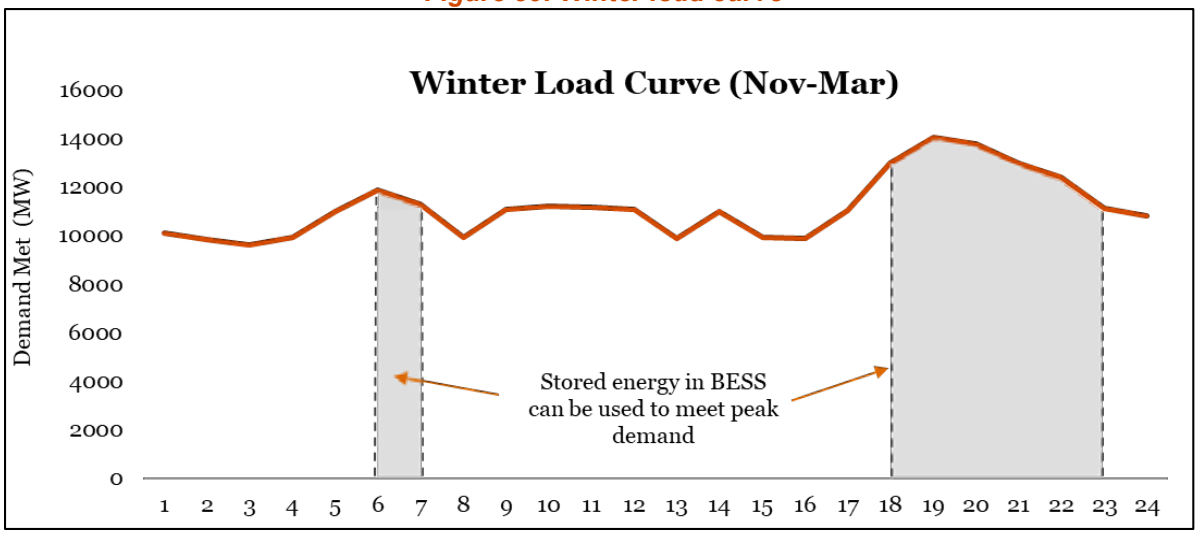
- **Summer Load Curve**: The peak hours can be observed from 19:00 hours to 3:00 hours in the months from April to October, with an average demand ~17 GW.

Figure 38: Summer load curve



- **Winter Load Curve**: The peak hours can be observed from 6:00 hours to 07:00 hours and 18:00 hours to 23:00 hours in the months from November to March, with an average demand of more than 11.5 GW.

Figure 39: Winter load curve



Currently, majority of the peak demand is being addressed by coal fired stations (operating at high PLF), many of which have higher fixed cost due to R&M expenses. In addition, the variable charges of

[38] UPERC, UPPC: https://www.uperc.org/App_File/AmplusGreenPowerOrder-PDF122202140517PM.pdf

these thermal stations are also susceptible to demand-supply of coal, and in recent times there have been rise in costs due to shortage of coal. Moreover, a large capacity of thermal plants in UP, about ~3 GW, has been operating for over 25 years and may retire soon.

In this context, for charging BESS during daytime, a strategy involving combination of solar energy system+ battery can be deployed. During afternoon (typically, 12:00-14:00 hours), the excess generation from low cost solar can be stored in battery system and released in the evening to meet the demand during peak hours (19:00-23:00).[39] Historically, the solar generation during this time slot is expected to be maximum and above strategy is also in alignment with UP Solar Policy 2022[40], which targets high level of solar penetration in the grid-10 GW utility scale solar projects, along with 2 GW distributed solar. The current installed solar in UP is only approximately 2 GW, whereas in next 5 years it is expected to increase by 16 GW to reach approximately 18 GW by 2027 as per policy. Hence, the generation from solar in daytime is expected to increase by huge amount, which can be stored and released during peak time 19:00-23:00 (as per UPSLDC 2022). The historical data for peak solar generation for few days has been indicated below[41].

Table 40: Solar availability for select days during different time slots, UPSLDC

Solar Availability (in MW) during different time slots									
Date-Month, 2022	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
Aug-13	812	806	929	1028	954	780	608	350	131
Sep 13	601	676	755	839	836	623	356	155	13
Oct-13	1203	1341	1347	1366	1282	925	575	180	12
Nov-13	1220	1410	1470	1397	1136	798	409	79	7

Apart from managing the peak load, by deploying RE+BESS based system, the state T&D utilities will be able to defer the cost associated with augmentation of distribution and transmission infrastructure (CAPEX deferral). At the same, the strategy will support UP DISCOMs in reducing their power purchase cost (PPC) by minimizing the need to procure power from costlier source[42] or power exchanges at higher rates during peak times. In addition, BESS can provide the voltage support to connected PV generation to support the power quality of the grid.

Lastly, by installing BESS in downstream of the congested transmission sections, electricity can be stored during peak times and released when the congestion levels have dropped. This presents a useful business case for integrating BESS at transmission level to manage transmission congestion

8.3. Energy storage in supporting EV Charging

The electric vehicle segment is a critical demand driver for the state, considering the growing population and urbanization level. The UP EV policy 2022[43] has also laid out aggressive targets for EV and EVCI to stimulate demand, including 100% transition of public transportation and government vehicles to EV in major cities[44] by 2030, development of charging infrastructure in every 25 km along Expressways/Highways, and creation of charging/swapping facilities in public and commercial space. Such high level of EV penetration may entail increase in demand during evening/night peak hours, further aggravating peak demand situation in the state. From the EV charging load curve pertaining to

[39] https://www.eass.upsldc.org/eass/docbase/mis/peakhours.pdf (Evening peak hours in UP)
[40] http://upneda.org.in/MediaGallery/Uttar_Pradesh_Solar_Energy_Policy2022_English_draft_one-07-08-22-final.pdf
[41] https://www.eass.upsldc.org/eass/portal/mis/PortalMISReports.jsp, UPSLDC 2022
[42] The average power purchase cost of thermal plants generally sees an upward escalation and as such many power plants will have energy charge more than INR 2.49 per unit
[43] Uttar Pradesh Electric Vehicle Manufacturing and Mobility Policy 2022
[44] Including Lucknow

Lucknow as well as the power demand curve, it is evident that the peak time for EV charging coincides with actual peak at city/state level. Hence, the case for charging the battery with solar during day and releasing the stored energy during night time (peak for EV charging in Lucknow is 10:30 pm) is strong. Here again, BESS solution can be targeted to support increasing uptake of EVs in the state.

- **RE+ BESS+ EV Charging**: By implementing RE+BESS with EVCI, the state can reduce overall carbon footprint by lowering GHG emissions from both vehicles and conventional power plants. The proposition further reduces the strain on the grid and mitigates the need for additional investment on non-RE based resources to deliver the required quantum of energy.

Although the solution has seen limited traction in the country, the strategy has been deployed successfully globally, specially involving solar rooftop-based charging. Charging via solar rooftop helps in meeting the EV power demand requirement without burdening the distribution lines and further mitigates distribution losses. Alternatively, RE power maybe sourced through open access route, which will involve exporting power over long distances, and can lead to significant T&D losses. Hence, installation of RE system closer to EV load or at the charging station itself is the best fit option.The proposed solution has been explained in the flowchart below.

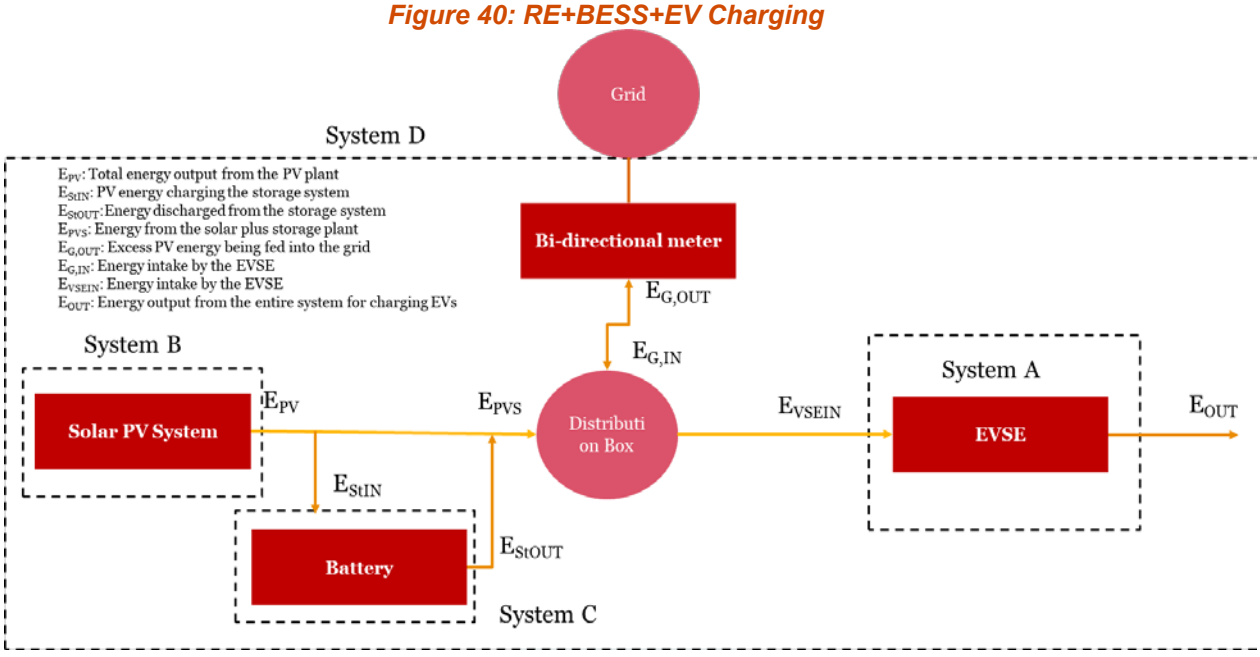
Solar+ BESS+ PV Carport in Ladakh

In Aug 2022, Convergence Energy Services Limited (CESL) developed first of its kind solar powered EV station in Ladakh involving solar rooftop installations on carport. 100 kW solar panels with 860 kWh Li-ion battery storage system have been deployed to charge 10 no. of 4-W EVs (Hyundai Kona). Provision for exporting surplus power from the solar carport for captive needs of buildings has also been provided, incase charging is not needed.

Driivz supports the integration of renewable power and smart EV charging in Netherlands

ElaadNL, the knowledge and innovation center in the field of smart charging infrastructure in the Netherlands, has put renewables (solar and wind) into action, combined with smart EV charging energy management. They are balancing the energy demands of 57 charge points, reducing total demand, and leveraging clean energy. Furthermore, they're getting real-time insights about the charging station uptime and alerts when things go wrong through the smart meters. The data is combined to deliver analysis of energy used for EV charging and as well as the quality of the electricity and the available energy levels. ElaadNL has fine-tuned the system to define which chargers receive green energy only, allowing it to optimize usage.

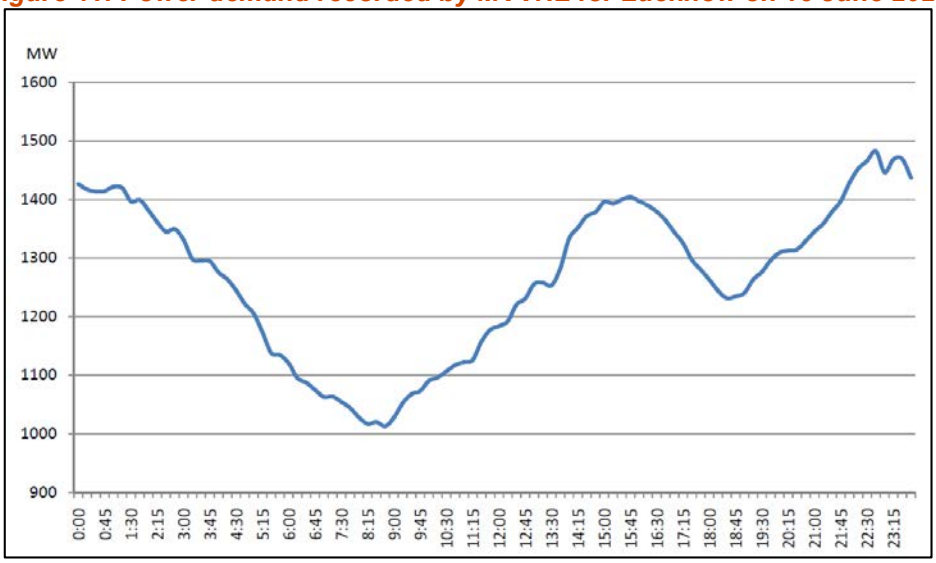
Figure 40: RE+BESS+EV Charging



Within this proposed solution, solar energy will act as the primary source of power for supplying to the EV charger. If the RE system is deficient, then BESS will step in to supply the remaining power. However, if both solar and BESS are unable to meet the demand, energy from the grid can be used to supply the remainder. When the EV is not available, battery can be charged with the solar, and can be used to supply to the grid. Optimal solar technology option- carport, ground mounted, and rooftop as per space availability and type of location will have to be assessed. The UP Open Access Regulations 2019 also permits consumers to procure power through open access mode under captive or third-party sale option.

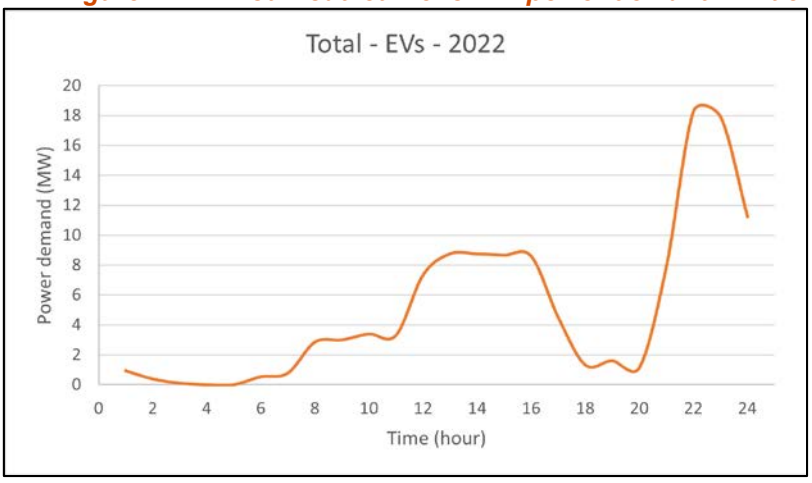
At city level, the 24-hour load profile for Lucknow recorded for previous years, provides specific insights into consumer behavior for EV charging. The load curve for Lucknow city during a typical summer day has been presented below, having a peak load of ~1500 MW at night (22:30 hours).

Figure 41: Power demand recorded by MVVNL for Lucknow on 15 June 2022



In addition, the EV charging power demand for the city for the year 2022 has been presented below.

Figure 42: 24-hour load curve for EV power demand in Lucknow



The maximum demand for EV charging coincides with the overall peak demand hours (19:00 hours-23:00 hours) for the state. The recorded peak is about 18 MW at 22:00 hours, with consumers charging their EVs at nighttime. A similar trend is expected in the future also, with rising EV penetration, further contributing to the peak demand at night. Hence, the case for charging the battery with solar during day and releasing the stored energy during nighttime (peak time for EV charging in Lucknow) exists.

The implementation strategy for RE+BESS+EV at city level will involve techno-commercial assessment to assess feasibility for individual component EV charging station, RE integration and battery sizing. The following approach can be adopted for optimal project deployment.

1.Optimal location identification and site assessment for setting up EV charging station

- Geo-mapping: Defining project layout and boundaries, including mapping of sites on grid
- Mapping space availability for optimized usage
- Assessing number of vehicles to be charged at single point
- Estimation of charger requirements
- Analyzing overall adequacy of location of EV charging

Grid Connectivity and Load Assessment

- Assessment of overall load profile, demand pattern, in.cluding peak demand analysis
- Analysis of current electrical infrastructure and current generation
- Assessing electricity tariff

Solar feasibility assessment

- Assessing optimal solar technology option as per space availability and type of location identified- carport, ground mounted, and rooftop
- Conducting site assessment to estimate solar resource, civil and electrical infrastructure requirement for solar deployment
- Conducting energy yield assessment to analyze yearly output
- Conducting system sizing, including preparation of BOM
- Analyzing overall power evacuation and implementation strategy

•Battery Sizing

- Conducting battery sizing for solar+ BESS charging by analyzing following key factors: Operation hours, Autonomy days, Solar charge controller efficiency, Inverter efficiency, Battery DoD, EV Charger Efficiency (AC to DC), Rate Factor and Temperature Derating
- Analyzing case for surplus or deficit from Solar+ BESS, post EV charging (injection or withdrawal from grid)
- Analyzing need for additional battery requirement, given insufficient solar
- Designing overall implementation strategy in commercial setting

•Impact Assessment

- Financial assessment covering IRRs, payback, etc.
- Socio-economic impact on local community
- Project deployment risks related to solar+ BESS deployment for EV charging

- **BESS+ EV Charging:** The battery storage technology may be deployed for EV charging by directly using energy from the grid - charging the battery during the off-peak hours from the grid, and then using the stored energy to charge the EV during night or peak hours. Such a proposition

again allows for commercial benefit of reducing consumption during peak hours, however, does involve electricity from conventional fuel for battery charging. The solution may be implemented in areas involving space constraints, where installation of RE/solar or sourcing power through open access is not possible.

8.4. Cost economics of battery storage solutions

The commercial economics becomes a vital element for large scale adoption of battery storage across key consumer applications. With the supply chains becoming more resilient, and improvements in material science and R&D, the cost of manufacturing batteries has reduced substantially over the years, improving the business case for storage-based solutions. Added to this, the economies of scale for matured cell chemistries such as Li-ion have further supported downward trajectory of battery pricing. As per BNEF estimates, the cost of Li-ion battery pack is projected to reduce from 135 USD/kWh to 62 USD/kWh by 2030. Since batteries comprise a significant portion of the overall cost for battery storage project (40-50% in $/kWh terms), the cost for implementation of energy storage is expected to reduce significantly in the next decade. The Department of Energy (DoE)[45], USA estimates the price for different cell chemistries for battery storage implementation, as indicated below.

Table 41: Global Li-ion battery-based storage cost estimates for 2030

Storage Component	LFP Technology (1 MW, 4-hour system)		NMC Technology (1 MW, 4-hour system)	
	2021	2030	2021	2030
DC Storage Block ($/kWh)	182	119	215.5	141
DC Storage BOS ($/kWh)	42	31	41.3	30.8
Power Equipment ($/kWh)	84	74	84.6	74.8
C&C ($/kWh)	40	29	40	29.8
System Integration ($/kWh)	50	42	56.6	48
EPC ($/kWh)	61	51	68.9	58.4
Project Development ($/kWh)	73	62	82.7	70.1
Grid Integration ($/kW)	30.9	26	30.9	26.2
Total Installed Cost ($/kWh)	**448**	**340**	**504**	**381**
Total Installed Cost ($/kW)	1793	1362	2016	1525

The global costs for utility-scale battery storage are on a higher side (**~INR 12-13 Crores/MWh**), given the increased cost of project development, EPC and system integration and associated costly manpower. In comparison, the cost of battery storage projects in India, is increasingly becoming competitive as deployments rise. Aggressive tendering involving RE+BESS, Round the clock (RTC), standalone storage, and hybrid technologies at state and central level in last 3-4 years has improved the commercial viability for storage solutions. Some of the cost-details of recent project tenders have been analysed below.

- In 2021, Tata Power won SECI's auction for a 20 MW solar power project with a 50 MWh battery energy storage system to be deployed at Phyang, Leh-Ladakh. The cost of the awarded project was around INR 3.86 billion (O&M cost for 20 MW solar project for 10 years was fixed at INR 181.71 million)[46] The cost of battery storage component is estimated at **INR 5.92 crores / MWh**[47].

[45] 2022 Grid Energy Storage Technology Cost and Performance Assessment Report, DoE
46 https://www.livemint.com/industry/energy/tata-power-solar-to-set-up-large-scale-battery-storage-of-50-mwh-at-leh-11628774146465.html
[47] Assuming 4.5 Crore/MW cost for solar project

- In 2022, JSW energy won the auction to set up pilot projects of 500 MW/1000 MWh battery energy storage systems by quoting INR 1.08 million / MW/ month[48] , translating into **INR 7.76 crores/ MWh** with a project tenure of 12 years

- In Dec 2022, Greenko won NTPC's tender for 3000 MWh energy storage project by quoting INR 3.8 million/MWh/year[49], translating into **INR 9.5 Crores /MWh** for a project tenure of 25 years

Given the latest trends in Indian markets, the cost for standalone battery storage project is estimated at INR 8-10 Crores

8.5. Energy storage manufacturing landscape

As indicated before, the demand for advanced cell chemistries (ACCs) and lithium-ion batteries in the state is expected to increase significantly in the coming decade on account of increasing penetration of EVs in the transport system, RE integration with the grid, behind the meter usage, and consumer electronics applications. To meet this growing demand, the supply side measures need to be strengthened. Currently, the UP government does provide many incentives to attract investments to encourage domestic manufacturing of battery and related components in the state.

UP EV Policy 2022 Manufacturing Support

- Promotion of EV Clusters to cater to EV battery and related component manufacturing
- Provision of external infrastructure like roads, power, water, drainage, waste management, etc.
- Encouraging R&D on next generation of battery management systems, battery chemistries, fuel cell systems and intelligent transportation systems
- Creation of dedicated land banks with trunk infrastructure for potential EV investors in the state
- Single window clearance for timely clearances and approvals through Nivesh Mitra
- Fiscal Incentives based on size of project
  - Ultra-Mega Battery Project: 30% capital subsidy of eligible fixed capital investment subject to max INR 1000 Cr per project
  - Mega Battery Project: 20% capital subsidy of eligible fixed capital investment subject to max INR 500 Cr per project
  - Large Battery Project: 15% capital subsidy of eligible fixed capital investment subject to max INR 75 Cr per project
  - MSME project: 10% capital subsidy of eligible fixed capital investment subject to max INR 5 Cr per project
- 100% Stamp duty reimbursement to integrated EV Project & Ultra Mega Battery project; For other categories 50-100% reimbursement, depending upon region
- 50% reimbursement of fees paid for obtaining quality certification
- 75% reimbursement of patent registration fees for acquiring domestic/international patent
- Skill development incentives in the form of stipend of INR 5000 per employee per year
- Establishment of Centres of Excellence (CoE) in the field of EV/ Battery / Charging

In terms of manufacturing landscape, currently, either lithium-ion cells are imported from China and assembled into battery packs in the state, or already assembled battery packs are imported to be sold directly to the consumers There are numerous battery pack manufacturers operating in the state meeting the demands of various industries, as tabulated below.

Table 42: Key battery players in UP

Battery Player	Manufacturing Capabilities
Karacus Energy	• Leading lithium-ion battery pack manufacturers in Uttar Pradesh providing powerful, durable, reliable, lightweight, maintenance-free, and customized battery packs for EVs in the state

48 https://mercomindia.com/jsw-renew-energy-wins-seci-tender-1gwh-bess/
49 https://mercomindia.com/greenko-wins-ntpcs-3000-mwh-energy-storage/

PPAP Technology Limited	• Established a lithium-ion battery pack manufacturing facility in Noida with an installed capacity of 150 MW per annum with target customers in mobility and storage segments
Sunflare Solar Private Limited	• Leading manufacturer of the lithium-ion battery pack from Ghaziabad-manufacturing LFP battery packs for solar streetlights and other small-scale stationary storage applications
Electratech (sub-assembly of Samsung India Electronics Limited)	• Established an automated assembly line for battery pack designing and manufacturing in Noida for consumer electronics applications particularly mobile phones

Some players are also in decision making phase and planning to establish manufacturing facilities in the state. For example, 'Lohum', an integrated lithium-ion battery solution provider has announced that it will set up 3 GWh capacity single-location integrated lithium-ion battery manufacturing and recycling factory in Noida, within the next year. The integrated factory will incorporate a recycling capacity of 2 GWh annually and a battery manufacturing capacity of 1 GWh, with a total investment of INR 300 Cr. Currently, Lohum has two 300 MWh co-located plants for the production and recycling of Li-ion batteries. Similarly, a prominent US player with Indian subsidiary- 'Power Global India' is also targeting to set up 1 GWh battery plant in Noida, capable of producing 4 lakh batteries per annum.

The battery manufacturing ecosystem in UP to a large extent will be driven by the success of UP EV policy, which targets sizeable investments across the value chain. In addition, efforts are being made at central level by Niti Aayog and other agencies to promote giga-scale battery manufacturing facilities under ACC-PLI and Niche-ACC tendering.

8.6. Summary of Recommended Initiatives

Some key action points, along with timeline to improve battery manufacturing ecosystem for the state have been presented below.

Table 43: Summary of Recommended Initiatives over the short, medium, and long term

Key Challenge	Possible Recommendations	Timeline
Policy	○ Development of a battery manufacturing roadmap/vision document with specific targets for battery production to cater to growing demand.	Short Term
	○ Undertaking pilot project for RE+BESS+EV charging to demonstrate use case and easy replication	
	○ Spurring up battery storage demand in the state by incentivizing demand creation avenues. For e.g., the demand for RE+BESS+EV charging may be improved by providing ToD tariff for renewables during peak times. In addition, state should be more aggressive in pursuing BESS based tendering to create pipeline and visibility for manufacturers to step-in.	
	○ Supporting battery manufacturing ecosystem by providing incentives across the value chain (other than battery pack)	Medium-Term
	○ Government may explore providing financial support to DISCOMs to set up grid storage solutions and charging infrastructure. The user fee collected through use of common infrastructure	

	may be paid back to government over a period to recoup the initial investment	
	○ Developing policy programmes for longer duration with minimal amendments to gain investor confidence (preferably 7-10 years)	
Creation of more robust supply chain for EV battery/component manufacturing	○ Engaging in technology partnerships for setting up processing and refining facilities in the state for key raw materials, and promote manufacturing of downstream battery components (cell, anode, cathode, electrolyte, etc.).	Medium Term
	○ The state government with support from central agencies can look to work with mineral companies and enter long term contracts and strategic tie-ups for supply of critical battery minerals, given the concentrated nature of supply chains globally	Long Term
Trunk infrastructure	○ Identification of new land parcels for development of battery manufacturing/EV parks for manufacturing	Short Term
	○ Undertake development of trunk infrastructure to boost manufacturing- easy logistics, connectivity, utilities (power, water), and waste treatment (sewage/effluent/battery scrappage)	Medium Term
R&D and testing infrastructure	○ Engage prominent R&D institutes (such as IIT, NIT, etc.) actively engrossed in research and innovation on new emerging battery technologies, cost reduction strategies, cheaper alternatives, and material science. Such capabilities will be needed to improve competitiveness and gain familiarity with latest emerging trends	Short-Long Term (Continuous Process)
Capacity Building and Awareness	○ Workshops and other public consultation programmes should be undertaken with investors to brief about key incentives, overall plans and vision of the state for improving its attractiveness	Short Term
	○ Developing skilled manpower base in areas related to mineral extraction, processing, refining, and recycling, by organizing study tours/visits or engaging international consultants	Short-Long Term (Continuous Process)
	○ On the financing front, the government needs to undertake capacity building of local banks and key financial institutions in the state to reduce risk perception for better lending terms, interest rates, collateral demanded, and overall loan appraisal process for battery storage manufacturing	Medium Term

09 Battery Recycling

9. Battery Recycling

Battery recycling and waste management is a critical area for future given the upcoming battery manufacturing facilities in the state and the associated environmental costs. The production of batteries generates a significant amount of scrap waste that needs to be properly processed and recycled to limit risk of release of hazardous toxic gases in the environment. If the increasing amount of battery waste is not handled properly, these batteries could end up in a landfill and create environmental hazards. For example, lithium-ion battery wastes can get absorbed and accumulated in edible plants and can enter the food chain, thereby causing various genetic, reproductive, and gastrointestinal problems. Additionally, the need for raw material and critical battery minerals is anticipated to rise dramatically in sync with the state's rising demand for batteries. Given, there are only few natural deposits of critical battery minerals, it is practically necessary to have recycling infrastructure and technologies in place to meet the demand of battery makers.

Li-ion batteries, typically used in EVs contain critical minerals like lithium, cobalt, manganese, graphite, and nickel which have high energy density thus extracting them is essential both economically and commercially. The share of battery minerals present in different Li-ion batteries has been analysed below.

Table 44: Share of battery minerals in Li-ion Batteries

Metals	Share found in Battery Chemistry (% of battery weight)	Abundance
Cobalt	LCO (15%), NMC 111 (5%), NMC 622 (2%) NMC 811 (3%) and NCA (2%)	Rare Metal
Nickel	NMC 811 (13%), NCA (11%), NMC 622 (10%) and NMC 111 (5%)	Rare Metal
Lithium	NMC, LFP, LCO, NCA and LTO [All 2-3%]	Abundant
Copper	LMO (16%), NCA (12%) and LFP (11%)	Abundant
Graphite	LCO, NCA and LMO (15% each)	Abundant

In India, recycling lithium-ion batteries is majorly done via two channels- ‘end-to-end recycling, and ‘mechanical extraction of black mass’. Under end-to-end recycling the player undertakes the complete operational aspect of the recycled product starting from receiving the used batteries from collection centres, extraction of black mass, and segregation of critical minerals to finally making the recycled batteries. This model is not widely adopted yet in India due to policy and demand issues and technology barriers. Although, with the entry of big players into the market, the scenario is forecasted to change.

The other mode of lithium-ion battery recycling in India is the extraction of black mass via a mechanical process (dismantling). In this, the companies receive the used batteries from the organized and unorganized sectors and by using the mechanical process extract the black mass (separating aluminium, cobalt, and plastic components from the rest of the materials left in the form of a black mass). They further send it to other large companies which are technologically equipped to extract minerals out of the black mass or transport it to their centralised hub in foreign countries. Currently major players in recycling of batteries and electronic waste in India are either doing black mass only or stops after extracting 2-3 metals.

Since Uttar Pradesh had the largest EV sales in India in 2022, developing a strong recycling ecosystem in the state can aid in determining the resale value of batteries for reuse/recycling applications. Resale risk is one of the asset risks that is currently hindering the confidence of financial institutions in mobilizing finance for EVs. While collection and recycling of end-of-life Li-ion batteries will recover the value of the minerals, the value of the residual capacity can be captured through second-life applications. This way, creating a resale market for batteries from EVs, can reduce the asset risk that financial institutions perceive. This will increase the mobilization of finance for EVs, thus improving the adoption of EVs.

A circular economy for battery components is thus becoming an increasing necessity.

BatX Energies- Leading player for battery recycling in India with recycling facility located in Noida, UP

Only a few e-waste recyclers in India operate with lithium-ion batteries, and one such business is 'Batx Energies Pvt. Ltd'. Batx developed its lithium-ion battery recycling facility in Noida, with a capacity of 5000-10000 tons per annum. The facility recycles used lithium-ion batteries to extract battery metals chiefly lithium, nickel, cobalt, and manganese which are then supplied to battery cell manufacturers to create a closed-loop circular economy for lithium-ion cell manufacturing.

The plant can recycle batteries used in all types of applications ranging from electronics to electric vehicles. After years of scientific research and experimentation, Batx has developed its own proprietary Net Zero Waste, Zero Emissions process for recycling end-of-life lithium-ion batteries.

The batteries coming for recycling are initially completely discharged (pre-treatment) and are then crushed using a mechanical separation unit for the physical separation of the core elements. They extract a black mass of less than 1% impurities from used lithium-ion cells. Thereafter, using their proprietary process, they extract the highest quality salts of critical minerals such as Li, Co, Ni, etc. These extracted minerals are then sold to the national and international battery material leaders and refining companies following a global pricing mechanism based on market discovery.

The company has recently raised USD 2.3 million in a seed funding round led by JITO Angel Network and Hero Family office to establish a commercial-scale rare earth battery materials extraction plant with artificial intelligence (AI).

9.1. Key Challenges for Battery Recycling

Battery recycling is a multistep process, which requires proper logistics to procure scrap batteries, capital-intensive plant setup, and additional technologies and cell chemistries that are feasible for long-term business. Some of the key challenges pertaining to recycling have been discussed below.

- **Lack of policy on battery recycling/reuse**: There is no concrete state level policy on battery recycling/reuse mandating waste batteries to be collected and sent for recycling to prohibit disposal in landfills and incineration. Limited availability of collection centres for end-of-life batteries further exacerbates the issue. Also, establishment of recycling plant requires significant upfront CAPEX, and the margins for recycling of some battery chemistries (such as LFP) may not present an appealing case for recyclers. Hence, all these issues need to be addressed through a well-defined policy instrument.

- **Lack of waste handling regulations, standards, and certifications:** Li-ion batteries are considered hazardous since they have corrosive, flammable, toxic, and explosive characteristics. Most of the collection of batteries is through informal mechanisms hence it lacks standards for collection and transportation. This may pose a great risk of any mishap.

- **Usage of battery minerals in alternative industries:** The battery minerals (such as lithium, cobalt, graphite, nickel, manganese) obtained via the recycling process are majorly used in other industries like aviation, pharmaceuticals, ceramics, cement, etc. This leaves limited raw material to flow back to the original battery manufacturer, thereby influencing the circularity prospect.

- **Labs for quicker testing:** The number of labs for validation of diverse materials of different batteries is limited. In addition, the generation of final test report is a time-consuming process.

- **Economic Feasibility:** The economic value of recycling batteries is primarily dependent on the battery chemistry (assuming full recovery efficiency). Although LFP is one of the most extensively used battery chemistry, the margins involved in LFP recycling are not very appealing to recyclers due to the lower economic value and high recycling costs. Furthermore, LFP does not contain any valuable metals except lithium, which is present in a very small quantity. Therefore, recyclers must tailor their processes to boost plant productivity and the ability to process a wide range of battery chemistries

- **Capacity Building:** In the absence of any manufacturing facilities for Li-ion battery production in the country, the manpower has limited skillsets to be deployed in upcoming facilities and would require time and effort to learn new skills.

9.2. Key Recommendations for Battery Recycling

In order to improve the battery recycling network, it is necessary to have a robust battery recycling and disposable ecosystem in the country.

- **Development of policy on state level battery recycling:** An investor friendly policy attracting more players in the battery recycling/reuse space needs to be developed. The government should facilitate setting up of collection centers for end-of-life batteries at dealerships by battery manufacturers in consultation with UP Pollution Control Board (UPPCB) for battery recycling at these centers. In addition, the government should support in creation of battery disposal facilities in vicinity of charging stations. Incentives in the form of streamlined procedures with a focus on single window clearance, resolving land acquisition issues, developing trunk infrastructure, manufacturing clusters, and cheap and uninterrupted power supply will be required.

- **Tie-ups for setting up collection channels:** Several informal sector players can be leveraged to establish proper battery collection channels. Owing to such tie-ups, a formal communication channel has been established between the collection recenters of the recycler with that of the informal battery collectors.

- **Mandating specific recovery rates:** There is no provision as of now regarding the amount of material recovery that is expected from the batteries. Fixing specific recovery rates will encourage more participation from the formal sector while helping in the development of a healthy supply of raw materials for battery manufacturing. The recovery rates can be set as per the battery technology/ chemistry and should be suitably reviewed and updated continuously.

- **Skill development:** The recycling hubs shall require trained manpower to scale up operations. The network of Industrial Training Institutes (ITIs) may be leveraged by introducing courses related to battery recycling processes. Courses through Skill India centres may also be updated to include battery capabilities

- **Establishing labs for faster sample checks:** The process of obtaining the final report will be sped up by the establishment of new labs for the validation of heterogeneous materials of various batteries as well as the determination of the purity of the recycled material. Therefore, by facilitating quicker analysis, it will be easier to determine the intended use of the recycled minerals, resulting in lower storage costs.

- **R&D for efficiency improvement in the recycling process:** The recycling process needs to be designed in such a way that it provides flexibility to treat various battery chemistries and shapes. This added flexibility may add costs in setting up the process but will increase plant productivity and recycler profits. For example, LFP is not suitable for pyrometallurgy or hydrometallurgy owing to the presence of phosphorous ions. The operation cost could be reduced by 30% if LFPs are processed separately as they do not contain cobalt or nickel.

UP EV Policy: The State Government shall promote setting up of 'Collection centres' for end-of-life batteries at dealerships by EV/Battery manufacturers in consultation with UP Pollution Control Board (UPPCB) for Battery recycling at these centres. The State Government shall promote 'Battery disposal facilities' at Swapping/ Charging Stations.

Several guidelines and strategy documents have been notified by the Union Government which includes, the National Electric Mobility Mission Plan (NEMMP) 2020, Model Building Bylaws 2016 (Amended in 2018) & Urban Regional Development Plans, Guidelines and Standards for Charging infrastructure for EVs, National Mission on Transformative Mobility & Battery Storage, Scrapping Policy, etc.

The key action points, along with timeline for implementation for battery recycling for the state has been presented below.

Table 45: Summary of Initiatives over the short, medium, and long term

Key Challenge	Possible Recommendations	Timeline
Lack of policy and regulations on battery recycling/reuse	○ Development of concrete policy framework comprising of subsidies, single window clearance, tax exemptions, and other fiscal and non-fiscal incentives.	Short-Term
	○ Clear targets for setting up battery recycling plants and collection centres in vicinity of EV charging station	Short-Term
	○ Specific incentives for recycling of 'LFP technology', considering huge volumes for EVs and lower margins	Medium-Term
	○ Promote duty-free import of black mass for recyclers whose technology, efficiencies, and environmental impact have been approved by credible agencies	Long-Term
Lack of waste handling regulations, standards, and certifications	○ Developing legislation for adequate storage and disposal of used LiB to improve immediate health, safety, and environmental benefits	Short-Term
	○ Formalization of recyclers and waste traders, and/or obligations for battery recyclers to sell manufacturing scraps to formal sector recyclers	Medium-Term
	○ Defining specific recovery rates for different battery chemistries with periodic review and updating	Short-Term
	○ Specifying guidelines for transportation and handling of used LiBs	Medium-Term

Lack of battery manufacturing from recycled minerals/ metals	○ The state government can design a portal wherein OEMs can register the batteries that are being sold, which in turn can be used to keep a track of the reverse logistics	Medium-Term
	○ Establishing circularity through signing of formal agreements between recycler and battery manufacturer, so that post recycling the minerals are again utilized in battery manufacturing industry. A model agreement may be developed by state agency.	Short-Term
Labs for quicker testing	○ Establishing appropriate testing infrastructure for quicker testing and improved recovery processes	Medium-Term
	○ Roping in leading international recyclers that are working on fully automated dismantling processes for improved efficiency and cost savings	Medium-Term
Capacity building	○ Engage start-ups and prominent state institutes- NIT, IIT, IIM, etc. wherein the industry may tie up with academia for practical implementation regarding extraction of raw minerals from battery waste at higher efficiencies	Short-Long Term (Continuous)
	○ Establish platform for periodic dialogue and consultation between UP government and industry player on battery-related policies and regulations	Short Term
	○ Leveraging ITIs in the state for proper skill development	Short-Long Term (Continuous)

10

Urban Transport and Development

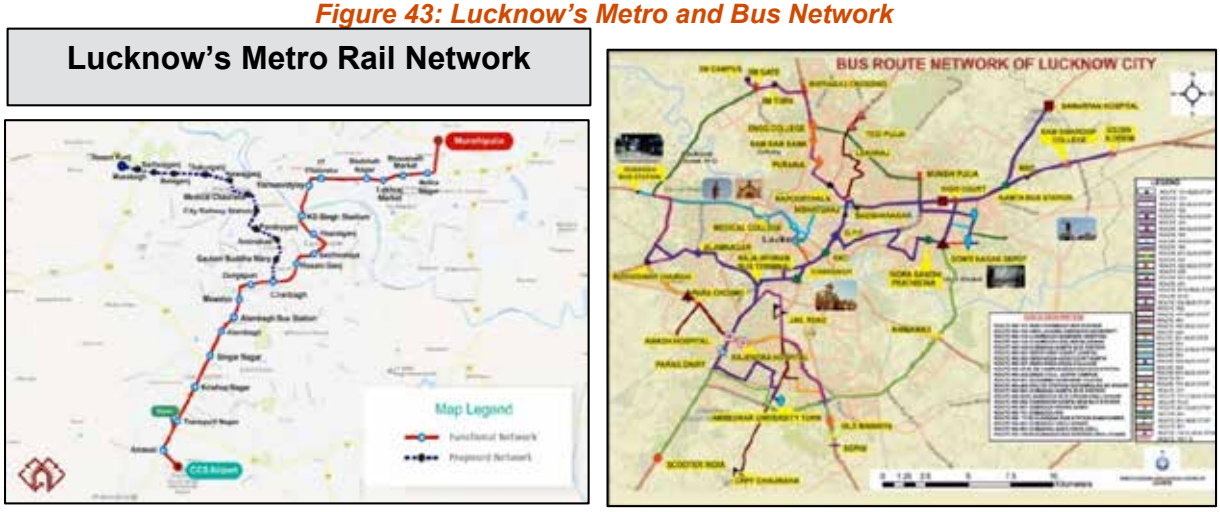
10. Urban Transport and Development

10.1. Introduction

Urban transport is a critical component of urban infrastructure and supports practically every function of a city. A well developed, environmentally friendly, and technologically up-to-date transportation system is necessary to promote economic growth and social welfare for the city. The burgeoning population, increasing urban sprawl, and rising incomes have led to increased pressure on urban transport systems, with an associated increase in congestion, emissions, fossil fuel use, and noise pollution. Since 2013, the number of on-road vehicles have seen an 85% increase. Rising fuel prices have impacted livelihoods across the city and remain a major concern for the government to manage.

In response, Lucknow has taken several steps forward with its ambitions of a robust public transport system complete with metro rail connectivity across the major corridors of the city. With the announcement of the Electric Vehicle Manufacturing and Mobility Policy 2022, it now stands ready to step into a new era of urban transport.

Figure 43: Lucknow's Metro and Bus Network



Source: Stakeholder Consultations, LCTSL and LMRC Website.

The goal for the e-mobility movement then is to not just replace ICE vehicles with their electric variants, but to improve the overall transport landscape of the city by increasing the share of public transport and the provision of integrated last-mile connectivity. According to the Prime Minister, the new mobility paradigm for India is clean, shared, and people centric. This can only be accomplished by the convergence of new technologies and business models to implement innovative mobility solutions. Already, 140 electric buses are plying across the city, purchased under FAME-I and FAME-II. An ever-growing fleet of electric autos and e-rikshaws is also servings the citizens' transportation needs.

This chapter will cover several components of the Urban Transport ecosystem, identify challenges, and show potential initiatives that can be taken to overcome them. The topics covered are as follows-

1. Coordinating Agencies involved in Urban Transport
2. Improving Air Quality Index
3. Non-motorized Transport
4. Traffic Management
5. Parking Management
6. E-buses and Green Route Planning

10.2. Coordinating Agencies involved in Urban Transport

Multiple agencies cover various aspects of the urban transport landscape of the city. Duties vary from the construction and maintenance of roads to the registration and PUC certification of vehicles Due to the often-overlapping roles of these agencies, significant cooperation is required for the push towards electric mobility. Several factors need to be kept in mind simultaneously. E-mobility covers not only vehicles but also the entire support structure of charging, registration, and intelligent route mapping of public transport. Certain areas where coordination is essential are as follows-

- Route mapping and fares of LCTSL need to be approved by the office of the Transport Commissioner. The approval for electric rickshaws on critical bus routes may undercut the LCTSL buses and reduce their utilization.

- The building of charging infrastructure involves a wide variety of land authorities. Approval on private and colony land may hinge on the Housing and Urban Planning department and the Lucknow Development Authority, while the Municipal Corporation leases out its own land. Charging and parking space for buses would be provided in part by LCTSL at their Depots, while LMRC provides space at its own stations.

- In practice, the charging of electric vehicles would not be restricted to the departments that own them- for example, EVs for solid waste collection would use charging points in their operating areas. There needs to be a platform for cooperation between agencies for planning charging routes that encompasses all available charging points.

- Construction and maintenance of charging points in various locations would involve assistance from PWD, DISCOM technicians, and private contractors.

Therefore, a common platform for electric mobility planning, which encompasses land allocation, routing, and sharing of charging infrastructure is required to achieve a synergistic urban transport ecosystem for electric vehicles.

Table 46: Common platform for coordination between agencies

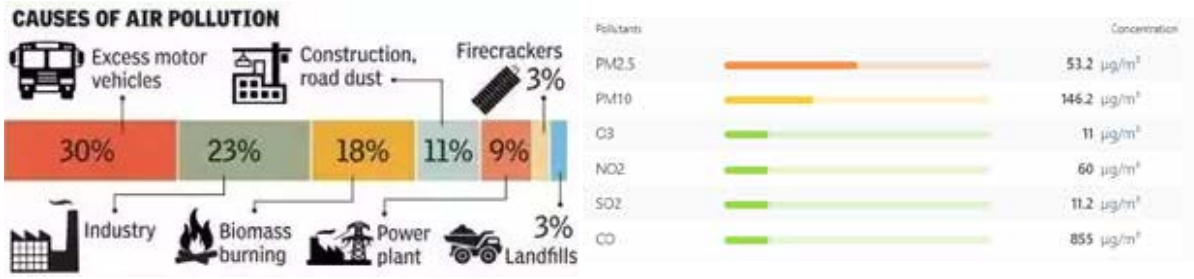
Initiative: Common Platform to Coordinate Public Transport & Govt. Vehicle Charging	
Stakeholders- • **Housing and Urban Planning** • **Lucknow Development Authority** • **Office of the Transport Commissioner** • **LCTSL** • **LMRC** • **DISCOMs** • **Private contractors, for consultation on**	The working group on "Fast Track Development of Charging Infrastructure" being formed under the UP EV Policy 2022 is an excellent candidate for bringing together the needed set of stakeholders onto one table. Some of the significant outputs this working group can delivery are- • Synergizing the route mapping and operations of LCTSL, UPMRC, and electric rickshaw corridors in Lucknow. As these three compete for the same set of commuters, it is important for planners to be aware of all of them such that there is no inadvertent cannibalization of revenue and over deployment in one route. • Coordinate the sharing of each agency's charging infrastructure among all others and create guidelines on providing access to the general public wherever feasible. • Create guidelines for construction of charging points beyond those available for public charging stations issued by the Ministry of Power. These can cover installation of smaller charging facilities in venues such as malls, hospitals, government depots, parking spaces, etc. In the future, a permanent committee can be set up to ensure continuous and smooth coordination in these matters.

construction related guidelines.	**Outcomes-** • Improving the revenue streams of these services and bringing a larger number of citizens onto an electric mode of transport. • Improving the operations of government electric vehicles in the city and providing higher utilization for charging points. • Improve speed and consistency of charging point construction across diverse locations.

10.3. Air Quality Index

Vehicular Congestion contributes to harmful CO_2 emissions and release of other toxic elements causing serious neurobehavioral disorders. Transport sector is one of the major contributors to Air Pollution in cities and requires strong steps to be undertaken to make the transition to sustainable mobility. To improve air quality and public health, we need a holistic and multisectoral approach. Transport planning and environmental planning are both integral parts of urban planning. To get rid of the vehicle emissions due to congestion problem, big electric buses may be introduced. That may substitute a few smaller cars and reduce the problems of congestion, pollution and parking space. Electric vehicles have zero emissions and are therefore, eco-friendly with low maintenance costs mainly consisting of battery replacements depending on the amount of usage. The figure below show the major sources of pollution and Lucknow's air quality. As shown in the figure, PM2.5 concentration in Lucknow is 10.6 times the WHO annual air quality guideline value[50].

The National Clean Air Programme (NCAP) was launched in 2019 to address air pollution in 102 cities, to which 30 more cities were added later.



These 132 cities are called non-attainment cities as they did not meet the national ambient air quality standards for the 2011-15 under the National Air Quality Monitoring Program. The state of UP has 17 non-attainment cities. A few recommendations - Setting up and running EV Charging Stations through Agencies, converting the ULB vehicles to EV, setting up Solar PV rooftop electricity generation, smart parking, parking cum charging stations, plastic recycling, Construction & Demolition waste processing, solid waste management, plantation, etc.

Table 47: Summary of recommended initiatives over the short- medium- and long-term

Challenges and Barriers	Probable Solutions	Action Timeline
Vehicular tail-pipe emissions: There are vehicles plying over their life cycle	Phasing out of vehicles that are 15 years old. Alternatively retrofitting could be proposed.	Short Term
Vehicle Emission checking on road	Technologies such as software-based PUC check on roads and the use of RFID should be practices. Various contributors to pollution on road like vehicle tail-pipe emissions, building	Medium Term

[50] www.iqair.com/in-en/india/uttar-pradesh/lucknow

	demolition dust should be regulated using pollution control planning.	
Vehicle emissions from idling of vehicle	Certain municipal vehicle vehicles such as sweepers, waste collection, mist cannon, water sprinkler, that are used every day and are also a source of pollution can be switched to EVs.	Long Term

10.4. Integrated Traffic Management System

With the growing urbanization and vehicle traffic on road, it gets challenging to handle the traffic congestion in a big city like Lucknow. There is a huge amount of data related to travel time, space utilization, traffic volumes, etc which could be useful to assist the commuters to make informed decisions. With the help of new technologies, the City of Lucknow is upgrading to Integrated Traffic Management System (ITMS), through which traffic efficiency can be achieved. This will help tackle rapid urbanization and increase in vehicles volume. ITMS enriches users with prior information about traffic, local convenience real-time running information, seat availability etc. which reduces travel time of commuters as well as enhances their safety and comfort. It will provide greater information to the authorities to proactively manage the ongoing traffic situation.

Table 48: Traffic Management System Corridors in Lucknow

1	Bandariyabagh to pakka Pul (Mahatma Gandhi Marg)	**11**	Lalbatti to Gosaiganj (Sultanpur Varanasi Road)
2	Shahmina Tiraha to Dubagga Tiraha (Hardoi Road)	**12**	Kaisarbagh Ashol Lat to Nehru Chauraha (Cantt Road)
3	Shahmina Tiraha to Dubagga Tiraha (Hardoi Road)	**13**	Barabirwa Chauraha to Karriyappa Chauraha (VIP Road)
4	Kamla Nehru (Medical Cross) to Alambagh Chauraha (Victoria Street) (Tulsidas Marg - Talkatora)	**14**	Charbagh to Parivartan Chowk (Gautam Buddh Marg)
5	Pakka Pul to Itauja Sitapur Road	**15**	Charbagh to Gol Market (Station Road)
6	Parivartan Chowk to Engineering College (University Road)	**16**	Kati Bagiya to Charbagh
7	Badshah Nagar to Indra Nagar (Faizabad Road)	**17**	Shaheed Path Mod Kanpur Road to Kamta Shaheed path Mod (To Faizabad Road)
8	Polytechnic Chauraha to IIM (Bhithauli Tiraha) - (Ring Road)	**18**	Bandariyabagh to Polytechnic (Lohiya Path)
9	Nirala Nagar Mod to Dhyanchand Stadium Tiraha (Kursi Road)	**19**	Gandhi setu - 1090 to Chinhat Tiraha (Hanyman Road)
10	Bandariyabagh to Mohanlal Ganj (Raibarelly Road)		

There are 19 corridors where the ITMS will be implemented in Lucknow as mentioned in the table above. The major components of ITMS will be Variable Message Signs, Smart Card- "ONE LUCKNOW", Smart Bus Shelter. This would include adaptive reuse of existing structures and land parcels identified to facilitate bicycle hiring, Free WiFi, information centre, E-suvidha Kendra -“ONE LUCKNOW KENDRA”, IPT Mode terminal, Public Toilets, commercial areas, Parking and solar based battery charging points for E-rickshaws. This will help providing a dedicated space and reduce traffic congestion while facilitating commuter’s ease. Another outcome of these interventions would be increased share of public transportation. "One Lucknow Card" will be a medium of single payment for different modes of public transportation i.e. metro, bicycle hiring, city bus and parking. This card can later be expanded to other modes such as autos, taxis etc. Smart bus shelters with features of

passenger information system, Ticket vending machine and water ATMs will help facilitate commuter's ease. These mobility intervention features when clubbed with other interventions will help in reduction of fuel consumption and fatal accidents.

Table 49: Summary of recommended solutions over the short- medium- and long-term

Challenges and Barriers	Probable Solutions	Action Timeline
Data and technology: Insufficient data collection and use of data analytics to make informed decisions in planning and management of traffic management systems.	*Improve the collection, aggregation, and analysis of traffic data to aid city-wide network design through an assessment of data needs and the establishment of a traffic data consortium.*	*Short Term*
Public awareness and stakeholder engagement: There is a disconnect between planning and enforcement agencies.	*Increase engagement and coordination among stakeholders to design better junctions, educate users of traffic etiquette and laws, and improve enforcement of laws.*	*Short to Long Term (Continuous process)*

10.5. Non-Motorized Transport

The non-motorized transport (NMT) transport consists of bicycle and pedestrians as well as innovative modes like e-bike and e-scooters. First and last mile connectivity remains a big challenge due to improper infrastructure. The inclusion of NMT for the city level planning will help eliminate use of ICE vehicles for short distance journey. Bicycles are still favored as a mode of transport for short-distance travel by a subset of commuters. As a pollution free and healthy alternative to motor-based transport, they provide multiple benefits. Ease of parking and the ability to carry small packages makes them ideal for short trips and daily needs such as grocery shopping. The National Family Health Survey (2019-21) showed that more than 75% of households owned at least one bicycle. In fact, UP ranked 2nd out of all states in bicycle ownership.

The city has supported these travelers by the widening of roads and the addition of bike lanes to certain routes. By 2016, 82km of cycle track had been constructed, 35km was underway and an additional 95km was proposed.

Manual rickshaws, though in lessening numbers, still ply in locations like Hazratganj, St. Francis College, and other popular locations. High traffic and limited parking space make personal vehicles difficult to use, creating a niche for this form of transport.

While this segment of transport serves to enhance the reach and mobility of citizens, it comes with several issues that need addressing-

1. For pedestrians, there are issues regarding sidewalks that are broken down, encroached, and overgrown with vegetation
2. Due to the sparse availability of track, lack of maintenance, and encroachment, most cyclists share the same road as other vehicles. Manual rickshaws especially operate in high traffic areas, putting both at risk of accidents.
3. Bicycles and manual rickshaws have low speeds, and this makes it difficult for them to maneuver around motorized traffic and vice-versa. They lower the overall speed of

traffic on a road and are at risk of collision due to the difference in speed with other vehicles.

4. While safety measures such as reflective vests, helmets, and lights are recommended, there is very low adherence to these rules. Without these visibility-enhancing measures the risk of accidents is much higher.
5. Driving manual rickshaws is a highly strenuous job and puts the driver at risk of injury and long-term musculoskeletal issues.
6. Cycling may not be an accessible form of transport for the elderly and those with other conditions that make strenuous exercise difficult.

The city of Lucknow has numerous projects to upgrade the city infrastructure to facilitate non-motorized transport (NMT) like bicycle and pedestrians. A few upgrades related to pedestrian friendly pathways are – pedestrian infra with barrier free design and street furniture; Pelican crossing for interconnecting parks (Begum Hazrat Mahal Park & surrounding areas); increment in Availability of footpath along roads, etc. These interventions will help interconnect the parks so as to help pedestrians to move easily from one park to another.

Upgrades related to bicycle include cycle track, smart ticketing, temporary encroachment regulation & penalty system to prevent vendors to encroach on footpaths, roads etc. This will encourage walkability and cyclability in the city. The Lucknow One app was re-launched by Lucknow Municipal Corporation in 2020 in a new version as 'Lucknow One Citizens' app. It provides all services to the people through a single window, including information on parking lots. This will also help encourage NMT as its features of parking, bicycle hiring and charging points for E-rickshaws will help facilitate commuters ease as well as eliminate congestion caused due to parking on roads. The use of NMT will improve the first and last mile connectivity to a large extent.

Cycle streets are high-quality cycle connection tracks also used by low levels of motorized traffic. The city of Lucknow had introduced cycle tracks. Approximately 150,000 people[51] in Uttar Pradesh use cycles as a means of their commute, commonly used by school kids and daily wagers. Within urban areas, cycle streets should be considered for main cycling routes (2000+ cyclists/day) with low traffic speeds (less than 30 km/h). A bicycle-sharing system allows for mid-distance journeys (2-3 km) where public transport is not available, or service is irregular. Areas where these cycle tracks were laid include: Airport Road, Bakshi Ka Talab, Bangla Bazaar, Telibag, Vikas Nagar, Kursi Road, Nirala Nagar, Aliganj, Hazaratganj, Mahanagar, Kapoorthala, Chinhat and Gomtinagar. However, these cycle tracks are not being used for the purpose they were built for. The picture that is observed across the city is that the Hazaratganj cycle track has been converted into an illegal parking area, some of the tracks in VIP areas like those on the Golf Club, the Kalidas Marg and the Vikramaditya Marg have been occupied by squatters. Majority of the cyclists still use the main roads for commuting due to various reasons, like disconnect in the tracks, vehicles parking on them, street vendors using them as business platforms, squatters sleeping on them, debris dumping, etc. These challenges are imposed due to improper usage and maintenance of built infrastructure. Innovative shared-transport system that includes electric standing scooter, electric bicycle using QR code as well as renewable energy to charge has a long way before they get implemented.

Table 50: Summary of recommended solutions over the short- medium- and long-term

Challenges and Barriers	Probable Solutions	Action Timeline
Public awareness: The existing mindset of the public does not prioritize NMT options	Develop a public engagement strategy for NMT planning and design, involving a guidelines document, facilitated convenings, and demonstration projects.	Short Term

[51] https://www.ecoideaz.com/expert-corner/rtp-cycle-tracks-in-lucknow-boon-or-bane

Interagency capacity and coordination: Oversight, monitoring, and evaluation are consistent challenges in implementation of NMT projects.	Form a steering committee, with a nominated coordinating officer, for coordinating all city-level agencies and activities related to NMT and its connection to public transport.	Medium Term

Table 51: Summary of recommended initiative for Last Mile Connectivity

Initiative- E-bike and E-scooter rentals for Last Mile Connectivity	
Stakeholders- • **LMRC** • **Lucknow Municipal Corporation** • **Local Businesses** • **Electric bicycle and scooter companies**	At location such as Metro stations, markets such as Hazratganj and other popular public spots, e-scooters and e-bicycle stands can be set up to rent out to customers looking to visit nearby locations Areas of highest likely utilization- such as Aminabad market, Hazratganj, and Chowk can be identified for a pilot project, and the viability of these rentals established. Metro stations with the highest footfall can also be places for initial deployment. This initiative has been successfully carried out in Delhi, with companies such as Bounce, Ecogear, Yulu, and Evo setting up electric scooter and electric cycle stands in partnership with Delhi Metro. 
	Outcomes • This would provide added convenience, lower environmental footprint, and increase the viability of using public transport to reach these locations since rental electric vehicles are available for last mile connectivity. • Adding to customers' mobility would also increase patronage for local businesses, that can help sponsor and support this endeavor.

10.6. Parking Management

Parking in a densely populated city remains a big challenge due to unavailability of land and improper enforcement. This adds to the discomfort of the city dwellers and demotivation to drive to various city centers. With the uptake of EVs, there needs to be guidelines for setting up charging stations on parking lots at various locations. These locations could be on-street parking or city designated parking spaces like bus depots, metro stations, dining, shopping complex, etc. Most cities start with a controlled parking zone with time restrictions and parking fees in the center or relocate parking to areas that have lower parking pressure (e.g. to the edge of the center, or Park & Ride at public transport hubs). The objective is to limit on-street parking and re-design these spaces for other (more sustainable) public use.

Some of the major challenges regarding parking in Lucknow city are as follows-

1. The rapid increase in the number of on-road vehicles and the lack of designated parking lots in most localities has led to on-road parking, constricting the flow of traffic and inconveniencing pedestrians.
2. Parking has become a major constraint for the use of the Lucknow Metro, as only 13 out of 21 stations have a designated parking space. Even these spaces are prone to filling up, leading to haphazard, obstructive on-road parking around both parking and non-parking stations. Citizens using personal vehicles for part of the journey are unwilling to risk them getting towed and are unable to use the metro's services.
3. Disparity in costs between private and LMC owned parking spaces, as well as several instances of scams where outside persons collect parking fees in the name of the parking lot owners.
4. Access to parking is especially important for electric vehicles, as charging points installed in building parking lots are one of their only means of charging outside homes and commercial charging stations.

A few measures to facilitate parking spaces include – expansion of paid or time-restricted zones increase in fees, parking for people with special needs and private parking can be used by the public in exchange for a fee. Effective but fair parking enforcement (with appropriate fines) is an integrated part of parking management. With the EV penetration increasing, it will be mandatory to install PCS at the public parking stations. Even at destination parking, commuters can park and charge their vehicles simultaneously while performing other activities – shopping, recreational, office work, etc.

The effective parking initiatives include new multi-level car parking, smart parking solutions for off street parking, smart parking solutions for on street parking, smart ticketing and better infrastructure for parking vehicles in the city. Multi-level car parking could be a major source of revenue as well as substitute roadside parking. There should be app-based parking. These would ensure reduction in traffic congestion and travel time due to unregulated on street parking. The effective road area that would be saved by provision of off-street parking could be used for other purpose like cycle track, pedestrian walkways, street furniture or planting trees.

UP EV Policy 2022 Parking Support

The Urban Local Bodies shall take up parking policy reforms in cities for developing public charging / swapping facilities in parking spaces, In the short term, local authorities may identify spaces for reservation in public parking for EV charging.

Table 52: Summary of Recommendations over the short-, medium-, and long-term

Challenges and Barriers	Probable Solutions	Action Timeline
Infrastructure: Limited signage and markings on streets to identify parking zones, spaces, and other important information.	Improve street design for parking and the use of other modes, including allocating and clearly marking parking spaces and placing parking spaces in proximity to other modes of transportation (e.g., parking at a public transport station).	Short Term
Park and Ride: Parking locations do not support public transport or first and last mile solutions.	Improved end-to-end trip planning (i.e., knowing available parking spaces near destination). Users identify real-time parking space availability near their trip destinations.	Short-Medium Term

Adherence to laws and Enforcement: There is limited enforcement capacity to increase adherence to parking laws (e.g., no double parking, or parking on footpaths) and fee collection.	Enhance enforcement capabilities through capacity building (e.g., training and personnel) of enforcement agencies and distribution of responsibilities.	Medium Term

Table 53: Summary of recommended initiative for use of LMRC infrastructure for EV charging

Initiative- Using LMRC Power Infrastructure to Support EV Charging at Station Parking	
Stakeholders- • **LMRC** • **LDA** • **Lucknow Municipal Corporation** • **Private landowners** • **Charging point operators**	Access to a transformer and high-tension lines is one of the biggest constraints for setting up charging points for electric vehicles, especially for higher-wattage chargers. The Lucknow Metro has ample access to power infrastructure all along its stations and track. Certain portions of station parking can be augmented with charging points and reserved for electric vehicles. Other nearby locations with sufficient space can also be candidates for these charging points, whether owned by LMC, LDA, or private individuals. Charging point operators can be brought on with revenue sharing agreements, as described in the UP EV Policy 2022. It would be important for LMRC staff to ensure these charging enabled spots are available only to EVs and are not encroached upon for parking by others.  **Outcomes** • This would encourage EV owners to make use of the metro for part of their journeys while giving them more access to charging, especially fast charging. • It would act as another revenue stream for the station, which can be directed towards maintaining the overall parking space.

10.7. E-Buses and Green Route Planning

Lucknow City Transport Services Ltd. is currently operating 140 electric buses across the city, along with 63 CNG buses. They service a combined peak of 45,000 customers a day, with 35,000 of them travelling on e-buses. E-buses are especially popular with the citizens, with their smooth, near silent operation and LCTSL's lower fares- as much as 10-20% lower compared to other cities in UP. Currently, they cover 11 out of the 17 bus routes in the city.

Table 54: Characteristics of E-Buses operating in Lucknow

E-Bus Characteristics		Remarks
Brand	40 Tata buses and 100 PMI Buses	Older tata buses, procured under FAME-I, are running without an annual maintenance contract (AMC). PMI buses procured under FAME-II have an AMC.
Size	9-meter buses, with 28 to 31 seats	
Business Model	Capex for buses under FAME-1 Opex for buses under FAME-2	LCTSL retains the revenue generated from passengers.
Range	80-90 km for Tata 150-180 km for PMI	Due to short distances within the city, even the longest bus routes do not exceed 35km in length. This allows buses to maintain a minimum state of charge of 20% throughout their operations. Around 50 PMI buses are also able to serve the suburban areas around Lucknow due to this. Notably, air conditioning has a large impact on range, taking up to 30% of battery charge per shift in peak summers.
Occupancy	180%-195%	Buses have proved highly popular, and it is not the demand that is leading to the low share of public transport. Rather, it is the limited number of buses.
Revenue	INR 30 per km	Despite high occupancy, low fares have lead to revenue that is unable to match the operational costs.
Charger Type	GBT DC Charger 240kW	Buses are able to charge at 4 substations in the city mid-operation, to maintain a minimum level of charge.
Charging Time	1.5-2.5 hours	Low charging times allow e-buses to work two 10-12 hour shifts a day.
Battery Lifetime	10 years	Larger, high-quality batteries come with long warranties, and impact of age is only visible after 3-3.5 years of operation.

Source: Stakeholder consultation with LCTSL

In selecting the routes on which e-buses will ply, LCTSL has aimed for maximizing occupancy. Their objective has been to shift as many customers as possible over to a zero-emission form of transport, as well as recoup the cost of these vehicles. Their lower fares also make them highly popular, ensuring very high occupancy rates.

UP EV Policy 2022 E-Bus Support

State Govt will promote transition of public transportation to EV in other urban and rural areas as well. For this, Green routes shall be identified in each district (other than 17 Cities with Municipal Corporations) by 2025 and ensure E-buses on each of these select routes.

Table 55: Summary of recommended solutions over the short- medium- and long-term

Challenges and Barriers	Probable Solutions	Action Timeline
Revenue: Income from bus operations is not enough to cover the total cost of owners	Rationalization of bus fares, keeping in mind the citizens' right to affordable transportation	Short-Term

Insufficient Vehicles: High occupancy implies that there is sufficient demand to support more vehicles and improve share of public transport.	Procurement of e-buses on Opex models, avoiding the burden of heavy capital investment by the city. Established OEMs like Tata and upcoming ones like PMI and Olectra can be looked at.	Medium to Long Term
Planning of Green Routes: Selection of routes on which newer buses will ply	Prioritizing and ranking current non-electric routes on the basis of footfall, such that maximum customers can be transitioned to a zero-emission mode of transport.	Short Term

Elaborating further on these solutions-

Initiative: Rationalization of Fares

Distance Travelled (km)	Fare (INR)
0-3	6
3-6	12
6-11	17
11-15	22
15-20	27
21-25	33
25-32	38
>32	44

New Fares

Distance Travelled (km)	Fare (INR)
0-3	9
3-6	18
6-11	25
11-15	33
15-20	40
21-25	49
25-32	57
>32	65

Current Fares (Left) to New Fares

In order to cover the shortfall in revenue, an increase in fares of 45%-50% is required. This can be done in a phased manner, with 20% initial increase in the first 6 months followed by a 25% increase afterwards. After the first increase, if there is excessive impact on long distance travelers coming to and from suburban areas, the burden can be shifted towards shorter distance travelers who are much larger in number. Alternatively, if hiring of e-buses under Opex model is able to reduce costs, the price hike can be avoided.

Further rationale for the change includes-

- Overall, bus fare has not kept up with inflation- Adjusting 2012 fares for inflation up to 2022 and comparing them with current fares shows a difference of nearly 10 rupees for a 20km ride.
- The need to cover operational costs, particularly repair and replacement costly of auxiliary parts such as pneumatic door systems.

Initiative- Hiring of E Buses under Opex Model	
Location	**Details**
Kolkata	Agreement for 1200 e-buses from Tata Motors, charging INR 40/km to the city for their operation, along with 50 buses from PMI Electro Mobility Solutions (PMIEMS) at INR 86/km The West Bengal Transport Corporation provides the conductors and the daily earning go directly to government coffers
Delhi	In principal approval to 1,500 buses under "grand challenge scheme" of CESL (Convergence Energy Service Ltd) on OPEX cost model.
Mumbai	Olectra will supply 2,100 electric buses on the gross cost contract/ Opex model for a period of 12 years, in an order worth INR 3675 Cr.

Rajasthan	48 AC e-buses owned and operated by GreenCell Mobility under FAME-II

Large Scale Opex Model E-bus Agreements between cities and OEMs

OEMs supplying buses under the opex model have the needed scale and expertise to bring down costs. Lucknow has already purchased buses from Tata Motors and PMIEMS, and LCTSL possesses the needed technical knowledge and experience to craft a suitable tender agreement. NITI Aayog has also come out with a Model Concessions Agreement for the Operation and Maintenance of Electric Buses, which can act as a guide for deploying this model. Newer electric buses with higher ranges will also enable electrification of bus routes that were not feasible with current ranges.
Competition from developing OEMs such as Olectra and PMI will also help bring down price to sustainable levels, and fares would be set fairly by the market, with suitable checks and balances from Lucknow's administration.

Initiative- Identification of Green Routes

Bus Route Network of Lucknow City. Source: LCTSL website

The feasible route for electric bus operation would need to be jointly identified by LCTSL and OEMs/Bus Fleet Operators as these would depend on the model and range of the e-buses in question. Furthermore, the Office of the Transport Commissioner needs to be consulted to ensure approved routes for e rickshaws are not overlapping extensively with the routes being considered, as this would lead to cannibalization of revenue between buses and e-rickshaws.

The utilization-based criteria used by LCTSL so far is ideal for Lucknow's e-mobility transition, as it places first priority on maximizing the number of customers using electric buses. The remaining 6 bus routes with no e-buses can be examined and ranked based on customer footfall. With the expansion of the available e-bus fleet, more such bus routes can be converted to green routes in this order.

The expansion of EV charging infrastructure is also outlined in its own chapter, and with the new routes will become feasible as the operating range of e-buses increases. Already, 4 substations across the city are used for opportunity charging of buses. Similar locations with enough space and power infrastructure have been identified and have the potential for acting as e-bus charging stations.

11

Consumer Awareness for Electric Mobility

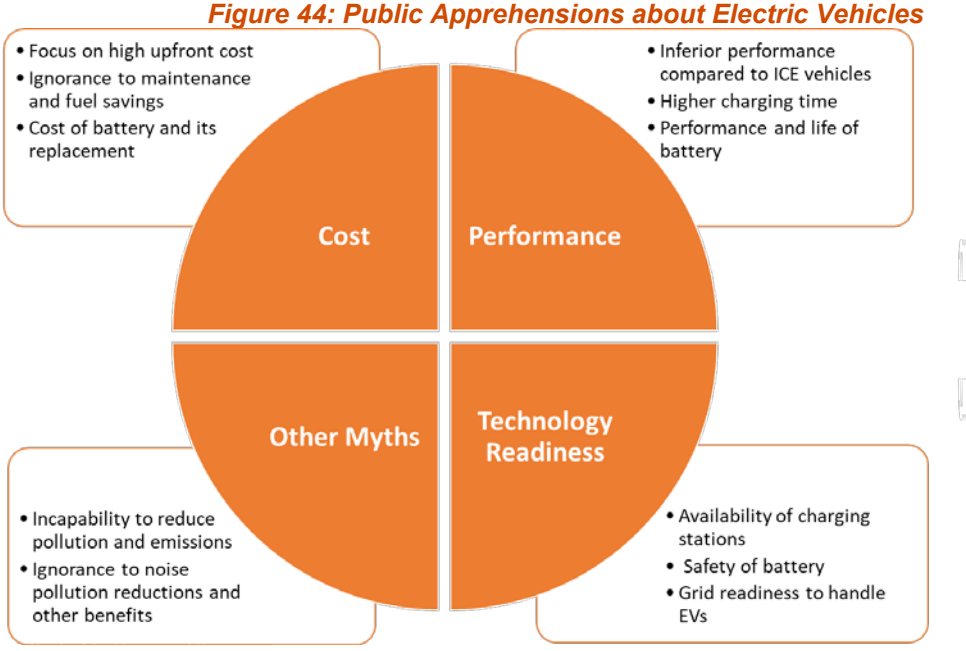
11. Consumer Awareness for Electric Mobility

11.1. Introduction

Due to wider acceptance and popularity EV sales are growing, but a number of barriers and obstacles are keeping them from becoming more widely used. The growth of the markets for electric vehicles is essentially dependent on how much prospective buyers are aware of and comprehend the potential advantages of electric vehicles. However, the research that is now available suggests that there is a general dearth of information and awareness concerning electric vehicles. Most customers are still substantially ignorant of EVs, unaware of their capabilities, and without the knowledge necessary to compare BEVs to conventional automobiles.

The draft Uttar Pradesh Electric Vehicle Policy proposes a range of support incentives and tax exemptions to facilitate increased share of EVs on road during the implementation period. The demand for EVs and the tax benefits that are available for their purchase are, however, unknown to a substantial portion of new car buyers and potential EV drivers. Similar to this, buyers in the city are ignorant of the various manufacturers and models; they only recognize a few well-known EV models, indicating little awareness of the variety of models in the market. Customers are more inclined to regard electric vehicles more highly and consider them as a choice for future purchases if they have exposure and details related to them. Consumer opinion and understanding of EVs can also be influenced and altered by practical exposure and driving experience; as consumers gain more time behind the wheel of electric vehicles, they begin to see them more favorably. In general, more informed or experienced consumers are more likely to place a higher value on electric vehicles, consider them as a potential purchasing option, and be prepared to pay more for the technology.

Figure 44: Public Apprehensions about Electric Vehicles



Uttar Pradesh leads the EV journey for India with a share of 10.2% for EVs among overall vehicle sales. However, there is still a lot that can be done to increase this share and support complete decarbonization of the transport sector in the state. Spreading awareness through various activities can help overcome myths among consumers prohibiting complete trust and readiness of the technology. This chapter examines the myths and obstacles that prevent consumers from adopting EVs, the significance of consumer awareness initiatives, and the primary awareness initiatives carried

out by EV marketplaces. Additionally, a roadmap for consumer awareness development at the city level is also proposed.

11.2. EV Consumer Awareness Activities

There are many different activities in use that assist in lowering consumer barriers connected to comprehension and awareness of electric vehicles. Activities to promote electric vehicles include public-private collaborations, awareness campaigns, OEM initiatives, city and state government programs. Considering the context for Lucknow the focus for different consumer awareness activities varies for different stakeholders and local planning authorities based on their priorities. The main EV consumer awareness initiatives that tend to raise awareness and encourage a rise in electric vehicle adoption are covered in the sections below.

Figure 45: Set of Consumer Awareness Activities

- Tools and Information

EV awareness can be propagated through information and tools. The information can be categorized and related to different elements, such as general information, cost comparison, finding public chargers, informing about incentives and vehicle types. The amount of information offered, how consumer-oriented it is, and how simple it is to find information vary widely for different awareness websites. The location and accessibility of public charging infrastructure is one of the most crucial pieces of customer information. Different stakeholders have made numerous charging availability maps and related mobile applications available, which adds another level of convenience for EV users and potential buyers.

- Public Events

Public events like electric vehicle displays, promotional test rides are good ways to get media attention and let people experience electric vehicles. In reality, current research indicates that one of the most reliable information sources is first-hand experience from experts on electric vehicles. Events like EV Melas, and Expositions give consumers hands-on experience with various models.

These occasions can be very important for boosting sales, EV adoption, and public knowledge of electric transportation.

- Exposure through Ev fleets

The addition of electric vehicles to fleets both directly enhances their use and exposes potential buyers to the vehicles more. Electric vehicles are accessible through carsharing/rental services, and governments and public fleets have embraced them to some level. Electrifying their fleets is a top priority for many businesses in the market, whether or not government incentives are provided. Fleet electrification can make EVs more visible on the road, which can be important for fostering potential consumers' confidence and faith in EVs. It also helps dispel fallacies about the performance and safety of EVs that are currently prevalent.

- Regional Planning Activities

The majority of governments now have associated EV and Charging station demonstration programs and some sort of action plan for the new technology. By creating a favorable climate to accelerate adoption and sales targets, including EV adoption initiatives in government budgetary actions can boost the EV business. There are several instances of broader government pledges that are crucial for creating roadmaps for the adoption of electric vehicles, in addition to demonstration projects in strategic locations that can include and enlist local stakeholders in e-mobility. These various initiatives, which focus on various facets of promoting the use of electric vehicles, have been beneficial in boosting the sector's growth.

- Campaigns and Forums

Electric vehicles are an emerging technology that has not reached beyond the “innovator” and “early adopter” consumer categories in most markets. The marketing of a new and different technology presents challenges, and the right messaging can be enormously helpful in increasing public acceptance. Campaigns can be launched focusing on increasing awareness of residents in target cities. The duration of the campaigns can vary over months and each week can focus on spreading awareness for specific themes, specifically for different vehicle segments and charging related awareness. Social media can act as a tool to share updates regarding policy implementation, incentives offered and, resolving frequent queries and grievances of consumers pertaining to EVs. Similarly, development of an EV forum can help facilitate stakeholder engagements to support implementation of EV Policy. The forums can be organized by knowledge partners for the cities to bring together government leaders, industry stakeholders, consumers and other multilaterals to discuss barriers, challenges and implementation steps for consumer awareness of the policy

- Awards and Recognition

Numerous awards are given out by governments and organizations to people, groups, or companies who have made significant contributions to the development of electric transportation. These include both broad recognition for environmental leadership and recognition for electric vehicle innovation. These initiatives can inspire OEMs to produce high-quality EV products and serve as benchmarks for consumers choosing brands. The popularity of awards honoring dealers that aggressively promote electric vehicles is also rising, and these awards may play a significant role in boosting regional acceptance of electric mobility.

- Auto Dealer Awareness Activities

Due to their significance in marketing and at the point of sale, dealer actions related to electric vehicles continue to get more attention. Programs that inform, involve, and encourage dealerships and their salespeople to assist electric vehicle sales could benefit the market's growth. Governmental strategies include establishing connections with dealer associations, hosting workshops and training sessions for dealers, and presenting prizes and honors. Dealer actions can be crucial in educating consumers about electric vehicles because they are in the unique position of interacting with customers. The sales of electric automobiles may be facilitated by improved customer experiences at the dealership.

- Consistent Signage and Labelling

Consistent labeling and signage can improve awareness by increasing visibility of EVs. Programs that develop standardized labeling and signage for infrastructure used by electric vehicles can assist raise awareness and convenience while also being crucial for safety. Both directional signs, which direct drivers to charging stations, and regulatory signs, which express limitations linked to charging and accompanying parking, such as time or access restrictions, require uniform signage. In order to identify EV driving charging and usage trends from their ICE counterparts, governments have been particularly active in this area. Even though these advancements are in the works, official harmonization of electric vehicle signage (such as that which denotes access to high-occupancy car and bus lanes, reserved parking, etc.) at the national and regional level are yet to emerge.

- Tourism

Outreach programs centered on tourism may also contribute to a rise in the popularity and use of electric vehicles. As previously indicated, there are several instances of electric vehicles being incorporated into rental and car-sharing fleets that cater to tourist locations. Additionally, promotions for electric vehicles at popular tourist locations help link the new technology with pleasurable driving experiences. Initiatives that link tourism and electric car awareness initiatives can help raise awareness among new prospective customers in addition to current users. Cascading new zero emission technology with tourism can be a special addition to draw more attention to the whole picture of climate change for potential technology users. Tourism draws attention to creativity, innovation, and distinguishing features of society.

UP EV Policy 2022 Consumer Awareness Support

A portal shall be developed as one stop platform providing all information related to the progress of EV in these cities including on locations of charging stations, EV density, available schemes, etc. In future, the portal may be integrated with PM Gati Shakti portal.

The State Government shall use multiple drivers to spread awareness and collaborate with the Central Government for Go-Electric Campaign to create awareness amongst people on need for reducing emissions.

Current status of consumer awareness activities

Government of India (GOI) and regional partners have been pursuing a number of efforts to boost transport electrification through various consumer awareness initiatives. The following tables provide an overview of the planning efforts made by National and state transport partners towards consumer awareness to accelerate EV adoption.

Table 56: Current status of consumer awareness activities

Sr. No.	Category	Initiative/ Activity	Description	Major Stakeholders
1	**Tools and Information**	e-Amrit Web Portal	One-stop destination for EV related information- available models, charging infrastructure, incentives, policies, and tools for calculating savings from EV use.	Niti Aayog (GOI)
		EV Dashboards	Various dashboards maintained by think tanks tracking adoption, cost, etc.	Think Tank
2	**Public Events**	Plugin India events	Events and workshops by Plugin, an EV advocacy group and social enterprise.	Private and government stakeholder
		India EV Show	India's largest EV trade show with 500+ delegates and 150+ brands, held in Mumbai.	Private Stakeholder

3	**Exposure through fleets**	Shoonya	Corporate branding program that provides logos indicating zero-emission delivery or raid-hailing, accompanied by online awareness drives and EV impact tracking tools.	Government body, Think Tanks, OEMs
4	**Campaigns and Forums**	Go Electric	A campaign by Ministry of Power, GoI consisting of workshops, webinars, tech talks, seminars, and roadshows to enhance EV uptake.	Central and State Government
		Har Nukkad EV	Street plays across Delhi promoting EV use	Civil society, OEM
5	**Awards and Recognition**	EV India Confex and Awards	Conference, workshops, and an award show felicitating EV entrepreneurs, products, and innovations.	Private stakeholders, OEMs
7	**Consistent signage and labelling**	Green Number Plates	All electric vehicles are provided a green number plate to distinguish them and indicate their environmental benefits.	MORTH (Central Government)
State level Initiatives				
1.	**Public Event**	EV Expo (Noida)	Expo bringing together EV stakeholders such as OEMs, testing laboratories, software designers.	Private Stakeholder
2.	**Campaigns and Forums**	Switch Delhi	Social Media campaign plus a number of events such as e-bus flag offs, online and offline EV forums, and public contests for EV initiatives.	Transport Department (Government of Delhi)
3.	**Regional planning**	Electrification of Public Transit	Delhi, Kolkata, Pune, Lucknow, Jammu, Mumbai and many other cities have deployed or plan to deploy electric buses to act as zero-emission public transport.	Various State and Regional Governments
4.	**Promotion through tourism**	Goa Tourism	Guided, experiential tours on electric bikes to promote sustainable tourism.	BLive (Private stakeholder)

Lucknow has lagged behind in awarenss building initiatives, with the only public EV related event being the flagging off of 42 electric buses by the Chief Minister. Serious attention needs to be paid towards implementing some of the above initiatives/activites in the city, with support from high profile government stakeholders. Expertise on these activities already exists within UP, with Noida being a commercial hub and a frequent venue for EV related events, and can be leveraged for Lucknow as well.

Best Practices:

Globally, countries can learn best practices, knowledge and experience for consumer awareness to achieve sustainable transportation maintaining balanced job ecosystem. Some of the best practices related to E-Mobility consumer awareness are mentioned below.

e-Amrit, India- One Stop Destination for all E-Mobility Information

e-AMRIT is a one-stop website for promoting electric mobility using electric vehicles (EVs) in India. By providing comprehensive information on legislation, incentives, charging stations, and business needs, the portal intends to make the switch from fossil fuel-powered automobiles to electric vehicles easier.

Plug'n Drive, Canada- EV Discovery Centers and Road Shows

"Plug'n Drive is a not-for-profit organization that runs multi-brand experiential centres and partners with road shows to provide test drive facilities and expertise to prospective customers. Their goal is

to accelerate EV adoption and maximize the related environmental and economic benefits. Customers can learn about these in a no-pressure, no-sales environment and test drive the latest models of EVs. They are educated on the benefits of switching to EVs through exhibits and friendly, knowledgeable experts.

The initiative proved highly successful, with over 10,000 visitors in the first year taking part in over 4,000 test drives. Post-visit surveys showed 94% willingness to make the switch, with almost 25% of visitors buying an electric vehicle within 3 months of their visit. Though initially hesitant to share floor space with their competitors, OEMs have now come to realize the benefits of participation."

11.3. Summary of Recommended Initatives

Compared to the overall population of Lucknow, only a tiny subset of current and prospective EV purchasers is driven to educate themselves. Proactive measures are needed at city government and regional authority levels to expand the EV market in Lucknow. Programs that raise public knowledge of EVs, inform consumers on advantages, and offer trial experiences through experience centers are necessary for the transition to EVs. Planning and awareness efforts must start at the local jurisdiction level to meet the goals of transportation electrification and develop a sustainable transportation sector. It is necessary to implement a phased plan including a near term/pilot phase, medium term/scale-up phase, and long term/self-propelled phase.

Table 57: Summary of Strategies and Initiatives for consumer awareness

Challenges and Barriers	Probable Solutions	Action Timeline	Stakeholders
E-mobility Information solutions	Development of a one-stop comprehensive easy to navigate website that provides all forms of e-mobility related information and tools for consumers	*Short Term*	UP State Government, LMC, LDA and Smart City
Public outreach and awareness	Conduct outreach and educational activities for potential consumers via reliable and trusted messengers- celebrities, public servants, etc. Launch of public events to spread awareness and demonstrate benefits offered by electric mobility, events may include campaigns, EV showcases, EV melas, ride and drive events along with public exposition events aiming to boost EV sales	*Short Term*	LMC, LDA, LNN, LCTSL, Transport Department, NGOs, OEMs
Physical exposure and experiential awareness	Create fleet electrification plans and pilot electrification of vehicles within local government bodies to increase exposure of EVs to consumers through fleets Regulatory interventions to promote usage of EVs and availability of public charging stations at tourist locations and public attractions along with partnerships to include EVs in rental fleets	*Medium and Long Term*	LMC, Lucknow City Transport, UPSIDA, MSME, Freight & Logistics Companies, Last mile delivery, LDA, Real State Companies, Private Owners
Inclusion challenges in regional planning	Create and develop regional planning programs to support electric mobility, encouraging themes like clean and green cities and electrification of freight and public transit in awareness programs can increase EV adoption rates	*Short and Medium Term*	Central Government, State Government and LMC, LDA, Smart City

Addressing queries on e-mobility	Development of Forums and Training programs for consumer and dealership awareness	*Medium and Long Term*	UPSIDA, MSME, OEMs
Boosting sales and product quality	Launching awards and recognitions to further electric mobility and help OEMs as well as their affiliated dealer outlets optimize EV sales readiness	*Long Term*	UPSIDA, OEMs
Signage and traffic legislation	Expand visibility for e-mobility through traffic legislations on consistent signage and labelling for EVs and public charging infrastructure	*Medium Term*	LCTSL, LMC, Transport Department and Lucknow Traffic Police Authority

12

Skilling for E-Mobility

12. Skilling for E-Mobility

12.1. Introduction

The EV market in India will be a USD 206bn opportunity by 2030, this opportunity is expected to drive a significant growth with cumulative investment needs of over USD 180 bn till FY30 in vehicle production and charging infrastructure. To realize this growth potential the EV sector shall require skilled workforce to cater the increasing workforce requirements. Central, state and regional government bodies must strive towards building an EV skilling ecosystem to benefit from the opportunities offered by the technology. Uttar Pradesh Electric Vehicle Manufacturing and Mobility Policy 2022 has provisions to promote establishment of Centers of Excellence (CoEs) in the State. Such centers shall focus on the design and use of EVs, improving the usage and efficiency of EVs and charging equipment. Promoting domestic R&D and manufacturing through initiatives calls for skilled workforce thus it is critical to create a local EV skilling pool locally to cater these opportunities and job demand in the emerging field. This chapter discusses the critical need for creating a skilling ecosystem in India, critical barriers, avenues that need to be prioritized and the way forward to a sustainable skilling ecosystem in India.

12.2. Need for Skilling

Commitments to greening economic sectors such as energy, agriculture, waste management, manufacturing and transport can't advance into concrete change if the necessary skills are not available. It is women and men with the right knowledge and skills who will take the decisions, develop and maintain the technology, green production processes and sustainable investment strategies that are required to build a resilient and sustainable ecosystem.

The automotive and transport industries are poised to shift rapidly from conventional ICE to EVs. This transition is expected to be accompanied by significant changes in technology, production processes, and consumption patterns, which in turn will impact employment generation in these industries. To enable more socially inclusive and equitable outcomes (besides environmental sustainability), government needs to ensure that the journey to a low-carbon future follows a just transition. As electric mobility becomes mainstream, several parts of the traditional automobile value chain—across the manufacturing, sales, and service sectors—will become obsolete, some will change fundamentally, and entirely new industry segments will be introduced. The conventional vehicle powertrain consisting of an engine, transmission, and drivetrain will shift to batteries, motors, and a host of other electronic components such as the control unit, battery management system, and thermal management system.

These impending changes are likely to result in job losses in the traditional ICE vehicle industry, while simultaneously creating new employment opportunities in the EV industry. These jobs will require new skill sets, for which the existing workforce must be upskilled even as new workers get trained. Further, these opportunities must be exploited to improve the readiness of youth entering the job market and increase the representation of women and marginalized groups in the workforce.

Skilling, reskilling and upskilling covers not just technical skills but, core/soft skills (such as environmental awareness, analytical skills, teamwork, innovation, communications, leadership, negotiation abilities, and management and entrepreneurship skills), which can offer a comparative advantage because they can easily be transferred across occupations. Other most wanted skills include sales and marketing, customer handling, repair, digital skills, scheduling and budgeting, to mention just a few examples.

12.3. Skilling Related Challenges

With increasing EV deployment, there is a critical need to create a sustainable ecosystem for the long-term growth of this industry. Development of new skills will address the “fear of change” and make the job market more receptive to new EV technologies. Similarly, the ready availability of trained employees will improve productivity and reduce cost for companies while facilitating a rapid EV transition. The EV industry currently faces a shortage of several skill sets across the value chain, from vehicle design to repair and maintenance. Although skill gaps affect the entire value chain, it is crucial to focus on priority areas to ensure a seamless EV transition. Some critical areas for skill development include EV driving and maintenance, product design, battery and vehicle assembly, and charger installations. Following are some of the challenges that EV skill industry currently faces.

Complex and Rapidly Changing Technology

Electric vehicles have been present for a while and over the past few decades the overall technology and associated components have evolved rapidly. Battery which is a critical component forming around 30-40% of the overall cost has seen tremendous development in terms of technological innovations and cost reductions. Although these innovations are beneficial for the sector and its adoption but, they mandate the workforce to develop adaptive skills and learn continuously. Other components like the Battery Management System (BMS) incorporates sophisticated and emerging technology like Artificial Intelligence (AI), telematics & data handling and complex algorithms. Manufacturing and R&D of these components calls for newly skilled workforce as these components were missing from the conventional ICE vehicles. Similarly, EVs have inherent safety challenges due to the batteries being prone to fire hazards. Proper handling of the batteries during their production and maintenance is critical additionally, if fire situations occur suppressing them requires specific skills. These criticalities mandate the manufacturing, service and emergency responder sectors to have specific skills for handling these components.

Lower EV Penetration

There are still considerable impediments to the widespread adoption of electric vehicles, as they presently only make up less than 1% of all new vehicle sales in India. This small market size causes fear among the workforce to learn new skills pertaining to EVs. Automotive job market in India is very competitive and driven by specific skillsets related to ICE Vehicles, the lower market share of EVs causes lower participation of workforce towards skilling and reskilling requirements. The workforce in India is also vulnerable to the lack of knowledge about right skills require to secure a job, this adds to the challenges for skilled workforce in EV sector.

Academia-Industry Gap

The deployment of skill development programs at scale will also ensure the sustained growth of the e-mobility industry, which currently relies on internal skilling processes for workers and supply chains. The current in-house skill development model may not be sustainable as it is expensive for small players. And untrained employees reach optimal productivity after 2–3 months of on-the-job training. Large-scale skill development is required to support the growth of the industry, academic and vocational institutes must lead the skilling initiatives. However, current academic curriculums in India are highly theoretical and lacks collaboration with industry. There is a gap in the curriculums as per industry requirements additionally, EV courses require combined skills from different streams which calls for specifically designed curriculum. Availability of skilled manpower will improve industrial productivity and turn-around time. Appropriate skilling of the workforce will ensure a sustainable transition of the formal and informal sectors.

Gender Equality and Other Challenges

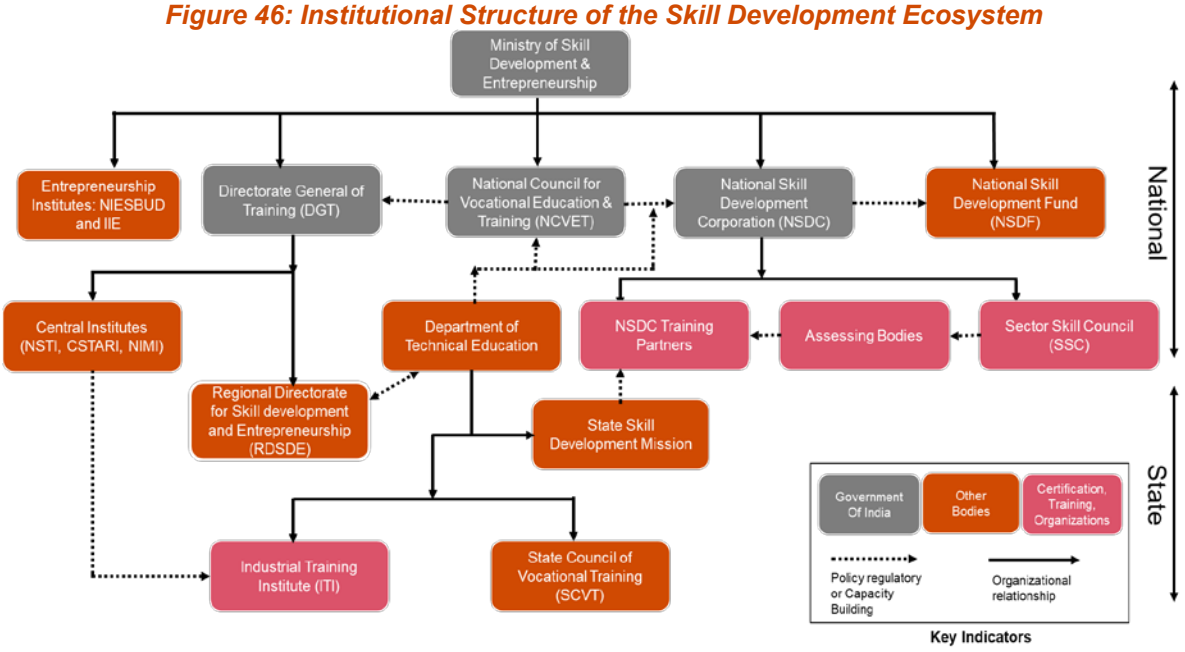
The transport industry is male dominated, with a dire lack of opportunities for women’s participation. Particular attention must be paid to ensuring that women are included in relevant skills training, so that these measures help reduce the gender gap and combat gender stereotypes rather than entrenching them. The job Industry in India also faces lack of industry standards related to training methodology for job roles pertaining to EVs. Development of these standards is crucial to overcome gaps in the emerging automotive jobs sector and specific requirements that workforce must pursue to secure these jobs. Additionally, there is a need to organize workshops at subsidized rates to increase

workforce participation. This will require massive investment, but it can create millions of new jobs and repurpose many existing ones. Particular attention must be paid to ensuring that women are included in relevant skills training, so that these measures help reduce the gender gap and combat gender stereotypes rather than entrenching them. The number of high-skilled and – especially – middle-skilled jobs have the potential to grow if there is investment in relevant skills training. Workers in construction, manufacturing, agriculture and sales may gain employment if the green transition is supported by skills development. This requires good coordination across different ministries and between public and private sectors.

12.4. Institutional Structure and Skill Development Framework

The skilling ecosystem in India has been evolving with efforts ranging back to 1956 when the National Council for Training in Vocational trades was formalized through establishment of it is. Skilling requires investment and in order to attract investments, In 2008-09 National Skill Development Corporation (NSDC) was formed to attract private sector investments in skilling. The Ministry of Skill evelopment an Entrepreneurship (MSDE) was formed in 2014 along with the Skill India Mission which was a major turning point in the skilling ecosystem. The institutional structure for the skill development ecosystem is shown below

Figure 46: Institutional Structure of the Skill Development Ecosystem



In Uttar Pradesh the state bodies responsible for training schemes and skill development include the Uttar Pradesh Skill Development Mission (UPSDM) and the Directorate of Training and Employment (DTE). Additionally, the Department of Vocational Education and Skill Development, Gov. of Uttar Pradesh includes the State Council for Vocational Training (SCVT), State Staff Training and Research Center (I.T.O.T), Unified Reimagined Innovation for Student Empowerment (URISE) and the Department of Training and Employment (DTE). These state government bodies are responsible for development of regulatory policies and capacity building programs, the certification and trainings are provided through regional Industrial Training Institutes (ITIs).

12.5. Current Status and Best Practices

Government and regional partners have been pursuing a number of efforts to boost transport electrification and infrastructure deployment by supporting stakeholder trainings and skilling activities. Table provides current status of EV skilling programs and initiatives at national and state level to overcome challenges and achieve a sustainable transport sector.

Table 58: Skilling Initiatives in India

Sr. No.	Initiative/ Activity	Program	Major Stakeholders
1.	Automotive Skills Development Council and Research triangle Institute (RTI) India in Kakinada, Andhra Pradesh	Comprehensive Institutional Capacity and Skills Development Program	Private Stakeholders, Regional Government, NGO
2.	MoU between Hero MotoCorp, Delhi Skill Entrepreneurship University (DSEU) and WRI Inia	EV Mechanics training Program	Private Stakeholders, Think Tank
3.	MG Motors, Auto Components Manufacturers Association of India (ACMA)	Skill development in EV Component Industry	Private Stakeholders, OEMs
4.	Hero Electric and American India Foundation (AIF)	Multi High Impact Skilling, Training employment and self-employment program	Private Stakeholders
5.	United group of Institutions MOU with ISIE India for Center of Excellence	E-Mobility Research and Skill Development	Private Stakeholders

Additionally, wide range of specialization courses, trainings and online course materials released by Institutes and Training Providers are available. However, due to the current nascency of the industry there is a lack of standardization leading to gaps in securing optimum benefits from the available skilling materials.

UP EV Policy 2022 Job Creation Support

- Create jobs in the EV ecosystem and set up skill centres for training in EV related jobs
- Incentivise 5 CoEs with a 50% grant cost up to IINR 10 crores each; released over 5 years
- Skill development incentive: provide one time reimbursement of stipend at the rate of INR 5,000 per employee per year to a maximum of first 50 employees to all defined manufacturing projects
- Quality certification charges reimbursement: provide one time at the rate of 50% of fees paid for obtaining certification upto INR 10 lakhs per unit to large and MSME EV/Battery projects
- Patent registration fees reimbursement: provide one time at the rate of 75% of cost/ expenditure incurred up to INR 50000 for acquiring domestic patent and up to INR 2 lakh for acquiring international patent to Large and MSME EV/ Battery projects

Potential Investment Required to Set up Center of Excellence

The total investment required to setup 5 CoEs, as mentioned in the UP State EV Policy is INR 99 Crore or USD 11.86 Million. This expense is required as a capital cost, given the investment for each CoE is INR 19.78 Crore or USD 2.37 Million. There will be annual operational expense of INR 0.49 Crore or USD 580,000 per CoE. The investment required to establish each Centre of Excellence –

Component	Value (in INR)
Construction of 30k square foot Center of Excellence	16.81 crore
Charging equipment (2x 250kW + 3* 122 kW + 3*DC001+5*7kW Type 2+3*AC001)	1.52 crore
Capital cost	~ 19.78 crore
Operational expenses per annum	~ 49.44 lakhs

Best Practices

Globally, countries can learn best practices, knowledge and experience in skilling workforce to achieve sustainable transportation maintaining balanced job ecosystem. Some of the best practices related to EV skilling are mentioned below.

India: Comprehensive Institutional Capacity and Skills Development Program

The Automotive Skill Development Council (ASDC) in partnership with Research Triangle Institute (RTI) India is developing a comprehensive institutional capacity and skills development program for e-mobility. The program focusses on public transport in Kakinada Smart City, Andhra Pradesh and is executed with support from Kakinada Municipal Corporation under the UK PACT.

Key Highlights:

- The project aims to overcome institutional capacity gaps for future public transport in smart cities.
- The program includes two technical training courses including EV repair & service technicians and EV charging station attendants.
- The modules for training aim to upskill candidates fulfilling minimum educational requirements, 66 eligible candidates to be offered training in order to generate employment opportunities and create skilled manpower in e-mobility segments.

UK: Electrification Skill Framework

The UK Electrification Skill Framework aims to develop (Continuing Professional Development) CPD courses, divided into levels which are modular, consistent with credit accumulation. The framework works on the principle of convene, curate and develop to meet priority need in skill ecosystem along with looking for future and mi term requirements. The curriculum is adaptive and changes in any current course is reflected in other portfolios and programs. Additionally, accreditation is available for all short and long courses from relevant professional bodies.

Distribution of courses:

- STEM: Engaging young professional to STEM activities to broaden exposure to opportunities available through electrification
- Short Courses: Available for ongoing professionals for upskilling and reskilling
- Long courses: Makes use of apprenticeship models to provide relevant reskilling, upskilling and new skilling to perform key roles

Australia: Approach towards workforce skilling

The Victorian Automotive Chamber of Commerce (VACC) in 2018 aimed towards identification of gaps and skillset requirements in the current automotive workforce. The identified requirements include software developer with diagnostics, programming and coding skills to remedy vehicle faults along with emergency responder skills as greater occupational health and safety compliance are required to protect both staff and the general public given the high voltage inherent with Electric Vehicles.

Actions undertaken:

- Based on the recommendations new certificate apprenticeship training develop for the emerging EV technician jobs.
- Certificate III Automotive Electrical Technology (AUR30316) apprenticeship course launched in Aug 2021
- Vocational Skills Gap Assessment and Workforce Development Plan which includes the recommendations by VACC was launched in 2021

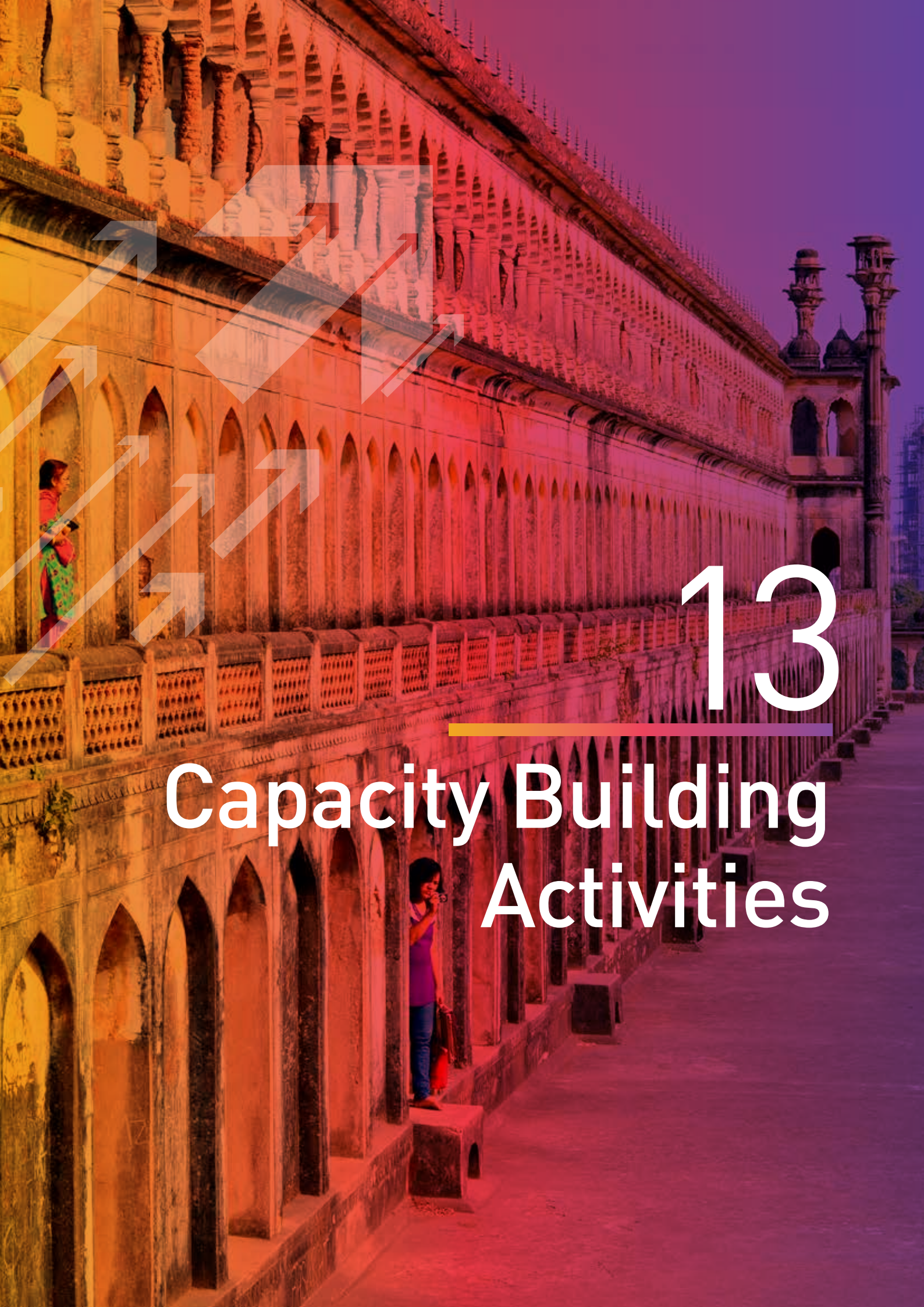
12.6. Summary of Recommended Initiatives

In order to develop a self-reliant and resilient automotive job sector in Lucknow and the state of U.P. it is imperative to develop strategies and take actions in a phased manner. The initial steps to a successful skilling ecosystem include strengthening collaboration and coordination between industry, educational and training institutions, and government to support responsive skills planning and development for tomorrow's workforce needs in the local automotive industry. Leveraging the regional strengths of local economies to cultivate a complementary and coordinated approach to talent development and availability is crucial. The near-term planning must include strategies to continuously build a strong, agile, and diversified talent pool in the city with the right skills for the sector now, and into the future through talent identification and engagement. Additionally, it is mandatory to support workforce to adapt and advance their skills and knowledge to the pace and scale of the automotive and mobility sector's transformation. Along with other strategies it is important to have continuous efforts towards building a gender inclusive industry with equal opportunities. Thus, strategies towards developing support groups promoting equal opportunities and increased women participation in automotive and mobility sector enabling industry access to diverse talent must be encouraged and considered in planning activities.

Table 59: Summary of Strategies and Initiatives

Challenges and Barriers	Probable Solutions	Action Timeline	Stakeholders
Development of curriculum for e-mobility	Development of curriculum collaboration committee for Automotive and Mobility Sector • Assist in proactive curriculum creation • Courses must reflect the fast-changing industry, and its corresponding talent and critical skill demands and requirements.	Short Term	Entrepreneurship and Industrial Development, UP Skill Development Mission, IET Lucknow, Government Polytechnic, Government ITI, OEMs
Industry exposure to students	Develop industry interaction programs for engineering, diploma and ITI students • Assist in promoting and enhancing broader knowledge and employment prospects in e-mobility • Prevent students from negative stereotypes of the field	Short and Medium term	LDA, LMC, LNN, IET, Government Polytechnic, Government ITI, OEMs
Availability of upskilling course	Develop online upskilling platform to give local talent access to short-term courses, micro-credentials, and learning materials • The courses can be developed by educational institutions and business • The courses aim to improve their skill set to match that needed for open employment	Short and Medium Term	LMC, LDA, LNN, IET, Government Polytechnic, Government ITI

Pilots and course validation	Execute pilot courses to validate credibility in scoring jobs • Utilize current clusters in local automotive and mobility industry • Support specific talent and skill needs and collaborate with regions outside of these clusters to improve regional integration.	Medium Term	UPSIDA, MSME, Ed-Tec Businesses, IET, Government Polytechnic, Government ITI
Availability of new skilling and reskilling opportunities	Development of reskilling platforms to encourage recruitment, and redeployment of talent from existing automotive job sectors • The platform must consist of courses with transferrable abilities to fulfill requirements by local automotive and mobility sector.	Medium Term	LDA, LMC, LNN, OEMs
Gender Diversity	Formation of an Advisory Committee for Equity, Diversity, and Inclusion for automotive sector to support EDI related initiatives and opportunities • The committee must support increased women participation and diversity in workforce	Short, Medium, and long term	Entrepreneurship and Industrial Development, UP Skill Development Mission, OEMs, MSME, UPSIDA
Prioritizing Future workforce demand	Utilize information on how the automotive and mobility sector is changing to guide the creation and ongoing evolution of a reskilling framework • Determining requirements for skills and workforce in Industry • Design of flexible initiatives and programmes to promote worker reskilling.	Long Term	Entrepreneurship and Industrial Development, Private Stakeholders



13

Capacity Building Activities

13. Capacity Building Activities

13.1. Introduction

Building capacity and exchanging experiences and best practices on technical as well as policy and strategy subjects at all levels helps maximize the development of sustainable electric mobility. Understanding the links between integrated multimodal transportation, electric mobility, and energy through capacity building activity can help solve issues pertaining to the development of a sustainable transport sector maintaining the same level of services.

The aspirations to shift towards a clean transport sector through complete electrification faces several barriers due to the nascency of the technology. The adoption of e-mobility is emerging and for a smooth transition in Luckno stakeholders must focus on each level from management of priority on ground services (recharging, maintenance, first responders) to long term aspects of a Transit oriented Development (TOD). For EVs to be kept running, charged, and secure, the infrastructure surrounding them needs to be maintained by professionals. To do this, a workforce of EV repair specialists, electricians who install EVSEs, and first responders to situations involving EVs or EVSE must be trained. To support the public and private sector collaboration necessary for electric transportation, training on stakeholder engagement and collaboration may be required. To assist in their work, the national and local policy communities can receive expert consulting services.

Over the years knowledge sharing and capacity building to provide holistic solutions has become more efficient, the ways in which information is distributed have significantly changed, particularly during the global COVID-19 pandemic. The majority of capacity-building initiatives have moved away from traditional classroom settings and toward new digital forms like webinars, online workshops, and courses, to mention a few. Additionally, international exchange of knowledge, skills, and best practices in order to overcome challenges effectively has become easier.

13.2. Capacity Building Activities

Training in technology and its management, fleet management, business models, life cycle assessment methodologies from conception to final disposition, integrated multimodal approaches, and digital solutions are few possible activities that can help with the adoption of electric mobility and mode shift promotion. Considering the context for Lucknow the focus for different capacity building activities varies for different stakeholders and local planning authorities based on their priorities. Major capacity building activities that tend to support smooth transition of services and encourage a rise in electric vehicle adoption are covered in the sections below.

Management of Technology and Services

EVs pose an imperative challenge in terms of a completely newer technology and being in an early adoption stage. For a smooth transition it becomes necessary for regional stakeholders to consider smooth management of services for consumers. Access to services like maintenance, energy replenishment and first responders becomes critical for consumers to have complete faith and trust before purchasing a PEV. Thus it is critical for stakeholders to facilitate trainings for the following services to support the growth and pace of EV adoption and transition.

- Training for EV repair technicians
- Training for installation technicians of EV recharging stations
- Training for first responders

Strategies for Transit Improvement

Transit authorities need to understand critical barriers of increasing traffic and pollution in cities due to usage of personal motorized transport for day-to-day public transit. Thus, it becomes necessary for regional stakeholders to understand the planning and implementation of electrified E-Bus Rapid

Transit (BRT) systems as well as bus regulations and operations. Collaborations and trainings that provides information on how to restructure formal urban bus transport, improve service quality and set service level benchmarks is important for regional planning authorities and government. Critical trainings for transit improvements include

- Planning of transit network and E-Bus transit routes
- Planning E-Bus operations and recharging stations
- Monitoring and evaluation of services and vehicles
- Integration of formal bus transit with informal transport sectors

Financing and Business Models

Requirements for higher upfront investments for setting up innovative infrastructure, EVSE and public transit vehicles mandates the stakeholders to identify existing and innovative infrastructure financing business models which can be contextualized for Transit Oriented development (TOD) financing. It is important for planning authorities and local government to build capacities on concepts concerning regulations, application of regulations along transit infrastructure and importance of crucial stakeholders that maneuver finance to implement sustainable urban transport financing and foster the creation of sustainable urban transport systems. Critical trainings for financing and business models include.

- Understanding financing toolbox, instruments and designing for local context
- Metrics for analysis, investment, monitoring, and evaluation
- Debt finance sources & strategies
- Innovative business models for public transit operation

Regional Planning and Communication Solutions

In order to keep pace with advancements in technology and urban development, city development authorities and regional planning authorities need to consider looking for innovative solutions to cater traffic, parking and infrastructure needs. To achieve optimal benefits EVs call for recharging sites to be deployed efficiently, thus it becomes imperative for city planning and urban housing stakeholders to understand intricate solutions for EVSE availability in parking, housing and priority sites. Additionally, capacity building for communication solutions to overcome awareness barriers that hinders accelerated adoption is also imperative for relevant stakeholders, critical trainings include.

- Management of EVSE in existing parking solutions
- EVSE installations and solutions for urban housing societies
- Understanding innovative approach towards communication solutions

13.3. Current Status and Best Practices

Government of India (GOI) and regional partners have been pursuing a number of efforts to boost transport electrification and infrastructure deployment by supporting stakeholder trainings and capacity building activities. Table provides current status of capacity building programs and initiatives at national and state level to overcome challenges and achieve a sustainable transport sector.

Table 60: Capacity Building Initiatives in India

Sr. No.	Initiative/ Activity	Program	Major Stakeholders
1.	Collaboration to share US best practices with Indian states related to e-mobility	Electric Mobility-Center for Strategic and International Studies	US Government, Indian state governments, CSIS
2.	Training on E-Bus Procurement, planning and operation	TUMI E-Bus Mission	TUMI, WRI India, State Government

3.	Training courses, workshops, and master class through fostering Industry and Academia collaborations	IESA Academy	India Energy Storage Alliance (IESA)

Best Practices

Countries across the globe have been striving towards achieving complete electrification of transport sector. Due to the similarities between the challenges in achieving them, there is a great potential for exchange expertise, experience and best practices between different countries.

E-Bus deployment in transit vehicles: Beyond CO_2 reduction, electrifying public bus fleets could have other advantages, and many cities have already begun incorporating electric buses into their fleets. Deep capacity building and careful planning are paramount towards achieve successful e-bus deployment while maintaining the same level of services.

India: E-Bus UpSchool Training Programme (By UITP)

Under the bilateral technical cooperation project titled "Integrated Sustainable Urban Transport Systems for Smart Cities (SMART-SUT)," which was commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and co-executed by the Government of India's Ministry of Housing and Urban Affairs (MoHUA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The E-Bus UpSchool programme, run by UITP with assistance from GIZ India, is a national capacity building initiative designed to address the training requirements for growing the usage of electric buses in India. The capacity building programme is aimed at India's public and private bus operators, including state transportation undertakings, municipal transportation departments, and special purpose vehicles. It also includes original equipment manufacturers, state and central ministries, as well as other professionals from organisations involved in the country's electric bus industry's expansion.

EU: European Union Innovative electric bus technologies were evaluated as part of the ZeEUS project (Zero Emission Urban Bus System), which was directed by UITP on behalf of the European Commission. In its studies, cases from more than 60 European towns are presented, together with technological innovations from about 30 original equipment manufacturers (OEMs)

13.4. Summary of Recommended Initiatives

To achieve a sustainable transport sector in Lucknow it is imperative to develop strategies aiming to train relevant stakeholders for efficient development and smooth transition along with catering requirements for trained workforce and officials to meet priority requirements. The initial steps must focus on fulfilling priority areas including requirement of trained officials in supporting on-ground implementation of infrastructure and services. Leveraging international experience and capacity building programs for planning regional requirements pertaining to e-mobility must be targeted in a smooth and phased manner for medium- and long-term capacity building activities. The table below summarizes near medium- and long-term activities for capacity building of relevant stakeholders of Lucknow in electric mobility.

Table 61: Summary of recommended solutions over the short- medium- and long-term

Challenges and Barriers	Probable Solutions	Action Timeline	Stakeholders
Management of Technology and services	Training for EV repair technicians Training for installation technicians of EV recharging stations	*Short Term*	Transport Department GoUP, LCTSL, LMC, LDA, UP Fire Services

	Training for first responders		
Transit Improvement Challenges	Training for planning of transit network, E-Bus transit routes, monitoring and evaluation of fleet	*Short and Medium Term*	Transport Department GoUP, LCTSL
Financing and Business Models	Training on innovative infrastructure financing and business models	*Short and Medium Term*	LMC, LDA, LCTSL, Transport Department,
Regional Planning and Communication Solutions	Training for regional planning of supporting infrastructure and their management	*Short, Medium and Long Term*	LMC, LDA, Housing and Urban Planning (HoUP) and Lucknow Development Authority

14

Consolidated Roadmap for Lucknow

14. Consolidated Roadmap for Lucknow

14.1. Creating the Roadmap

In order to address the barriers and challenges identified through the study, each chapter provides a list of initiatives, activities, and recommendations for each thematic area covered by them. These outputs have been consolidated into an overall roadmap for Lucknow city covering the short-, medium-, and long-term. The roadmap presents solutions to improve the urban transport landscape, promote EV adoption, upgrade the power grid to support charging, generate awareness, and provide skilling opportunities to workers hoping to enter the field of electric vehicles. Alongside, it identifies areas where investment is necessary and provides an estimate of the amounts involved.

The complete roadmap is as follows-

14.2. EV Adoption- Personal, Commercial, and Public

Areas of Focus	Short Term	Medium Term	Long Term	Investments by 2030 and Savings
Government Fleets- Passenger 4Ws for Official Use and Patrolling (4W Sedans, Hatchbacks, and compact SUVs.	Make future purchases electric, target older, less efficient vehicles for replacement. Partner with charging network providers to support new EVs Train staff for the operation and lifelong maintenance of electric vehicles Create guidelines for EV procurement, covering technical details and available models for easier tendering	Adoption mandate to replace ICE passenger vehicles for each department, at 10% a year. Perform demand aggregation exercises across department to bring down cost of procurement Install charging points on office premises and maintain a database of all such chargers to share the network across all state agencies	Update EV procurement guidelines as new models enter the market	Number of Vehicles: 60,000 Additional Expense: INR 1320 Crore or USD 158 Million Total Operational Savings: INR 2250 Crore or USD 270 Million
Municipal Solid Waste Collection: Replace door-to-door collection fleet of around 1,400 vehicles with	Conduct a pilot project with a small number of EVs in one or more Zones of the city, note results and collect driver feedback	Conduct capacity building of officials on economics and technical details obtained through pilot, to scale up EV procurement for the whole fleet. Order vehicles in bulk to reduce price	As newer EV models with increased carrying capacity come out, investigate possibility their use as water sprinkler and road cleaning vehicles.	Number of Vehicles: 1400 Additional Expense: INR 6.61 Crore or USD 0.8 Million

EVs (3W & Mini-Trucks)		post successful pilot, train workers in optimal operating methods, and install chargers in LMC workshops and parking spaces.		Total Operational Savings: INR 17.67 Crore or USD 2.1 Million
Promote EVs for Personal Use: 2-Wheelers	Promote awareness regarding fuel savings and ease of domestic charging Releases guidelines on safe home charging, covering installation and fire safety	Promote existing concessionary EV loans from public banks such as SBI and Union Bank, and encourage more such schemes Provide interest free motor vehicle advances to government employees, or advantageous EMIs through bulk purchase		Number of Vehicles: 258,000 Additional Expense: INR 412.8 Crore or USD 49.5 Million Total Operational Savings: 6,708 Core or USD 780 Million
Corporate Employee Transport (4W cabs)	Promote and guide EV entrepreneurship through Invest UP Develop sufficient skilling programs and courses to meet rising demand of employees Provide reserved parking for EVs in public parking spaces, exemptions from toll tax and parking fees to improve ease of use	Increase policy limit on number of vehicles fleet operators can avail subsidy on, as EVs operate better with scale	Begin limiting use of CNG taxis once the EV transport services market matures	Number of Vehicles: 25,500 Additional Expense: INR 688.5 Crore or USD 82.6 Million Total Operational Savings: INR 1224 Crore or USD 146.9 Million
Urban Freight (2W, 3W Cargo, Mini Trucks)	Promote and guide EV entrepreneurs in the logistics field	Increase limit on number of vehicles a business can avail subsidy on Prioritize installaiton of charging infrastructure in high use areas such as Transport Nagar and other hubs. This would be conditional on companies'	Develop fast-charging infrastructure along highways to enable future models of EV trucks to operate inter city freight.	Number of Vehicles: 28,200 Additional Expense: INR 288.8 Crore or USD 34.7 Million Total Operational Savings: INR 3009.5 Crore

		commitment towards EV use		or USD 361.2 Million

The total expenses (as additional up-front cost compared to ICE vehicles) by 2030, considering sales projections, stand to be upwards of INR 2,716 Crore or USD 326 Million. The benefits however far outstrip this figure, with operational savings through new EVs adding up to INR 13,210 Crores or USD 1,585 Million.

14.3. Power Sectors, EV Charging, and Renewable Energy Integration

Planning For Public Charging Infrastructure

Areas of Focus	Short Term	Medium Term	Long Term
Public Charging Infrastructure Network Planning and Implementation	Create and establish roadmap for development of public charging infrastructure for Lucknow, with annual targets of charging points. Identify available public sites for installing charging stations, based on spatial analysis of EV charging demand in different parts of the city. Implement tender(s) for public charging infrastructure through PPP mode, with appropriate terms and conditions to ensure viability of charging as a business.	Develop standards and guidelines for communication protocols and smart charging equipment for public charging infrastructure	Continue developing charging infrastructure according to demand Estimated costs of public charging stations until 2030- Total 153 Crores or USD 18.4 Million **Type of Charger** / **Cost** **3.3kW** – INR 55.4 Crore or USD 6.65 Million **15kW** – INR 41.5 Crore or USD 5 million **50kW** – INR 35 Crore or USD 4.2 Million **50kW along highway** – INR 22 Crore or USD 2.6 Million
Policy and Regulatory Measures for EV charging infrastructure	Amend Lucknow building byelaws to require 20% of all parking spaces in new buildings to be equipped with EV charging as per the amended Model Building Byelaws. Create a mandate for existing commercial and institutional buildings with a parking capacity of more than 100 vehicles to set aside 5% of their	Integrate EV charging requirement in parking policies and urban planning policies for setting up charging points at on-street parking spots, public parking places and transit station parking areas.	

	parking spaces for EV charging. Notify safety regulations and guidelines to be followed for installation of charging infrastructure Mandate the provision of no-objection certificates (NOC) for installation of EV charging that adheres to all planning and safety guidelines		
Impact of EV Charging on the Grid			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Smart Charging	DISCOMs need to tie up with existing charging network providers to receive real time data of charging demand	Implementing two-way communication between the charger, DISCOMs, and the charging network provider to allow dynamic Time of Use pricing and subscription models.	
Adopting V2X Applications-vehicle-to-grid (V2G) and vehicle-to-building (V2B)		Creating data linkages between EVSE and DISCOMs to support future V2X deployment Begin piloting V2G in locations with strong power grid infrastructure with the installation of bi-directional inverters and other monitoring technology Begin piloting V2B solutions similarly in large building such as offices and malls.	Develop the V2X market as deployment increases, including congestion management services to the Distribution System Operator (DSO), balancing services to the Transmission System Operator (TSO) and energy trading with Balancing Responsible Parties (BRPs). Introduce role of V2G aggregators that organize returning power to grid on a scale that can meet its requirements Develop advanced V2X methods such as vehicle-to-vehicle and vehicle-to-load
Upgrading Network of Distribution Transformers **Total Expected**	Review the geospatial mapping of future charging demand, and partner with current and prospective charging operators for Lucknow to determine the initial	As charging demand and associated peak load will rise quickly post-2025, a large scale upgrade program will need to be carried out to meet the following years' demand.	Using the wealth of data generated by EVSE and provided by charging point operators, create models to predict upcoming charging

Investment by 2030: INR 74.3 Crore or USD 8.92 Million	areas where charging demand is high. Identify missing or overloaded transformers in these areas, and upgrade them.	Bulk purchasing for this purpose can be done to bring down costs.	demand and upgrade transformers accordingly.
Renewable Energy Integration in the Grid			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Installing the renewable energy systems locally at charging stations or multi-storey buildings	Install solar panels on electric bus depot in Dubagga to supplement EV charging with solar power A 550 kW solar installation at the depot would cost INR 2.4-2.6 Crore or USD 288,000-312,000. Considering energy costs, the payback period would be 4.4 years.	Identify other large shadow-free spaces such as parking lots and building terraces for solar installation, install smart meters.	
Purchase of renewable energy for charging stations		Create a single-window platform for charging point operators to avail green energy from the green open access market Identify missing or overloaded transformers in these areas, and upgrade them.	Upgrading renewable energy generation and transmission capacity in the state.
Revision of MVVNL Time of Day Tariffs	Use Time of Day tariffs to direct EV charging demand to hours of maximum RE generation (i.e., 11:00 to 15:00)		
Energy Storage Solutions			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Policy	Development of a battery manufacturing roadmap/vision document with specific targets for battery production to cater to growing demand. Undertaking pilot project for RE+Battery Energy	Supporting battery manufacturing ecosystem by providing incentives across the value chain (other than battery pack) Government may explore providing financial support to DISCOMs to set up grid storage	Developing policy programmes for longer duration with minimal amendments to gain investor confidence (preferably 7-10 years)

	Storage Systems (BESS)+EV charging to demonstrate use case and easy replication Spurring battery storage demand in the state by incentivizing demand creation avenues. For e.g., the demand for RE+BESS+EV charging may be improved by providing ToD tariff for renewables during peak times. In addition, state should be more aggressive in pursuing BESS based tendering to create pipeline and visibility for manufacturers to step-in.	solutions and charging infrastructure. The user fee collected through use of common infrastructure may be paid back to government over a period to recoup the initial investment	
Creation of more robust supply chain for EV battery/ component manufacture		Engaging in technology partnerships for setting up processing and refining facilities in the state for key raw materials, and promote manufacturing of downstream battery components (cell, anode, cathode, electrolyte, etc.).	The state government with support from central agencies can look to work with mineral companies and enter long term contracts and strategic tie-ups for supply of critical battery minerals, given the concentrated nature of supply chains globally
Trunk infrastructure	Identification of new land parcels for development of battery manufacturing/EV parks for manufacturing	Undertake development of trunk infrastructure to boost manufacturing- easy logistics, connectivity, utilities (power, water), and waste treatment (sewage/effluent/battery scrappage)	
R&D and testing infrastructure	Engage prominent R&D institutes (such as IIT, NIT, etc.) actively engrossed in research and innovation on new emerging battery technologies, cost reduction strategies, cheaper alternatives, and material science. Such capabilities will be needed to improve competitiveness and gain familiarity with latest emerging trends (continuous process)		
Capacity Building and Awareness	Workshops and other public consultation programmes should be undertaken with investors to brief about key incentives, overall plans and vision of the state for improving its attractiveness	On the financing front, the government needs to undertake capacity building of local banks and key financial institutions in the state to reduce risk perception for better lending terms, interest rates, collateral demanded, and overall	Developing skilled manpower base in areas related to mineral extraction, processing, refining, and recycling, by organizing study tours/visits or engaging international consultants

		loan appraisal process for battery storage manufacturing	
Battery Recycling			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Lack of policy and regulations on battery recycling /reuse	Development of concrete policy framework comprising of subsidies, single window clearance, tax exemptions, and other fiscal and non-fiscal incentives. Clear targets for setting up battery recycling plants and collection centres in vicinity of EV charging station	Specific incentives for recycling of 'LFP (Lithium Ferrous Phosphate) technology', considering huge volumes for EVs and lower margins	Promote duty-free import of black mass for recyclers whose technology, efficiencies, and environmental impact have been approved by credible agencies
Lack of waste handling regulations, standards, and certifications	Developing legislation for adequate storage and disposal of used LiB to improve immediate health, safety, and environmental benefits Defining specific recovery rates for different battery chemistries with periodic review and updating	Specifying guidelines for transportation and handling of used LiBs Formalization of recyclers and waste traders, and/or obligations for battery recyclers to sell manufacturing scraps to formal sector recyclers	
Lack of battery manufactur-ing from recycled minerals/ metals	The state government can design a portal wherein OEMs can register the batteries that are being sold, which in turn can be used to keep a track of the reverse logistics	Establishing circularity through signing of formal agreements between recycler and battery manufacturer, so that post recycling the minerals are again utilized in battery manufacturing industry. A model agreement may be developed by UPPCB	
Labs for quicker testing		Establishing appropriate testing infrastructure for quicker testing and improved recovery processes Roping in leading international recyclers that are working on fully automated dismantling processes for improved	

		efficiency and cost savings	
Capacity Building and Awareness	Engage start-ups and prominent state institutes- NIT, IIT, IIM, etc. wherein the industry may tie up with academia for practical implementation regarding extraction of raw minerals from battery waste at higher efficiencies Establish platform for periodic dialogue and consultation between UP government and industry player on battery-related policies and regulations Leveraging ITIs in the state for proper skill development (continous process)		

14.4. Urban Transport and Development

Areas of Focus	Short Term	Medium Term	Long Term
Coordinating Agencies involved in Urban Transport- • **Housing and Urban Planning** • **Lucknow Development Authority** • **Office of the Transport Commissioner** • **LCTSL** • **LMRC** • **DISCOMs** • **Private contractors**	Use the working group on "Fast Track Development of Charging Infrastructure" outlined in the UP EV Police 2022 to bring together stakeholders on one platform Synergize route mapping and operations of LCTSL and UPMRC with e-rickshaw corridors to prevent cannibalization of revenue and increase cross usage.	Create guidelines for construction of charging points for installation of smaller facilities in venues such as malls, offices Coordinate the sharing of each agency's charging infrastructure among all others and create guidelines on providing access to the public wherever feasible.	Set up a permanent committee for continuous and smooth cooperation in these subjects
Improving Air Quality Index	Targeted tracking and phasing out of vehicles reaching their end of life (15 years)	Implementing technologies such as software-based PUC check on roads and the use of RFIDs. Pollution control planning in high traffic areas, construction sites, and demolitions	Conversion of additional municipal vehicles such as sweepers and water sprinklers that see daily use to EVs
Integrated Traffic Management System (ITMS)	Identify high traffic areas where intervention is required Increase oversight and data collection through upgrading traffic control room	Develop and deploy the ITMS along 19 identified corridors Include information centers, public toilets, and charging points for 2-wheelers and e-rickshaws Increase share of public transport through "One Lucknow Card" to	Bring on board intermediate public transport- autos and taxis onto one card system to create a seamless commute Increase engagement and coordination among stakeholders to design better junctions, educate

		act as medium of single payment for different modes of public transport- in addition to bike hiring and parking	users of traffic etiquette and laws, and improve enforcement of laws. (Continous process)
Non-Motorized Transport	Deploy e-scooter and e-bicycle stands in metro stations and markets, to attract customers and provide added convenience	Design a public engagement strategy to promote the use of bicycles and walking for short distance travel	Form a steering committee with a nominated coordinating office for all activities related to NMT and synergizing it with public transport
Parking Management	Improved end-to-end trip planning (i.e., knowing available parking spaces near destination). Digitally enable parking spots such that users can identify real-time parking space availability near their trip destinations. This will take place alongside deployment of charging infrastructure which is by nature digitally enabled. Use LMRC high tension power infrastructure to fast track installation of public charging at and near metro stations.	Improve street design for parking and the use of other modes, including allocating and clearly marking parking spaces and placing parking spaces in proximity to other modes of transportation (e.g., parking at a public transport station) Approve multi-level parking projects near areas of very high congestion, such as Hazratganj and Chowk.	Improve street design for parking and the use of other modes, including allocating and clearly marking parking spaces and placing parking spaces in proximity to other modes of transportation (e.g., parking at a public transport station)
E-Buses and Green Route Planning	Rationalization of bus fares without undue strain on customers, to improve revenue for LCTSL. Current revenue is around INR 30/km, lower than the operational cost. Prioritizing and ranking non-electric routes on the basis of footfall, such that maximum customers can be transitioned to EV when bus fleet expands	Procurement of e-buses on Opex models, avoiding the burden of heavy capital investment by the city. Established OEMs like Tata and upcoming ones like PMI and Olectra can be looked at. Prices in this model can be as high as INR 86/km, but through scale companies such as Tata have brought it as low as INR 40/km. Phased expansion of the bus fleet, keeping in view future spikes in requirements such as the Kumbh Mela.	

14.5. EV Awareness, Skilling, and Capacity Building of Officials

EV Awareness			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Public Outreach and Informational Material	Development of a one-stop, comprehensive, and easy to navigate website that provides all forms of e-mobility related information and tools for the public. Launch of public events to spread awareness and demonstrate benefits offered by electric mobility, events may include campaigns, EV showcases, EV melas, ride and drive events along with public exposition events aiming to boost EV sales	Conduct outreach and educational activities for potential consumers via reliable and trusted messengers-celebrities, public servants, etc. Development of Forums and Training programs for consumer and dealership awareness	
Physical Exposure and Experiential Awareness	EV rallies to show off vehicles to the public Launching awards and recognitions to further electric mobility and help OEMs as well as their affiliated dealer outlets optimize EV sales readiness	Create fleet electrification plans and pilot electrification of vehicles within local government bodies to increase exposure of EVs to consumers through fleets Expand visibility for e-mobility through traffic legislations on consistent signage and labelling for EVs and public charging infrastructure	
EV Skilling			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Development of Curriculum, Industry Exposure for Students, and Reskilling	Development of curriculum collaboration committee for Automotive and Mobility sectors that will assist in proactive curriculum creation and reflect needs of industry. Develop industry interaction programs for	Develop online upskilling platform to give local talent access to short-term courses, micro-credentials, and learning materials. The courses can be developed jointly with educational institutions and businesses	Training in Research and Development in centers of excellence (CoE) to develop indigenous research capabilities The investment for each CoE is INR 19.78 Crore or USD

	engineering, diploma and ITI students to assist in promoting and enhancing broader knowledge and employment prospects in e-mobility	.	2.37 Million, including setting up charging infrastructure for testing and development. There will be annual operational expense of INR 0.49 Crore or USD 580,000 per CoE
Gender Diversity	Formation of an Advisory Committee for Equity, Diversity, and Inclusion for automotive sector to support EDI related initiatives and opportunities. The committee must support increased women participation and diversity in workforce (Continuous process)		
Prioritizing Future workforce demand	Development of reskilling platforms to encourage recruitment, and redeployment of talent from existing automotive job sectors The platform must consist of courses with transferrable abilities to fulfill requirements by local automotive and mobility sector.	Execute pilot courses to validate credibility in scoring jobs. Utilize current clusters in local automotive and mobility industry. Support specific talent and skill needs and collaborate with regions outside of these clusters to improve regional integration	

EV Capacity Building of Officials and Government Staff			
Areas of Focus	**Short Term**	**Medium Term**	**Long Term**
Management of Technology and Services	Training for EV repair technicians Training for installation technicians of EV charging stations Training for first responders in response to EV accidents	Training for planning of transit network, E-Bus transit routes, monitoring and evaluation of fleet	
Financing, business models, and regional planning		Training on innovative infrastructure financing and business models	Training for regional planning of supporting infrastructure and their management (continous process)

14.6. Size and Key Sources of Investment

The key sources of investment can be broadly classified into three categories – Non-Banking Financial Companies (NBFCs), Long-Term Investors and Banks. The table below identifies different stakeholders in each of these categories along with their roles. The required investment by 2030 for different category is also listed in the table below –

Table 64: Investment Size Required

Category	Areas of Investment	Investment Amount (in USD)
Charging Infrastructure	Setting up Charging Stations	18.5 million
	Upgrade Power Distribution Network	8.92 million
	Energy Storage	0.96-1.2 million per MWh
Rooftop Solar	550 kW installation at Dubagga Bus Depot to support e-bus charging	288,000-312,000
Skilling	Center of Excellence	2.37 million
EV Adoption	EV Sales	326 million

Table 65: Key Sources of Investment

Category	Stakeholder	Description
NBFCs	Captive vehicle financiers	OEM-owned NBFCs that provide specialized and subvention-linked products to customers
	Non-Captive vehicle financiers	Other privately owned NBFCs that provide smaller pools of finance at higher interest rates in non-metro areas
	Fintech companies	Privately owned companies that lend through technology and digital platforms
National Government Schemes	Central Government	The Revamped Distribution Sector Scheme (RDSS) allows DISCOMs to apply for funding to build upstream infrastructure for charging stations
Long-Term Investors	National development banks	State-owned Indian FIs that provide equity and/or debt to mobility startups, large fleet owners, and businesses for sustainable economic development
	Multilateral/ bilateral development banks	Publicly owned international FIs that provide equity and/or debt to banks, NBFCs, and businesses for transitioning fleets for sustainable economic development
	Venture capital funds	Private investors that provide equity to mobility startups, early-stage ventures and fintech
Banks	Public sector undertaking (PSU) banks	State-owned commercial FIs that provide longer tenure, lower interest loans
	Private sector banks	Privately owned FIs that specialise in larger transactions for institutions, fleets, and vehicles in urban areas

15 Appendices

15. Appendices

A.1. Appendix 1

Inputs for EV Penetration

	2021	2022	2025	2030
Number of 2W	63,318	69,017	**89,379**	1,37,520
EV Penetration rate (%)	2%	5%	**20%**	**50%**
Number of electric 2W (registration)	1,266	3,451	**17,876**	**68,760**
Number of 3W	785	812	**898**	1,063
EV Penetration rate (%)	5%	10%	**40%**	**100%**
Number of electric 3W (registration)	39	81	**359**	**1,063**
Number of E-Rickshaw	6215	7147	**10870**	**21864**
EV Penetration rate (%)	100%	100%	100%	100%
Number of 4W Private	36,172	39,034	**49,053**	**71,784**
EV Penetration rate (%)	1%	2%	**5%**	**15%**
Number of electric 4WPrivate (registration)	181	586	**2,453**	**10,768**
Number of 4W Comm.	7,135	8,286	**12,978**	**27,414**
EV Penetration rate (%)	1%	3%	**10%**	**30%**
Number of electric 4W Comm. (registration)	71	249	**1,298**	**8,224**

Inputs for Emission Calculation

Vehicle Life Cycle		
Glider and Powertrain		
Power train	t CO_2 eq	tCO_2eq/t vehicle
Gasoline ICEV	7.2	5.2
BEV	6.5	4.7
Maintenance		
Power train	g CO_2 eq/km	
Gasoline ICEV	5	
BEV	4	
Battery Production		
Battery type	China (kg CO_2eq/kWh)	South Korea (kg CO_2eq/kWh)
NMC 111	77	69

NMC 622	69	64
NMC 811	68	63
LFP	51-56	46-50

Fuel Life Cycle		
Well to wheel (ICE)		
India (kg CO_2eq/L)	Well to Tank	Tank to Wheel
Gasoline	0.64	2.15
Diesel	0.92	2.76
Well to wheel (BEV)		
India (g CO_2eq/kWh)	Well to Tank	Tank to Wheel
India (CEA 2021)	790	0
SS	561	0

A.2. Appendix 2

Total Cost of Ownership Analysis

To judge the viability of electric vehicles across various segments, a total cost of ownership analysis needs to be performed. It gives the overall costs incurred by a user over a vehicle's lifetime, considering all the usual expenses of buying, fueling, and maintaining the vehicle under certain conditions of usage.

The lifetime cost depends heavily on operating conditions, i.e., utilization per day, maintenance costs, price of electricity/fuel, etc. that can be taken as a series of cash outflows spread over years.

The Net Present Value (NPV) of the lifetime expenses on a vehicle can then be calculated by taking a suitable discount rate and compared with an ICE vehicle to find the level of usage needed to achieve cost parity.

It has the following components-

- Capital Cost
  - Vehicle Cost
  - Taxes, registration, etc.
  - Financial Incentives
- Operational Costs
  - Annual Fuel/Charging Costs
  - Maintenance Cost
  - Battery Replacement Cost

Vehicle cost: Presently, the up-front cost of an electric vehicle exceeds that of an ICE vehicle. One of the major contributing factors is the cost of lithium-ion battery packs, which can range from 15% to nearly 40% of the cost of the vehicle. Reasons for this include expensive imports and skilled labor required for their assembly. Older EV models have battery packs available as low as $82/kWh, while high end models such as SUVs can go up to $300/kWh. Higher priced battery packs come with the advantage of much higher longevity. However, the price of batteries is trending downwards as technology advances.

Battery swapping serves to mitigate the up-front cost by allowing customers to buy vehicles without batteries. Batteries are instead owned by swapping station operators, who charge a flat fee or subscription for providing charged batteries that are swapped out once emptied. This model is favored by electric rickshaws with lower battery capacities, so that they can operate throughout the day with minimal downtime.

Another trend that favors the advent of electric vehicles is the increasing costs of environmental compliance among ICE vehicles as new standards such as BS VI are enforced. Already, the cost of diesel vehicles is increasing since more complex components are required to keep their emissions within legal limits.

Taxes, Registration, etc.: The on-road cost of vehicles have been taken for this analysis, as it includes additional expenses such as taxes and registration fees. These are most relevant for ICE vehicles, as electric vehicles are exempted from Road Tax and Registration fees for the first three years

Financial Incentives: As part of the announced-UP EV Policy (2022), several incentives have been given for the purchase of electric vehicles. These come in the form of-

- Road tax and registration fees exemption for first 3 years.
- Subsidy on purchase ranging from 10% to 15% depending on vehicle type, for early adopters.

These are in addition to the subsidies under FAME-II given to OEMs, which have already been included in the price of electric vehicles.

Operational Costs: An electric vehicle's primary advantage over ICE is its much lower operational cost. Charging an electric vehicle comes only at the cost of power for residential charging, although some states such as UP plan to offer concessional rates that are lower. Public charging stations are also affordable to the public, charging slightly higher rates or a flat fee for charging as much as a user wants.

Electric vehicles cost as much as 40% lower to maintain as compared to ICE vehicles and operate at a much higher efficiency (70-80%) compared to fossil fuel engines (20-40%). Within warranty, the battery packs require no maintenance at all, with the electric motor needing a lubricant change every few years. Most of the maintenance cost come from the wiring, motor control unit, brakes etc.

Battery Replacement: Battery warranties can range from 3 years for cheaper EVs, to 8 years or more for EV SUVs. Post that, the customer must pay for an expensive replacement which costs a sizeable fraction of the vehicle itself. This is included in the lifetime cost calculations for EV.

Finding TCO: This involves finding the net present value of the investment into an EV, using the discounted cash flow method. The upfront cost is added to the NPV of the battery replacement and operational costs for EVs, to arrive at the final NPV. Similarly, for petrol, diesel, and CNG vehicles of various types, the fuel cost is taken instead. We have assumed a vehicle lifetime of 10 years for this calculation.

By dividing the NPV with the total kilometers travelled over its lifetime, we can find the Total Cost of Ownership. Kilometers travelled will naturally differ across use cases, and TCO will be calculated

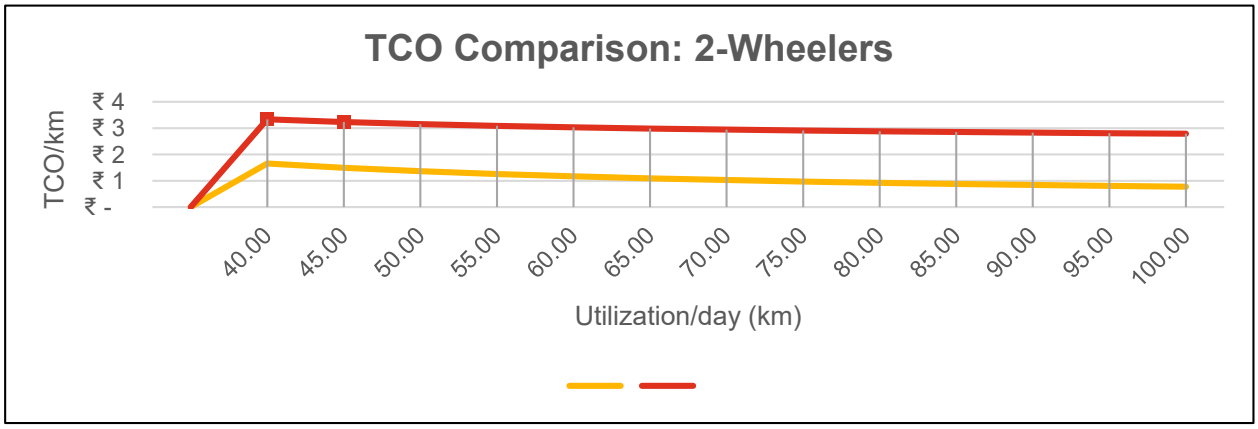
accordingly. Finally, by comparing NPVs of similar electric and ICE vehicles, we can calculate the lifetime savings from going electric.

A summary of the assumptions used is given below-

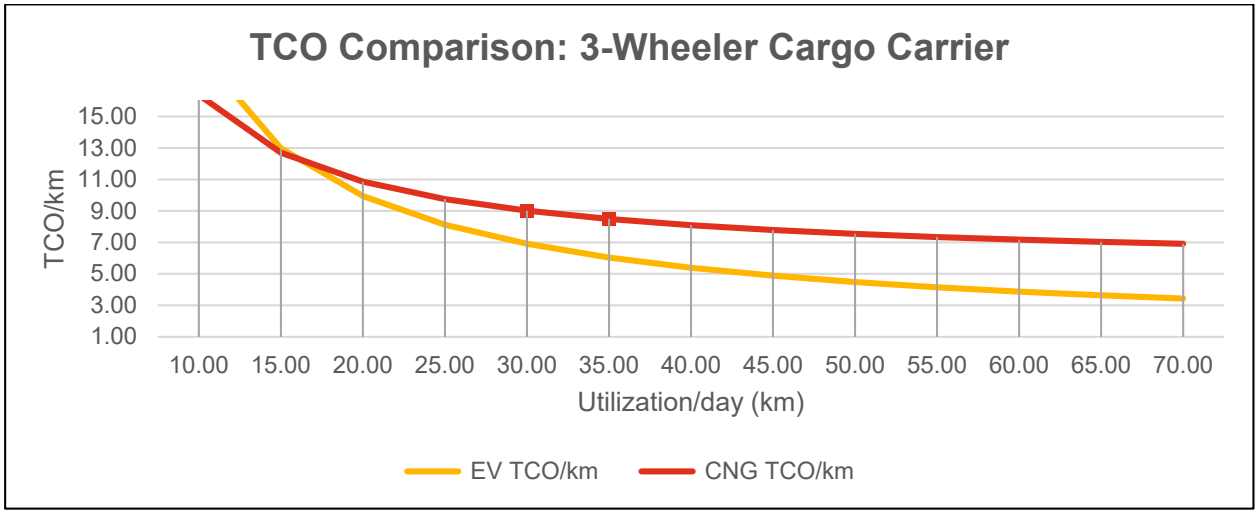
- Domestic charging tariff has been taken at INR 6 per unit.
- Commercial charging tariff has been taken at INR 7.50 per unit
- Technical specification of vehicles (mileage, battery capacity, etc.) have been taken from models commonly available in the market.
- Lifetime of vehicles has been assumed to be 10 years, except those used for Solid Waste Collection. They have a shorter lifetime of 8 years due to intensive wear and tear.
- Battery replacements over an EV's lifetime and the cost of batteries have been accounted for.

In practice, the performance, range, and efficiency of electric vehicles will differ according to various factors like temperature (affects battery life), quality of roads, the amount of passengers/weight of cargo. However, this analysis does provide indicative numbers to help judge the economics of various use-cases and make purchase decisions.

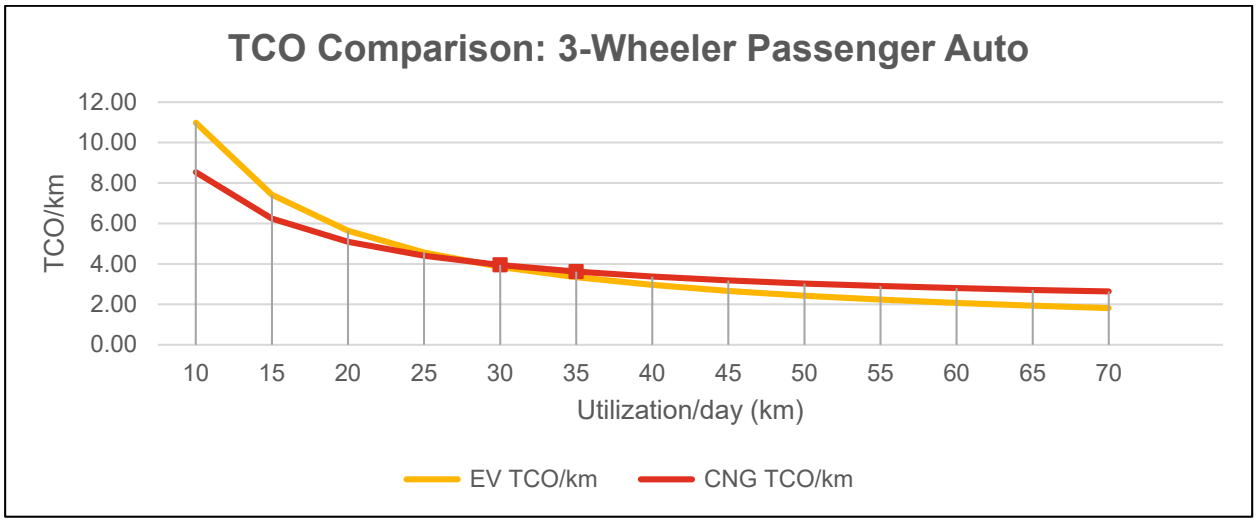
Results



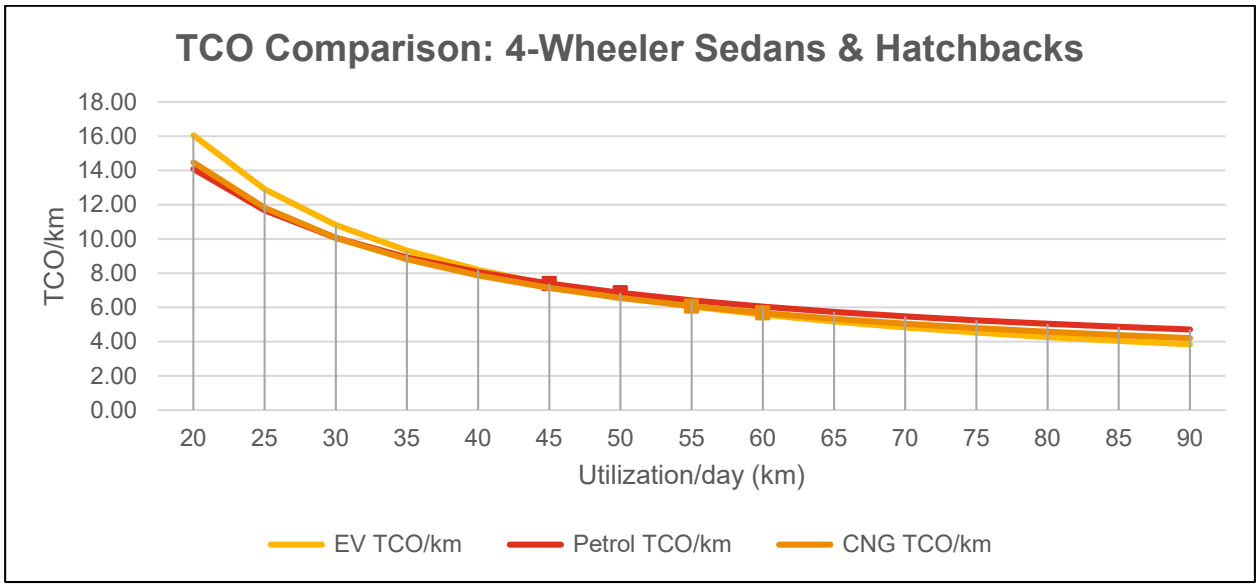
As one would expect, with their low cost and ergonomics, electric two-wheelers are able to easily achieve cost parity at even very low rates of utilization. A modest 10-15km driven every day brings them at par with petrol two-wheelers, with cost per kilometer dropping off sharply with increasing utilization.



Electric 3-wheeler cargo carriers, with their higher up-front costs and larger batteries, require a higher rate of utilization than 2-wheelers to achieve cost parity. 30-35km driven every day brings them at par with their CNG counterparts, with savings increasing gradually as utilization increases beyond this point.

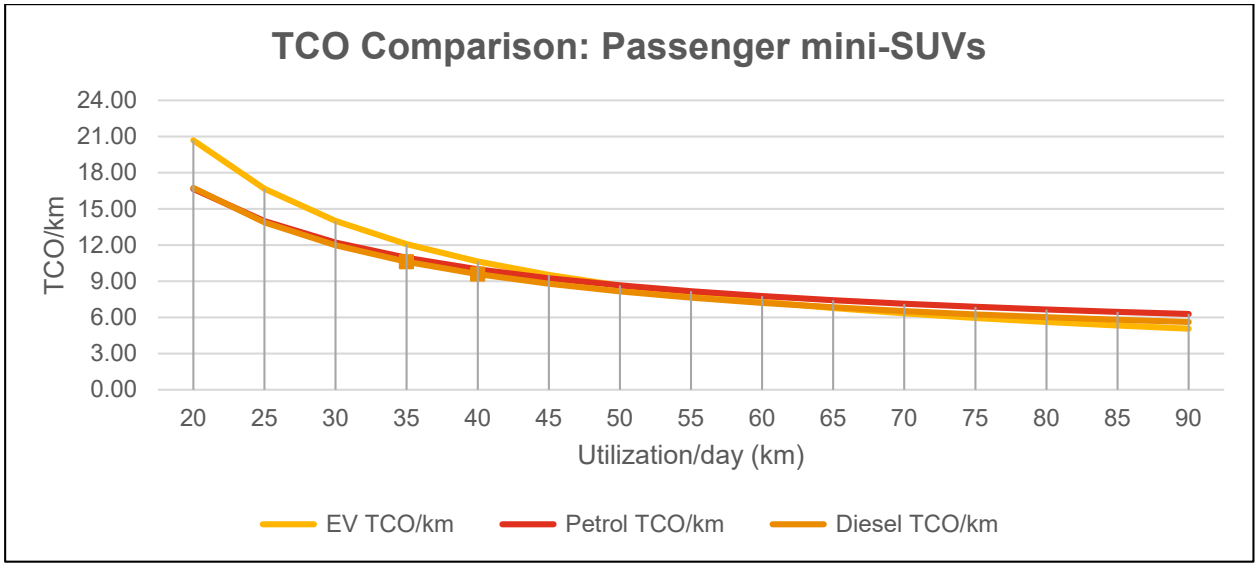


Passenger autos have a lower cost than cargo carriers due to a lighter chassis and smaller motor. While electric 3-wheeler passenger autos require a similar utilization at 30-35km, their TCO is lower.

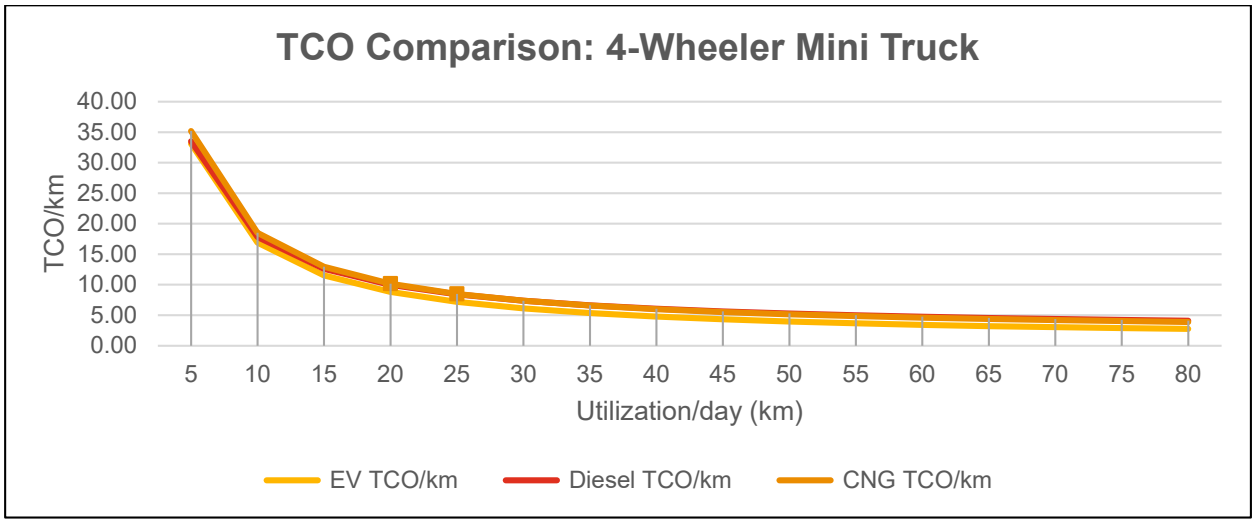


Electric 4-wheeler sedans and hatchbacks represent a significant up-front investment and require high utilization levels to reach parity with their petrol and CNG counterparts. A minimum utilization of 45-50km per day is needed versus petrol, which is difficult to achieve during personal use of the vehicle. CNG parity requires even more, at 55-60km per day. In comparison, the average commute for officegoers, both ways combined, is 30-40km across tier 1 cities.

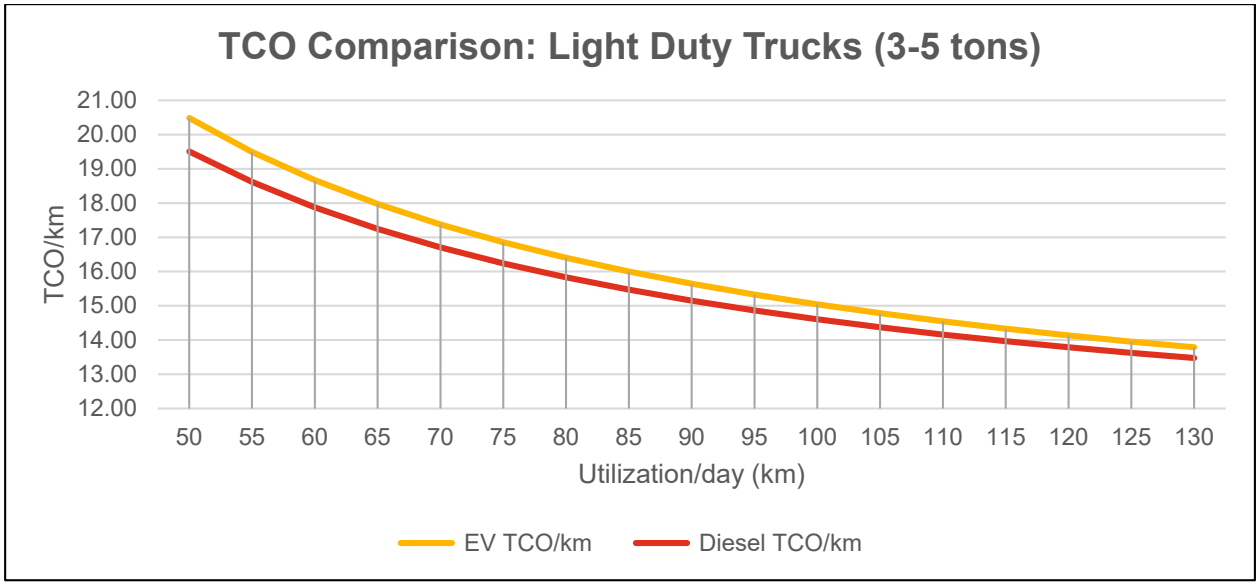
The reason why it is more difficult to achieve cost parity is the high fuel efficiency of ICE variants. Fuel costs are a major pain point for customers in this segment, so automakers have designed ICE vehicles to have as high a mileage as possible, reducing the advantage of electric vehicles in terms of operational cost. Nevertheless, cost savings are still significant and continue to rise as utilization increases. Ride-hailing drivers and taxi services using these vehicles will have no problem reaping these benefits.



In fact, higher end vehicles such as mini-SUVs achieve cost parity at lower levels than sedans and hatchbacks. A lower utilization for 35-40km per day is needed, which is due to the longer lifetimes of their batteries and less frequent replacements. However, due the cost of such models, the overall TCO is higher.



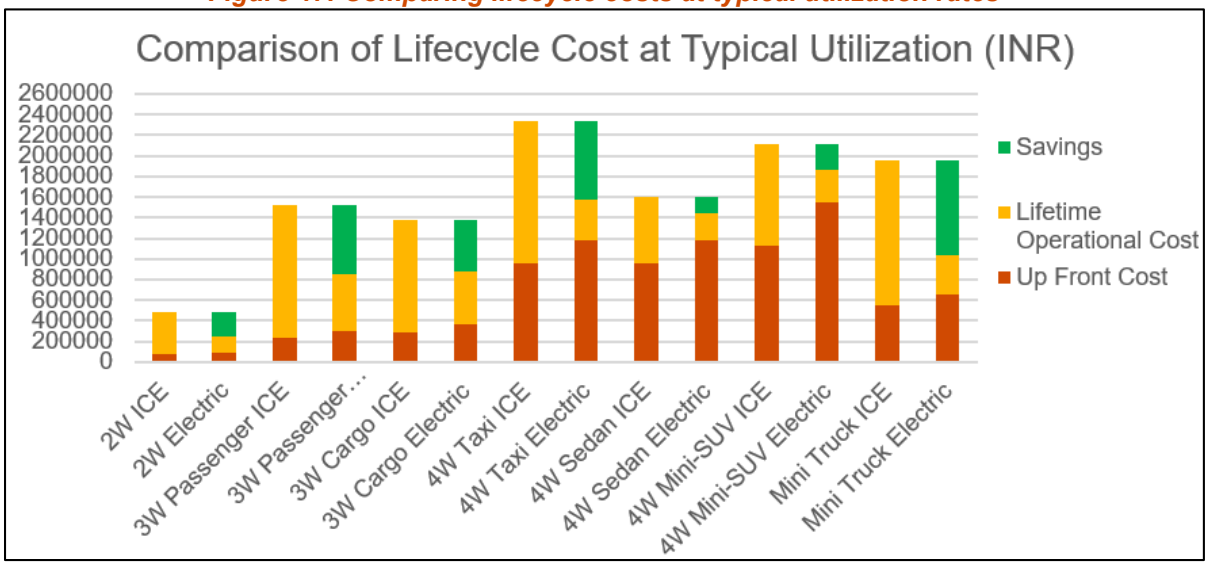
Similarly, for electric mini trucks, the longevity of their batteries makes only a single replacement necessary in the vehicle's lifetime. A low utilization of 20-25km/day is required to make them viable. These vehicles have a carrying capacity of around 700kg and can be used to carry a wide variety of local freight.



This segment consists of much larger vehicles, with a carrying capacity of 3-5 tons. They have larger batteries of above 60kwh, but a limited range of around 100km per charge. At this level of power consumption, there are little to no fuel cost savings versus diesel. While maintenance cost is lower, this is not enough to achieve cost parity at feasible utilization ranges. Therefore, light duty trucks are not included in the prioritized business cases.

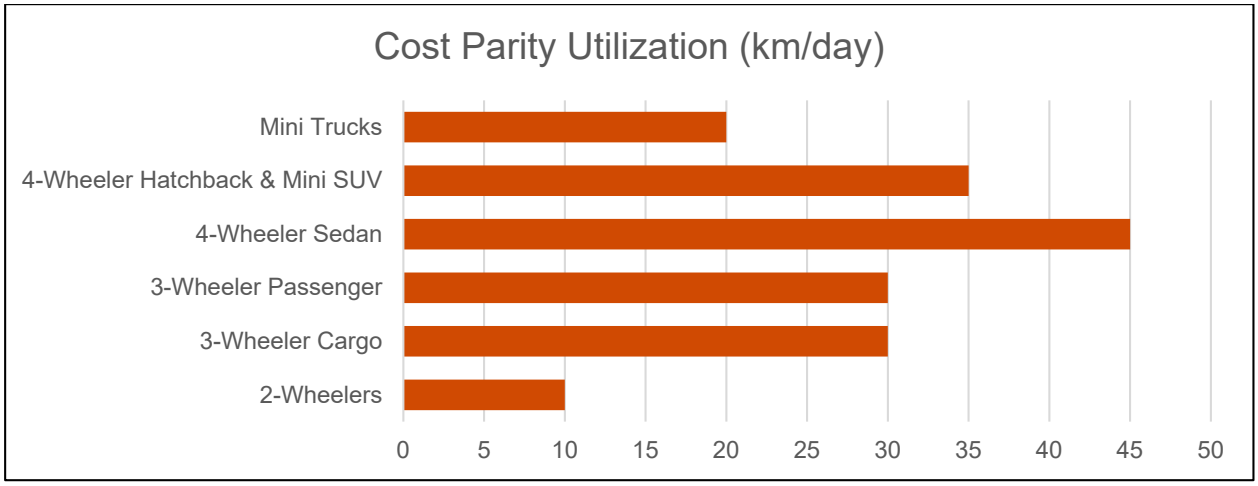
A summary of these results is given below-

Figure 47: Comparing lifecycle costs at typical utilization rates



Typical utilization numbers have been taken as 45 km/day for 2-wheelers, sedans, and Mini SUVs and 100 km/day for 3-wheelers, 4-wheeler taxis, and Mini Trucks. This is to reflect private versus commercial use. There are several notable results-

1. As shown by the analysis, electric vehicles used for commercial purposes are able to provide 30-40% lower lifetime cost due to their high utilization.
2. 2-wheelers are able to provide more than 50% savings even in private usage, due to only a small difference in up-front cost and the efficient nature of these vehicles.
3. Even for sedans and mini SUVs, cost parity is achieved at typical usage levels. In exchange, the user receives a zero-emissions, low-noise, and modern vehicle.



These serve as an important metric to filter possible business cases. In order to for substantial adoption to happen, there needs to be an economic rationale for the investment required to make the transition. When a business case's utilization exceeds these thresholds, electric vehicles offer a superior lifetime cost compared to their ICE counterparts.

A.3. Appendix 3

Methodology for estimating number of EV Public Chargers

Steps for estimating number Public EV charging infrastructure are given below.

Assumptions Considered

- For base year, number of ICE vehicles registered in 2021 were considered for electric vehicle projections.
- Based on ICCT's projections for 2030, a net battery capacity of 6 kWh was considered for e-2W segment, 9 kWh for e-3W segment and 62 kWh for e-4W segment.
- Based on ICCT's research, a y-o-y decrease in energy consumption of 0.65% for e-2Ws, e-3Ws and e-4Ws was considered.
- With cities expanding and with availability of better EV models, the daily distance travelled is assumed to increase across all vehicle segments.
- The share of public charging considered for all vehicle segments is as follows:
  - e-2W: 10%
  - e-3W: 50%
  - e-rickshaw- 50%
  - e-4W (private): 20%
  - e-4W (commercial): 50%
- For charger utilization rates, a 5% y-oy increase was considered where the average utilisation by 2030 will be around 50 - 60%.
- For e-2Ws, e-3Ws, e-rickshaws and e-4Ws, a c-rate of battery (charging rate) of 0.5 to 0.7 was considered until 2030.
- On the charger type, 3.3kW chargers for e-2Ws, e-rickshaws and e-3Ws, ,15kW chargers for e-4W (commercial) and 50kW chargers for e-4W (private) were considered.

STEP 1:Considering EV penetration rates for the city for different vehicle segments and target penetrations, number of EV s on road by 2025 and 2030 is estimated.

STEP 2: The daily kilometers driven by EVs for both private and commercial , the current and future battery capacities for e-2W, e-3W and e-4Ws are considered.

The total number of EVs on road is projected using the current growth trend of ICE vehicles and the penetration rates of EV in each vehicle segment. The total number of vehicles projected to 2030 and the penetration rates adopted are shown below.

Projected EVs on Road

Vehicle Segment	2025	2030
2w	42,416	2,58,366
3w	1,409	5,422
e-rickshaw	41,904	84,284
4w private	5,880	38,540
4w commercial	2881	25506
Total EVs on road	**94489**	**412118**

Penetration rates considered for 2025 and 2030

Penetration rates considered	2025	2030
E-2W	20%	50%
E-3W	50%	100%
E-Rickshaw	100%	100%
E-4W (personal)	5%	15%
E-4W (commercial)	10%	30%

(Source: NITI Ayog, BNEF, IEA estimates and Lucknow RTO)

STEP 3: The energy consumption per km is calculated and a y-o-y decrease in energy consumption levels is considered.

STEP 4: The daily energy needs for charging EVs is calculated and the share of charging to be fulfilled through public charging infrastructure is assigned.

Considering the current and future battery capacities and the energy consumption per km of EV,the future range for each EV vehicle segment is calculated.

With cities expanding and with availability of better EV models, the daily distance travelled is assumed to increase across all vehicle segments. The daily energy needs (in kWh) is then calculated using daily driving needs and energy consumption per km. Total daily energy needs to fully charge EVs in a given city or a region is then calculated using daily energy needs and number of EVs on road.

Estimated daily Energy needs

EV segment	BY 2025				BY 2030			
	Battery capacity (in kWh)	Energy consumption (kWh/km)	Daily driving needs (in km)	Daily energy needs (kWh)	Battery capacity (in kWh)	Energy consumption (kWh/km)	Daily driving needs (in km)	Daily energy needs (kWh)
e-2W	4.2	0.030438	50	**1.53**	6.0	0.029422	60	**1.79**
e-3W	9.0	0.055443	130	**7.28**	9.0	0.053593	140	**7.65**
e-rickshaw	5.0	0.038960	100	3.94	6.8	0.037660	120	4.62
e-4W (private)	55.0	0.158374	50	**7.97**	62.0	0.153089	60	**9.32**
e-4W (commercial)	25.0	0.158374	130	**20.72**	35.0	0.153089	140	**21.7**

Considering the percentage of time an EV is charged at public locations such as fuel stations, metro stations, etc, the share of energy needs that will be supported through public charging is estimated.

Share of Public Charging

Charging use-case	e-4Ws (Commercial)	e-4Ws (Private)	e-rickshaw	e-3Ws	e-2Ws
Public charging	50%	20%	50%	50%	10%
Workplace charging	25%	20%	25%	25%	10%
Home charging	25%	60%	25%	25%	80%

Total Energy needs from public charging per day

EV segment	Energy needs from public charging (KWh) per day	
	2025	2030
e-2W	6499	46316
e-3W	5126	20754
e-rickshaw	82567	194896
e-4W (private)	9375	71842
e-4W (commercial)	29850	276755

STEP 5: Considering a y-o-y charger utilization rate and maximum power drawn by an EV (based on battery capacity and C-rate) , the power delivered by chargers per day is estimated.

STEP 6:The cumulative number of chargers needed to support charging needs of EVs in the city is calculated

For estimating the Number of chargers, the current and future charger utilization rate, C-rate of the battery and maximum power drawn by an EV is estimated.

Maximum power delivered by the charger (kW) i.e., Power capacity of a public charger is assumed as 3.3kW chargers for e-2Ws, e-3W and e-rickshaws,15 kW chargers for e-4W (commercial) and 50kW chargers for e-4W (private)were considered.

Power delivered per charger (kWh) per day based on utilisation rate is then calculated using maximum power drawn by an EV and its utilisation rate. The cumulative number of public chargers required for the planning area is estimated using;

$$\text{Number of public Chargers} = \frac{\text{Energy need from public charging per day (kWh)}}{\text{Power delivered per charger (kWh/ day)}}$$

A.4. Appendix 4

Methodology for estimating battery swapping station

Assumptions Considered

- For base year, number of ICE vehicles registered in 2021 were considered for electric vehicle projections.
- Based on current swappable EV models available, a net battery capacity of 2 kWh was considered for e-2W segment, 4 kWh for e-3W segment with swappable battery for 2025.
- The percentage of EVs with swappable battery considered for 2025 is as follows:
  - e-2W: 10%
  - e-3W: 20%
- Based on the daily driving needs and range of EV, 1 swap per day is considered.
- Considering the number of batteries in circulation, no. of batteries required per day is considered as 1.5 times the number of vehicles
- One swapping station per 20 vehicle is considered

STEP 1:Considering EV penetration rates for different vehicle segments and target penetrations, number of EV s on road by 2025 is estimated.

STEP 2: Considering percentage of EVs with swappable batteries,number of e-2w and e-3w on road with swappable battery is estimated for the year 2025.

STEP 3: The daily kilometers driven and the range of e-2W and e-3Ws with swappable batteries are considered.

STEP 4: Considering one swap per day and the number of batteries that are in circulation, total number of batteries required for 2025 is estimated as 1.5 times the number of EVs with swappable batteries.

STEP 5: Considering 1 swapping station required for 20 vehicles, number swapping stations required for 2025 is estimated.

A.5. Appendix 5

Methodology for Geospatial Analysis of charging demand distribution.

1. Divide the area under planning into grids

2. Identify parameters that indicate potential charging demand and collate spatialized data for the selected parameters

3. Assign weightages to different parameters based on their estimated impact on potential charging demand

4. Combine the values of all parameters for the cells and categorize them based on potential demand, ranging from high to low.

5. Calculate the required number of charging points in each cell as a proportionate share of public charging points in city

Spatial parameters considered and weightages

The parameters that indicate potential charging demand is identified and the spatial data is collated. The spatial distribution of public EV charging demand is estimated by understanding the travel patterns the origin destination locations of various fleets under 2W, 3W and 4W vehicle segments. The spatial parameters considered, and their weightages are shown in the table below.

Spatial parameters considered and their assigned weightages

Spatial datasets	Definition	Source	Weightage
Population count	Includes the Census 2011 population data that has been projected to 2020 and distributed at a 1km grid level	World Pop	15%
Workplace cluster	Includes government office buildings	Google API	5%
Institutional cluster	Includes public and semi-public institutional buildings such as hospitals/health care centers (private and government) and educational institutions (school, college, university)	OSM, Google API	10%
Points of Interest	Includes shopping malls, movie theatres, eateries, and public parks	Google API	25%
Public transit stations	Includes metro stations, railway stations and bus depots	Governme nt websites	20%
Local businesses	Includes grocery stores and supermarkets	Google API	10%
Fuel stations	Includes petrol pumps and CNG stations	Google API	15%

A.6. Appendix 6

Calculating Peak Load Demand of EV Charging

1. e-4W commercial vehicles:

- Commercial e-4Ws in a city will be charged at the charging hub and public charging station.
- In total number of vehicles, 50% of vehicles are charging at public charging and 50% of vehicles are charging at charging hubs.
- SoC while the plug-in is 25%, 30%, and 40%.
- Amongst the total number of vehicles for each charging type, equal share of vehicles are considered for 25%, 30%, and 40% SoC.
- Power rating of the charger at the charging hub (AC slow charger) is 3.3 kW and 7 kW. Out of 100% of vehicle charging at charging hub, 50% of vehicles are charged by using 3.3 kW charger and remaining 50% of vehicles are charged by using 7 kW charger.
- Power rating of the charger at the public charging station (DC fast charger) is 15 kW and 50 kW. Out of 100% of vehicle charging at public charging station, 50% of vehicles are charged by using 15 kW charger and remaining 50% of vehicles are charged by using 50 kW charger.
- Battery capacity is 21 kWh for 2022, 25 kWh for 2025, and 35 kWh for 2030.
- C-rating of the battery is 0.5 for 2022, 0.6 for 2025, and 0.7 for 2030.
- Charging hub (overnight charging) – Plug-in starting from 9 PM, 10 PM, and 11 PM. % of the share is 33%.
- Public charging (Mid-day charging) – Plug-in starting from 12 PM, 1 PM, 2 PM, 3 PM, and 4 PM. % of the share is 20%.

2. e-4W non-commercial (private) vehicles:

- Non-Commercial e-4Ws in a city will be charged at home, workplace charging, and public charging stations.
- Each vehicle will only charge once in 3 days. So only 33% of total vehicles will be charged every day.
- In the total number of vehicles, 70% of vehicles are charged at residential charging, 10% of vehicles are charged at public charging stations and 20% of vehicles are charged at the workplace.
- SoC while the plug-in is 25%, 30%, and 40% SoC.
- Amongst the total number of vehicles for each charging type, equal share of vehicles are considered for 25%, 30%, and 40% SoC.
- Power rating of the charger at the charging hub (AC slow charger) is 7 kW.
- Power rating of the charger at the public charging station (DC fast charger) is 50 kW.
- Battery capacity is 41 kWh for 2022, 55 kWh for 2025, and 62 kWh for 2030.
- C-rating of the battery is 0.5 for 2022, 0.6 for 2025, and 0.7 for 2030.
- Residential charging (overnight charging) – Plug-in starting from morning 6 AM to 9 AM and evening 7 PM to 10 PM. % of the share is 20% for morning and 80% for evening. Amongst 20% of vehicles charging in the morning, 5% of vehicles are connected to the charger in every hour. Amongst 80% of vehicles charging in the evening, 20% of vehicles are connected to the charger in every hour.
- Public charging - all the vehicles are using public charging between 11 AM to 6 PM and charging up to 80% of SoC. % of the share is 11 AM to 6 PM - 12.5% per hour
- Workplace charging (mid-day charging) – Plug-in starting from morning 9 AM to 2 PM. % of the share is 16.6% per hour.

3. e-3W comercial vehicles – E-Autos:

- Commercial e-3Ws Autos in a city will be charged at the charging hub and public charging station.
- In the total number of vehicles, 50% of vehicles are charging at the charging hub, and 50% of vehicles are charging at public charging.
- SoC while the plug-in is 25%, 30%, and 40% SoC.

- Amongst the total number of vehicles for each charging type, equal share of vehicles are considered for 25%, 30%, and 40% SoC.
- Power rating of the charger at the charging hub (AC slow charger) is 7 kW.
- Power rating of the charger at the public charging station (DC fast charger) is 15 kW.
- Battery capacity is 8.2 kWh for 2022, 9 kWh for 2025, and 9 kWh for 2030.
- C-rating of the battery is 0.5 for 2022, 0.6 for 2025, and 0.7 for 2030.
- Charging hub (overnight charging) – Plug-in starting from 9 PM, 10 PM, and 11 PM. % of the share is 33%.
- Public charging (Mid-day charging) – Plug-in starting from 12 PM, 1 PM, 2 PM, 3 PM and 4 PM. % of the share is 20%.

4. e-3W comercial vehicles – E-Autos:

- Commercial e-3Ws Rikshaws in a city will be charged at the charging hub and public charging station.
- In the total number of vehicles, 50% of vehicles are charging at the charging hub, and 50% of vehicles are charging at public charging.
- SoC while the plug-in is 25%, 30%, and 40% SoC.
- Amongst the total number of vehicles for each charging type, equal share of vehicles are considered for 25%, 30%, and 40% SoC.
- Power rating of the charger at the charging hub (AC slow charger) is 3.3 kW.
- Power rating of the charger at the public charging station (DC fast charger) is 15 kW.
- Battery capacity is 4 kWh for 2022, 5 kWh for 2025, and 6.8 kWh for 2030.
- C-rating of the battery is 0.5 for 2022, 0.6 for 2025, and 0.7 for 2030.
- Charging hub (overnight charging) – Plug-in starting from 9 PM, 10 PM, and 11 PM. % of the share is 33%.
- Public charging (Mid-day charging) – Plug-in starting from 12 PM, 1 PM, 2 PM, 3 PM and 4 PM. % of the share is 20%.

5. e-3W comercial vehicles – E-Rikshaws:

- All 2-wheeler EVs in a city will be charged at home.
- Each vehicle will charge only once in 3 days. So only 33% of total vehicles will be charged every day.
- In the total number of vehicles, 50% of vehicles are charging at the residence in the morning from 6 AM to 9 AM with a share of 12.5% per hour and 50% of vehicles are charging in the evening hours from 6 PM to 10 PM with the share of 10% per hour.
- SoC while the Plug-in is 25%, 30%, and 40% SoC.
- Amongst the total number of vehicles for each charging type, equal share of vehicles are considered for 25%, 30%, and 40% SoC.
- Power rating of the charger at charging hub (AC slow charger) is 3.5 kW.
- Battery capacity is 3.5 kWh for 2022, 4.2 kWh for 2025, and 6 kWh for 2030.
- C-rating of the battery is 0.5 for 2022, 0.6 for 2025, and 0.7 for 2030.

6. e-busses:

- All e-buses in a city will be charged at the bus depot and opportunity charging dedicated for e-buses only.
- SoC while Plug-in is 25%, 30%, and 40% SoC in the night and 50% SoC at the mid-day charging.
- Amongst the total number of e-buses, an equal share of vehicles are considered for 25%, 30%, and 40% SoC.
- Power rating of the charger at the bus depot (DC fast charger) is 120 kW and 180 kW.
- Battery capacity is 125 kWh and 150 kW.
- C-rating of the battery is 0.75.
- Overnight charging – Plug-in starting from 10 PM, 11 PM, and 12 PM. % of share is 33%.
- Top up charging (Mid-day charging-1) for TATA buses- Plug in starting from 10 AM to 2 PM with share of 20% of buses are plugged in every hour.

- Top up charging (Mid-day charging-2) for TATA buses - Plug in starting from 3 PM to 7 PM with share of 20% of buses are plugged in every hour.
- Top up charging (Mid-day charging-1) for PMI Forton buses- Plug in starting from 8 AM to 12 PM with share of 20% of buses are plugged in every hour.
- Top up charging (Mid-day charging-2) for PMI Forton buses - Plug in starting from 1 PM to 5 PM with share of 20% of buses are plugged in every hour.

7. General:

- The efficiency of the charger is considered as 94% for 3.3 kW, 3.5 kW, 7 kW AC slow charger, and 15 kW DC fast charger.
- The efficiency of the charger is considered as 95% for a 50 kW DC fast charger.
- The distribution system loss is considered as 19.19% based on Madhyanchal Vidyut Vitran Nigam Limited report (TRUE-UP PETITION FOR FY 2020-21, APR PETITION FOR FY 2021-22AND ARR & TARIFF PETITION FOR FY 2022-23OF THE CONTROL PERIOD FROM FY 2020-21 TO FY 2024-25).

A.6. Appendix 6

The EV charging power demand for individual EV segments for Lucknow for the years 2022, 2025, and 2030

The 24 hours load profile for EV charging loads for the years 2022, 2025, and 2030 is given in the table below.

24 hours EV charging load profile for the years 2022, 2025 and 2030

Parameter	Year	Time (hours)																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total power demand (MW)	2022	0.9	0.4	0.1	0.0	0	0.5	0.8	2.9	3.0	3.4	3.3	7.3	8.8	8.7	8.7	8.6	4.5	1.3	1.6	1.1	7.9	18.3	17.9	11.2
	2025	13.2	8.2	3.8	0.7	0	6.4	7.9	10.5	11.7	7.3	7.8	30.7	33.8	33.5	32.6	32.0	8.6	7.5	9.3	10.3	45.9	64.2	62.5	29.7
	2030	136.6	100.6	71.9	48.6	0	63.0	77.2	83.3	91.3	37.1	38.5	196.1	199.8	198.7	192.7	187.7	19.6	64.7	77.5	89.1	240.9	341.4	333.4	212.8

24 hours EV charging load profile for the years 2022, 2025 and 2030 for different vehicle segment

Vehicle Type	Parameter	Year	Time (hours)																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
E-4W commercial vehicle	Total power demand (MW)	2022	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.6	0.6	0.6	0.2	0.0	0.0	0.0	0.5	1.0	1.2	1.0
		2025	7.3	4.8	2.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	6.4	6.4	6.4	6.4	0.8	0.0	0.0	0.0	4.4	8.8	12.0	9.8
		2030	86.5	66.9	54.6	44.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.5	79.5	79.5	79.5	79.5	-1.9	0.0	0.0	0.0	39.2	78.3	117.5	106.1
E-4W non-commercial vehicle	Total power demand (MW)	2022	0.3	0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.4	0.4	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.1	0.4	0.7	1.0	1.3	1.0	0.7
		2025	5.9	3.4	1.2	0.0	0.0	0.6	1.3	1.9	3.1	3.6	4.9	5.0	5.0	4.7	3.8	3.2	2.6	2.0	3.8	5.0	7.5	10.0	9.8	8.4
		2030	50.1	33.7	17.3	4.6	0.0	4.1	8.2	12.3	20.3	24.2	35.7	36.9	36.6	35.5	29.6	24.5	20.7	16.8	29.5	33.9	49.2	65.6	65.6	61.9
E-3W commercial vehicle (Autos)	Total power demand (MW)	2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
		2025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.7	0.7	0.7	0.1	0.0	0.0	0.0	1.1	1.2	1.2	0.1
		2030	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	3.7	3.7	3.7	3.7	-0.1	0.0	0.0	0.0	6.0	6.1	6.1	0.1
E-3W commercial vehicle (E-Rikshaws)	Total power demand (MW)	2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	4.8	4.8	4.8	4.8	1.3	0.0	0.0	0.0	5.9	8.0	8.0	2.1
		2025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.5	18.8	18.8	18.8	18.8	2.3	0.0	0.0	0.0	27.6	31.4	31.4	3.8
		2030	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.3	77.2	77.2	77.2	77.2	-1.9	0.0	0.0	0.0	91.4	128.6	128.6	37.3
E-2W non-commercial vehicle	Total power demand (MW)	2022	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.6	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.5	0.5	0.5	0.1	0.0
		2025	0.0	0.0	0.0	0.0	0.0	5.8	6.6	6.6	6.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	4.6	5.3	5.3	5.3	0.6	0.0
		2030	0.0	0.0	0.0	0.0	0.0	58.9	69.0	69.0	69.0	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1	47.1	55.2	55.2	55.2	8.1	0.0
E-Buses	Total power demand (MW)	2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.8	0.8	0.0	0.0	7.3	7.3	7.3
		2025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.8	0.8	0.0	0.0	7.3	7.3	7.3
		2030	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.8	0.8	0.0	0.0	7.3	7.3	7.3

A.7. Appendix 7

The cost estimation breakup of installing the rooftop solar PV system at Dubagga bus depot

The approx. cost estimation for setting up the 550-kW rooftop solar PV system at Dubagga bus depot is listed in the below table.

Cost estimation of 550 kW solar PV system

S. No	Equipment Name	Cost in INR
A	**Solar PV panels module**	
	350 Wp Polycrystalline INR 22/W	7700
	No of Solar PV panels	1571
	Total solar PV panel cost	12096700
B	**Solar PV inverter**	
	50 kW solar PV inverter - 224000/unit	224000
	No of 50 kW solar inverter	11
	Total solar inverter cost	2464000
C	**String combiner box/DCDB**	
	50 kW DCDB / unit	24500
	No of 50 kW DCDB	11
	Total DCDB cost	269500
D	**DC cable cost**	
	1Cx6sqmm - length in mtrs	5500
	1Cx150sqmm - length inmtrs	1100
	1Cx6sqmm - INR 55 / mtrs	302500
	1Cx150sqmm - INR 360 / mtrs	396000
	Total DC cable cost	698500
E	**GI strip for DC earthing**	
	25x3 strip - INR 45 / Mtr	45
	Length of 25x3 GI strip	1100
	Total Cost of 25x3 GI strip	49500
F	**Lightning protection system**	
F.1	Conventional type arrester - INR 850 / unit	950
	No of lighting arrester	22
	Cost of lightning arrester	20900
F.2	Down conductor - 25x3 GI strip - INR 45 / Mtr	45
	Down conductor - length in Mtrs	1100
	Cost of down conductor	49500
F.3	Earth electrode - chemical pit - INR 1100 / unit	1100
	No of earth electrode	44
	Cost of earth electrode	48400
	Total cost of lightning protection system	118800
G	**MC4 connector**	
	MC4 connector - INR 26 / Pair	26
	No of MC4 connector	3190
	Total MC4 connector cost	82940
H	**PV panel mounting/fixing clamps on shed**	
	PV panel mounting/fixing clamps on shed - INR 100 / unit	100

	No of clamps (2 clamps/for one panel)	2000
	Total cost for clamps	200000
I	**Aluminium Module mounting structure on buildings**	
	Aluminium Module mounting structure on buildings - INR 1100/set	1100
	No of structure (one set for two modules)	286
	Total Cost of module mounting structure	314600
J	**ACDB**	
	ACDB - 50 kW - INR 17,500 / unit	17500
	No of ACDBs	11
	Total ACDB cost	192500
K	**AC cable**	
	4Cx240 sq.mm - length in mtrs	1100
	4Cx240sqmm - INR 930 / mtrs	930
	Total cost of AC cable	1023000
L	**AC earthing**	
L.1	75x3 GI strip - INR 130 / Mtr	130
	75x3 GI strip - length in Mtrs	1100
	Cost of 75x3 GI strip	143000
L.2	Earth electrode - chemical pit - INR 1100 / unit	1100
	No of earth electrode	22
	Cost of earth electrode	24200
	Total cost of AC earthing	167200
M	**Other Accessories**	
	Other accessories - DC parts - INR 25,000 / 50 kW	25000
	Cost of DC accessories	275000
	Other accessories - AC parts - INR 25,000 / 50 kW	25000
	Cost of AC accessories	275000
	Total cost of other accessories	550000
N	**Installation cost**	
	Installation cost - INR 8 / W	4
	Plant capacity	550000
	Total installation cost	2200000
O	**Total cost of 550 kW solar PV system - in Crore**	**2.04**

Note:

1. Cost details are considered from India mart
2. Applicable GST is additional