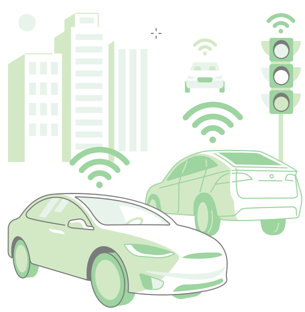
Accelerating Net Zero transition of public transportation systems in the city of Kolkata



The Energy and Resources Institute
Creating Innovative Solutions for a Sustainable Future

Suggested citation: TERI. (2023). Accelerating Net Zero Transition Kolkata. The Energy and Resources Institute.

Project Team Reviewers

Mr K Ramanathan, Distinguished Fellow

Mr A K Saxena, Senior Fellow

Mr P K Bhattacharya, Senior Fellow

Team Members

Mr S. Gautham, Associate Fellow

Mr Tattaiyya Bhattacharjee, Research Associate

Mr Gaurav Yadav, Research Associate

Mr Mahavir Singh, Research Associate

Ms Christie Anil Joseph, Research Associate

Mr K Umamaheswaran, Consultant

Mr Mukesh Kumar, Research Associate

External Reviewers

Mr Narayankumar Sreekumar & **Ms Priyadarshini Alok,** Shakti Sustainable Energy Foundation

PUBLISHED BY

The Energy and Resources Institute (TERI)

FOR MORE INFORMATION

TERI, Darbari Seth Block IHC Complex, Lodhi Road, New Delhi 110 003, India

Tel: +91 11 2468 2100 or 2468 2111 | Fax: +91 11 2468 2144 or 2468 2145

Email: vkjkumar@teri.res.in | Web: www.teriin.org | http://netzerokolkata.teri.res.in/

Message

The year 2023 is a landmark year for us. The ancestor of WBTC, the Calcutta Tramways Corporation is celebrating its 150th year anniversary and serendipitously enough, CSTC is also celebrating its platinum year of existence. I am also told that this is the 50th year at TERI as well, so this study is coming at a very important juncture for all the stakeholders concerned.

The study delves into the future of electric mobility in Kolkata. It is a very pertinent exercise done. The result is outstanding and my heartiest congratulations go to the study team for successfully completing this study "Accelerating Net Zero Transition of Public Transportation in the city of Kolkata". I would like to thank the study team of TERI comprising of Mr. K. Umamaheswaran, Mr. Tattaiyya Bhattacharjee, Mr. Gaurav Yadav, Mr. S. Gautham, Mr. Mahavir Singh, and Ms. Christie Anil Joseph for the rigorous work that has been carried out for the study.

I would also like to thank Mr. Soumen Maity, Mr. Debabrata Guha and all the members of WBTC for providing the TERI team with all necessary support for the completion of the project.

Mr. Rajanvir Singh Kapur (IAS)
Managing Director- WBTC


P
P





TAX

Acknowledgements

TERI acknowledges the award of the study on **"Accelerating net zero transition of public transportation systems in the city of Kolkata"** by Shakti Sustainable Energy Foundation, New Delhi.

The study team would like to thank **Mr. Narayan Kumar Sreekumar,** Associate Director (e-mobility) and **Ms. Priyadarshini Alok,** Assistant Manager (e-mobility) for their continuous support during the course of this study.

The study would not have been possible without the assistance of the discom officials and the transport department officials. The study team would like to thank the following officials for their support in data collection and sharing valuable insights to make this report informative.

» Mr. Rajanvir Singh Kapur, IAS, Managing Director, West Bengal Transport Corporation

» Mr. Debabrata Guha, Senior Engineer, West Bengal Transport Corporation

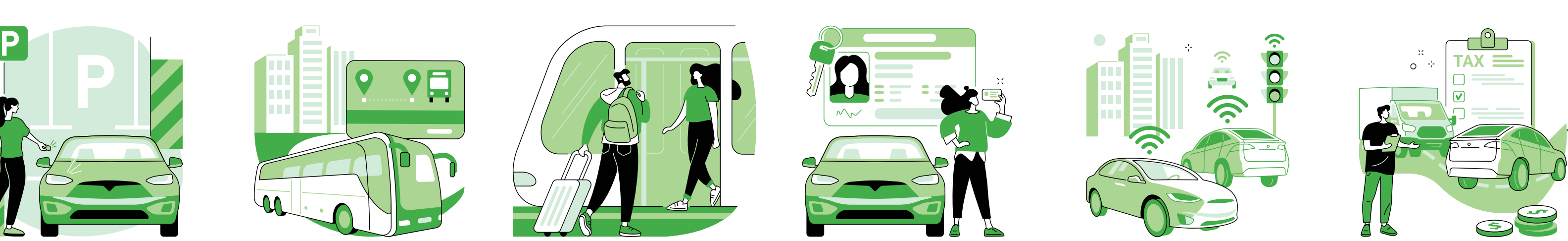
» Mr. Rajib Das, Dy. General Manager, Calcutta Energy Supply Corporation

» Mr. Partha Kumar Nayek, Chief Engineer, West Bengal State Electricity Distribution Company Limited

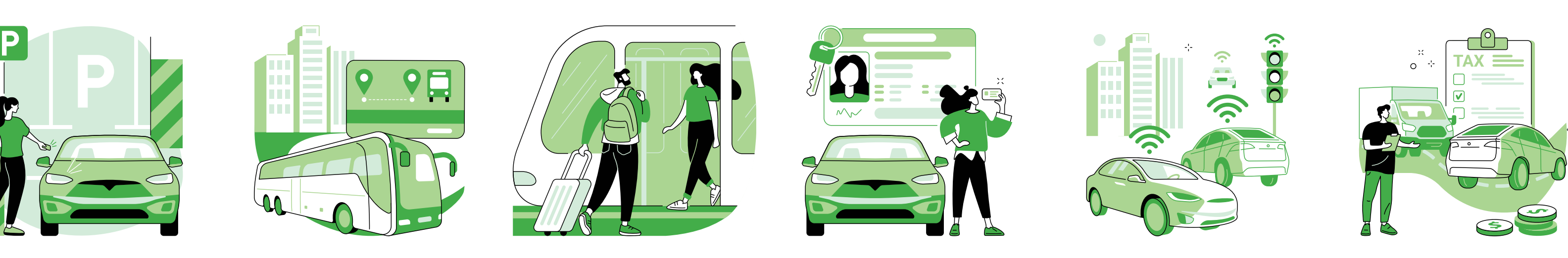
The study team would like to thank the team of **Arcwhales GIS Solutions** for their contribution towards carrying out the on ground surveys and providing a comprehensive assessment towards this study.

Further, the study team would like to thank the contributions of all participants of the stakeholders' discussions and the participants of the capacity building programme for their active participation and contribute to this study.

Table of Contents


P
P
TAX

List of Figures

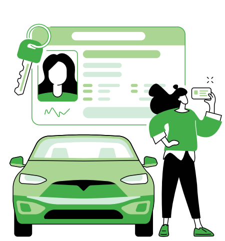

P
TAX

List of Tables

List of Abbreviations

WBTC	West Bengal Transport Corporation
CTC	Calcutta Tramways Corporation
CSTC	Calcutta State Transport Corporation
WBSTC	West Bengal Surface Transport Corporation
CCS	Combined Charging System
GB/T	GuoBiao Tuijian
NAC	Non Air Conditioned
L/F	Low Floor
CESC	Calcutta Electricity Supply Company
WBSEDCL	West Bengal State Electricity Distribution Company Ltd.
EV	Electric Vehicle
RTO	Regional Transport Office
RTA	Road Transport Authourity
KMC	Kolkata Municipal Corporation
BSS	Battery Swapping Station
CS	Charging Station
SoC	State of Charge
GHI	Global Horizontal Irradiance
GHG	Green House Gases
CNG	Compressed Natural Gas
LPG	Liquified Petroleum Gas
CPO	Charge Power Outlet
SDG	Sustainable Development Goals
STU	State Transmission Unit
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
PM	Particulate Matter


P
P




TAX

Executive Summary

West Bengal has a history to be associated with electrification of transportation systems. Kolkata, the capital city of West Bengal, introduced public transportation system running on electricity in 1902 and has also been the first to introduce electric buses for public transport in the city. The introduction of electric mobility represents a unique opportunity to leverage the electricity infrastructure for accelerated and cost-effective mobility deployment.

TERI carried out this study to develop strategies to achieve net zero transportation in the city that would support the Transport and the power department of West Bengal to assess innovative and efficient models for the procurement to deploy advanced fleet systems in the city.

The study brings out the feasible locations for setting up of charging stations throughout the city of Kolkata through the assessment of the existing fleets, routes and carrying out a vehicle density survey in and around the city.

Further, the study analyses the energy demand, power requirement, site suitability of Charging infrastructure for e-2W and e-4W, and battery swapping stations for e-3W. Also, the renewable energy (specifically solar) potential for generation of electricity, along with the decarbonization roadmap for public transport is presented in this report.

Recommendation for e-buses

WBTC aims to achieve a target of 1180 e-buses by 2025, from the present fleet of 80 e-buses. Hence, the charging infrastructure needs to be adequately robust to cater to the increased demand. Two recommendations are proposed in this regard.

Recommendation 1: Having Charging Point Utilization within 50%

Case - 1a: Uncontrolled Charging: In this case it is assumed that the buses get charged in a random manner depending on the existing availability of buses in the depot.

Case – 1b: Controlled Charging: In this case it is assumed that the buses get charged in a predefined manner such that the buses are allocated specific slots in the depot.

Recommendation 2: Having Charging Point Utilization above 50%

Case - 2: Optimized Charging: In this case, it is assumed that the buses primarily get charged during the night time and multiple buses can get charged with a single charger. However, the buses can also get charged intermittently during the daytime at depots.

The energy consumption scenarios of the aforementioned cases are summarized in Table 1:

Table 1: Energy & Power Demand of 1180 E-buses

Case	Type of e-bus	Proposed Charger Type	Proposed Charger rating	Number of Chargers	Power Demand (MW)	Hours of operation of charger per day	Daily Energy Demand (MWh)
Case 1a	9 mtr	Fast Charger only	120 kW (Fast)	548	65.7	8.4	551.88
	12 mtr	Fast Charger only	2*120 kW (Fast)				
Case 1b	9 mtr	Fast Charger only	120 kW (Fast)	548	58.5	8.4	491.4
	12 mtr	Fast Charger only	2*120 kW (Fast)				
Case 2	9 mtr	Fast Charger only	120 kW (Fast)	246	29.5	13.9	410.05
	12 mtr	Fast Charger only	2*120 kW (Fast)				

The charger utilization for the above cases is given in Table 2:

Table 2: E-bus charging scenarios

Sl. No.	Parameters	Case 1A- Uncontrolled Charging	Case 1B- Controlled Charging	Case 2- Optimized Charging
1	Number of Bus depots	14	14	14
2	Number of E-buses/ depot	85	85	85
3	Number of chargers proposed (guns)	548	548	246
4	Type of Charger	CCS	CCS	CCS
5	Rating of Charger/gun	120 kW	120 kW	120 kW
6	Single gun/ Double gun	9m- single gun 12m- double gun	9m- single gun 12m- double gun	9m- single gun 12m- double gun
7	Battery capacity of buses	9m- 200 kWh 12mNAC- 300 kWh 12AC- 400 kWh	9m- 200 kWh 12mNAC- 300 kWh 12AC- 400 kWh	9m- 200 kWh 12mNAC- 300 kWh 12AC- 400 kWh

Contd...

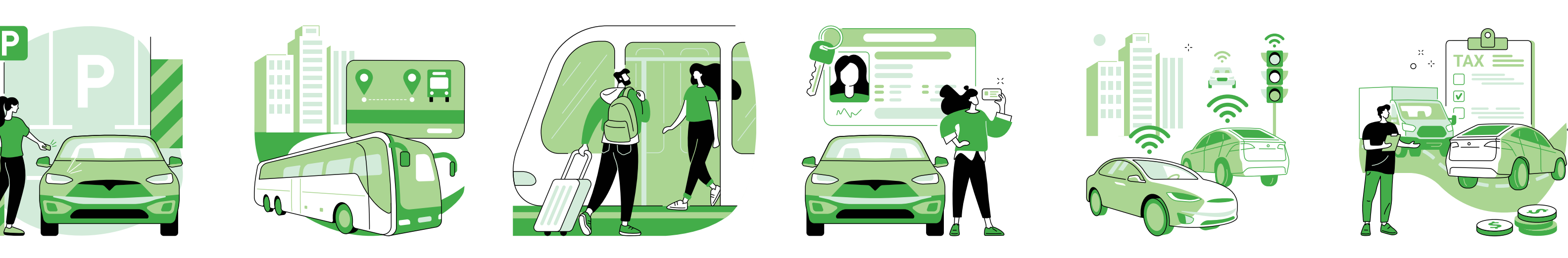


Table 2: *Cont.....*

Sl. No.	Parameters	Case 1A- Uncontrolled Charging	Case 1B- Controlled Charging	Case 2- Optimized Charging
8	Assumed charging time per bus	2 hrs. (conventional) + 45 mins. Opportunity	2 hrs. (conventional) + 45 mins. (Opportunity)	2 hrs. (conventional) + 45 mins. (Opportunity)
9	Time of maximum utilization of charger (in hrs.)	8.4	8.4	13.9
10	Peak Demand	65.7 MW	58.5 MW	29.5 MW
11	Charger Utilization	35%	34%	58%

Recommendation for e-2W, e-3W and e-4W

The site suitability analysis following route mapping and field survey has yielded the following results.

Table 3: Energy & Power demand of e-2W/3W/4W

Type of vehicle	Proposed Charger Type	Proposed Charger rating	Number of Chargers	Power Demand (kW)	Hours of operation of charger	Energy Demand (kWh)
e-2W	Slow Charging only	10kW	34	340	12	4080
e-3W	BSS Only	30kW	22	660	12	7920
e-4W	Slow Charging	15kW (AC Type 2)	48	720	12	8640
	Fast Charging	50 kW (DC Type)	20	1000	12	12000
Total			**124**	**2720**		**32640**

It can be observed that the total energy demand is 32.64 MWh for the chargers, and the sites have been identified at 60 locations comprising 124 chargers.

Three stakeholder consultations were conducted in between May 2022 and March 2023, and one capacity building workshop was organized in May 2023. The capacity building workshop was organized for WBTC technical and managerial department employees on the following topics.

Technical Departments	Managerial Departments
» Charging Technologies » Charging Infrastructure » Load Estimation » Green Energy Utilisation » Asset Utilisation	» Charging Scheduling » Operations » Financial Models » Revenue Streams » Integrated Fleet Operation

Decarbonization Strategy

Public fleet Decarbonization strategy for Kolkata was also prepared as part of this study outlining a deployment schedule of Public buses under WBTC, ferries, and 3-wheelers till 2050. The roadmap also identifies the potential impact on air pollution and greenhouse gas emissions in the city because of electrifying public transportation systems, as well as opportunities for integrating renewable power with these systems. In addition, the roadmap enables WBTC to identify potential funding sources and revenue streams to facilitate fleet electrification and associated infrastructure upgrades.

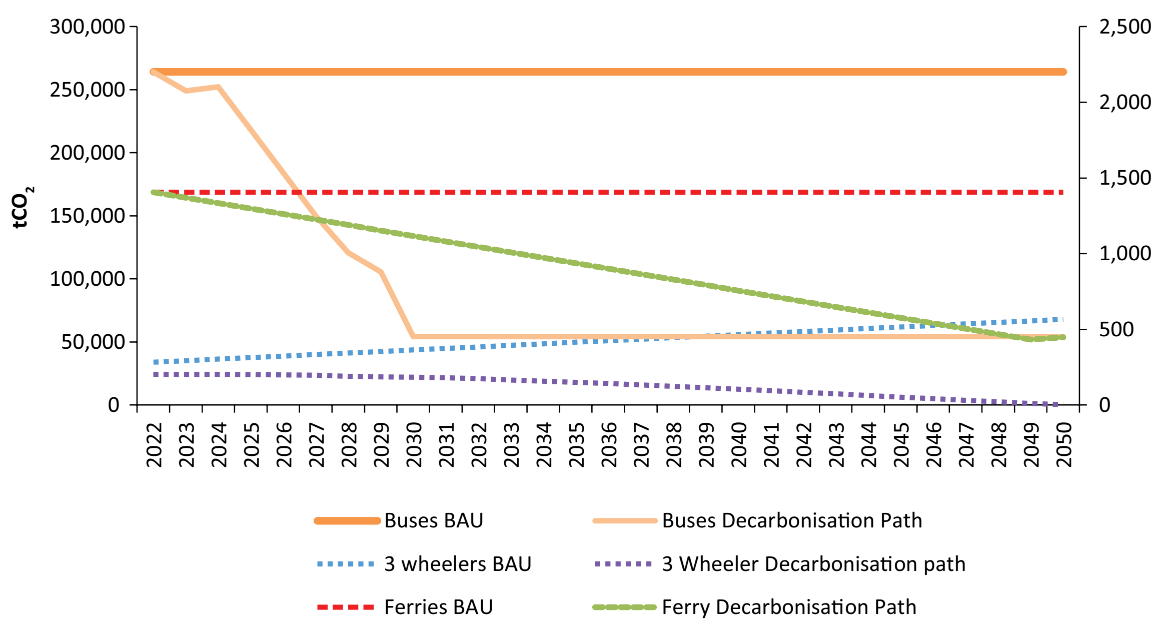
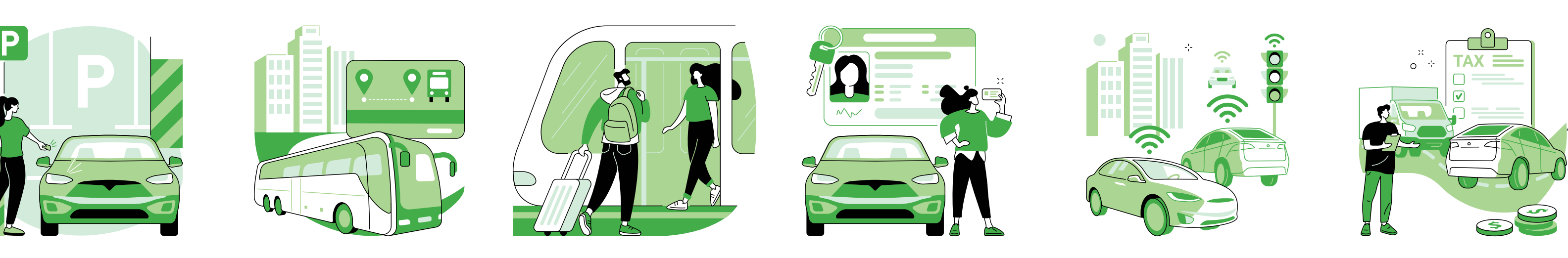


FIGURE E 1: Decarbonization pathway for various vehicle segments

** Only buses under WBTC are being considered for the study*



1. Introduction

The city of Kolkata is spread linearly along the banks of the Hooghly river, with extensive mangrove systems and tidal flats on the fringes of the city. Being one of the major economic centres, transportation is a key driver for the city. There exist multiple modes of transport for commute in the city. Public transportation includes buses, ferries, three-wheelers, urban freight, cabs and tramways. Private transportation includes cars and two wheelers.

The electricity supply in the city is catered by two DISCOMs namely- Calcutta Electricity Supply Company (CESC) and the West Bengal State Electricity Distribution Corporation Limited (WBSEDCL).

1.1 West Bengal Electric Vehicle Policy

The Power Department of the West Bengal Government released the Electric Vehicle Policy in 2021 with validity of 5 years, i.e. until 2026. The key highlights of the Kolkata EV Policy are depicted in the Figure 1:

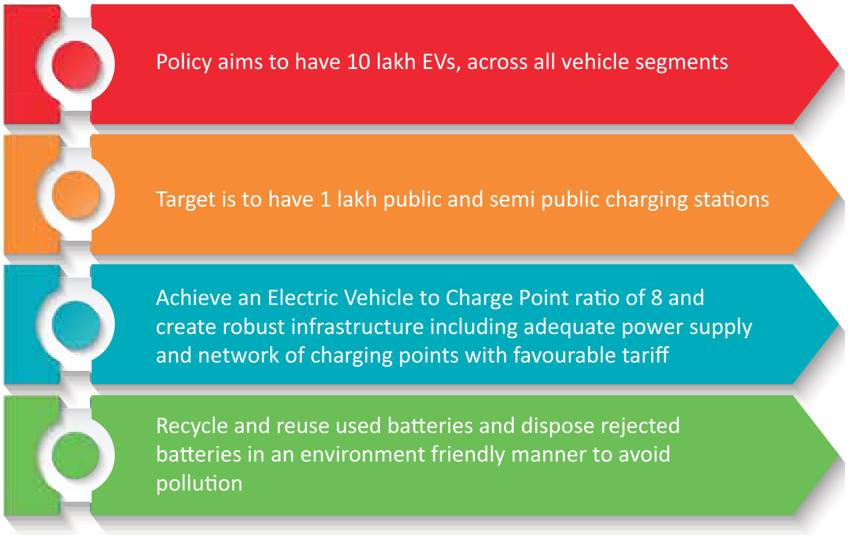


FIGURE 1: Highlights of West Bengal EV Policy

Specifically for the Charging Infrastructure, the Policy encourages setting up of swapping stations in the form of kiosk to service two-wheelers and three-wheelers. Also, existing private building and commercial buildings will set up charging/battery swapping stations. The discom is obligated to release supply to the charging stations and the swapping stations within 48 hours of application[1].

[1] https://wbpower.gov.in/wp-content/uploads/Electric%20Vehicle%20Policy%202021%20(Kolkata%20Gazette%20Notification).pdf

1.2 EV Scenario in Kolkata

The vehicles in Kolkata are registered across 7 Regional Transport Offices (RTOs) namely PVD Kolkata, Kasba, Salt Lake, Behala, Alipore, Barrackpore, and Barasat. The EV Registration in West Bengal and Kolkata during 2013-2022 is shown in the Figure 2. It is observed that there is an increasing trend of adoption of EV in Kolkata over the years, except during the COVID period of 2020-21 when it had a fall.

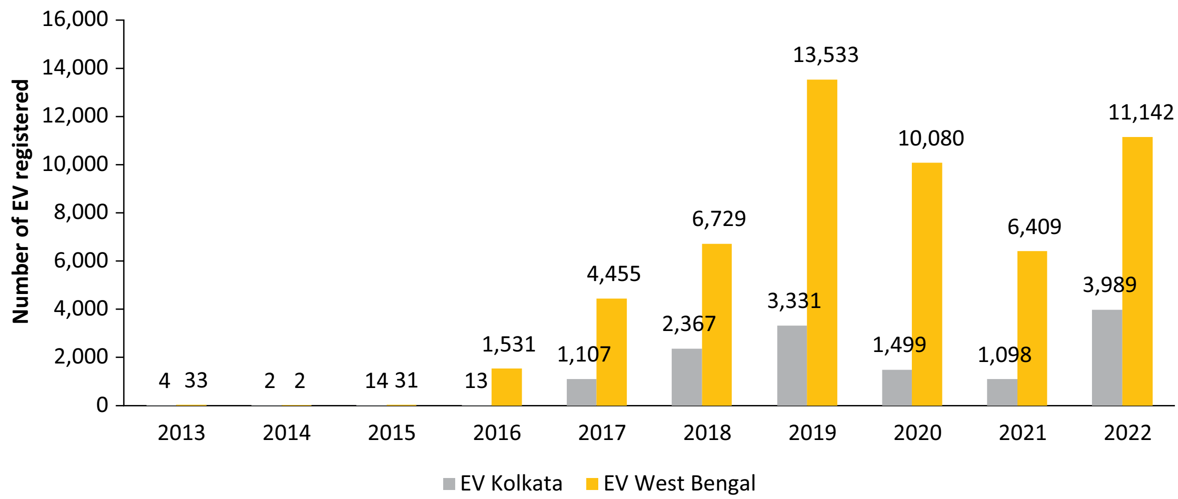


FIGURE 2: EV Registration Details of Kolkata

Source: Vahan Database

The Kolkata Public transport fleet details are given in the Figure 3:

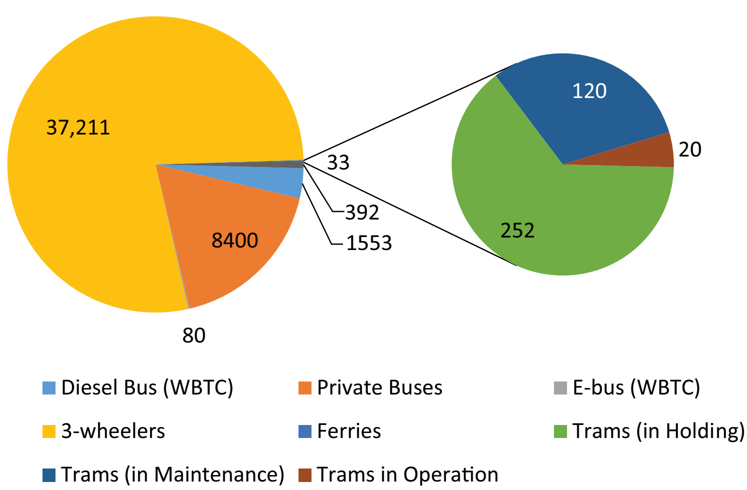
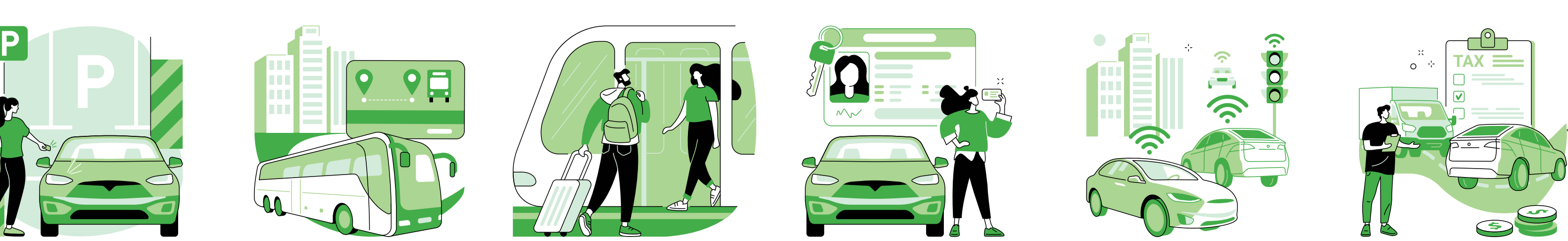


FIGURE 3: Public Transport Fleet of Kolkata

Source: WBTC and Transport Department



1.3 Vehicle Routes in Kolkata

Bus Routes

There are 348 bus routes being operated by WBTC out of which 215 routes (62%) are for intra-city movement and the rest (38%) are for inter-city movement. WBCSTC (44%) operates on most of the routes, followed by WBCTC (40%) and WBSTC (16%). The average operational time is of the order of 12 hours for the intra-city route. The details of the routes of WBTC in Kolkata are provided in Figure 4:

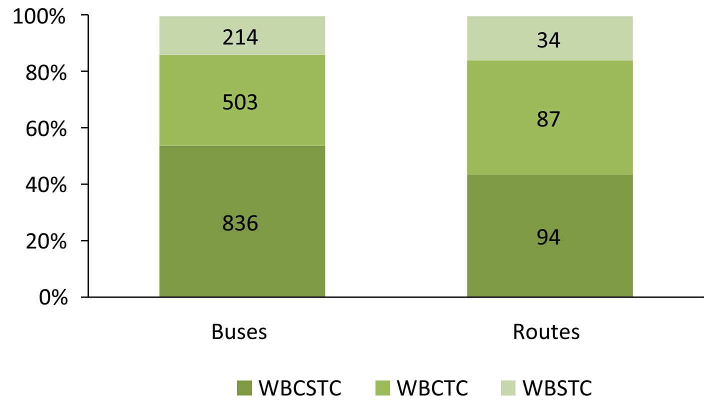


FIGURE 4: Bus Routes decomposition

Three wheelers' Routes

The three-wheelers are operated by private owners on routes permitted by the Road Transit Authority (RTA). There are currently 489 approved routes within which the 37,211 three-wheelers/autos are allowed to operate throughout Kolkata. The jurisdiction includes the Kolkata Metropolitan Area, Howrah, Bidhannagar and Barrackpore. Details are given below in Table 4:

Table 4: Route Analysis of 3-wheelers

Parameter	Numbers
Total road distance covered by 3-Wheelers (km) per day	2542
Average distance covered by a 3-Wheeler (km) per day	5.25
Number of three wheelers/km	14.6
Number of Locations with 3 –wheeler operations	152
Number of hotspots (permits more than 1000)	3
Contribution of hotspots in terms of number of permits	25%

Ferry Routes

There are currently 33 operational ferries under the WBTC. The overall operation and management is overseen by the West Bengal Surface Transport Corporation (WBSTC). Out of the 33 operational ferries, there are 29 Cross Ferry Vessels which help in public transportation and operate on a regular basis. There are 4 cruise type ferries which operate 2-3 times a month and are mostly used for the purpose of tourism.

Table 5: Existing Ferry Route Details

Sl. No.	Origin	Destination	Via (if any)	Route Distance (km)	Route duration (min.)	Frequency (min.)	Ticket Price (Rs.)
1	Belur	Dakshineshwar	-	4	25	30	11
2	Belur	Kutighat	-	2	7	20	6
3	Belur	Bagbazar	-	4	25	30	11
4	Fairlie	Kutighat	Bagbazar - Kashipur - Ratan Babughat	9.5	60	20	11
5	Shipping	Belur	Howrah - Bagbazar	9.5	60	20	21
6	Howrah	Fairlie (BBD Bag)	-	1	6	5	6
7	Howrah	Shipping	-	1	8	7	6

Source: WBTC

Tram Routes

The total number of trams in possession of the company is 252, out of which 138 trams are regularly maintained and are ready to operate. The actual number of operating trams is 18-20 along the currently operating routes, given in the Table 6. The depots which are currently under operation for scheduled maintenance and deployment are Rajabazar, Park Circus, Gariahat, Tollygunge, Khidirpur, and Esplanade.

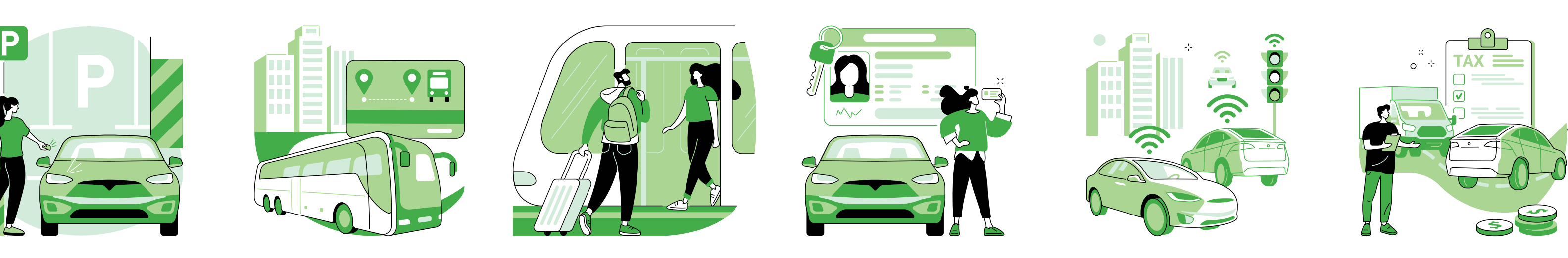


Table 6: Existing Tram Routes (as on August 2022)

Sl. No.	Route No.	Origin	Destination	Via	Distance (one way) in km	No. of Operating Trams	Duration (min.)	Ticket Price (Rs.)
1	36	Khidirpur	Esplanade	Fort William	5	Non-Operational		
2	24/29	Ballygunge	Tollygunge	Rashbehari	5.5	8	35	6-7
3	25	Esplanade	Gariahat	Park street	8	10	45	6-7
4	5	Shyambazar	Esplanade	College Street	5.5	Non-Operational		
5	18	Howrah Bridge	Bidhannagar Station	Rajabazar	9	Non-Operational		
6	11	Shyambazar	Howrah Bridge	Vivekananda Park	6	Non-Operational		

Source: WBTC

1.4 Organization of the report

Chapter 1- A brief introduction about the West Bengal EV Policy, existing EV Scenario in Kolkata, and vehicle fleet & routes for public transport.

Chapter 2- Details on EV charger: types of chargers, rating of chargers and other technical specifications.

Chapter 3- Approach, Methodology and strategy adopted for the study.

Chapter 4- Details of power demand and energy demand for the e-buses in Kolkata

Chapter 5- Details of power demand and energy demand for the e-2W, e-3W, and e-4W in Kolkata

Chapter 6- Details the public fleet decarbonization strategy for Kolkata

Chapter 7- A brief on the stakeholder discussions and capacity building workshop

Chapter 8- Summary of the recommendations and conclusion of the report.

2. EV Charging Infrastructure

The Electric vehicle (EV) Charging Infrastructure comprises of the electricity supply (which includes distribution transformer(s)), energy meters, cables and distribution panels, which provide reliable input power supply to Electric Vehicle Supply Equipment (EVSE). For efficient EV charging, proper networking and communication among DISCOM/grid operators, EVSE and EV should be enabled for charging, monitoring and management as a grid resource.

The EVSE is classified based on the type of charging technology used. It can be categorised as below;

» **Slow Charging:** Slow charging is typically used for charging through chargers rated between 3 kW and 6 kW. It generally takes about 6-8 h for charging an EV through a slow charger rated around 3 kW. Slow chargers make use of an on-board charger, which is sized based on input voltage from the grid.

» **Fast Charging:** This technology uses chargers having high power output that are capable of charging an EV in minimum 15 minutes up to 80% of battery state of charge (SoC). These types of chargers are in the range of 20–100kW power rating. Fast charging is normally used for four-wheelers, and e-buses, which have a higher battery capacity.

» **Battery Swapping**: This form of charging technology involves replacement of a depleted EV battery by a fully charged new battery, instead of re-charging the depleted on-board battery. In battery swapping, EV users swap their empty batteries with charged batteries at swapping station. The EV user hence does need not buy battery during purchase of EV.

» Fast charging is generally required for EVs to support ongoing trips, such as major road networks, or on highways.

2.1 Types of Chargers

Table 7 gives the types of chargers, as per Ministry of Power, that are available in India. Broadly, the chargers are classified into Fast Charging and Slow Charging.

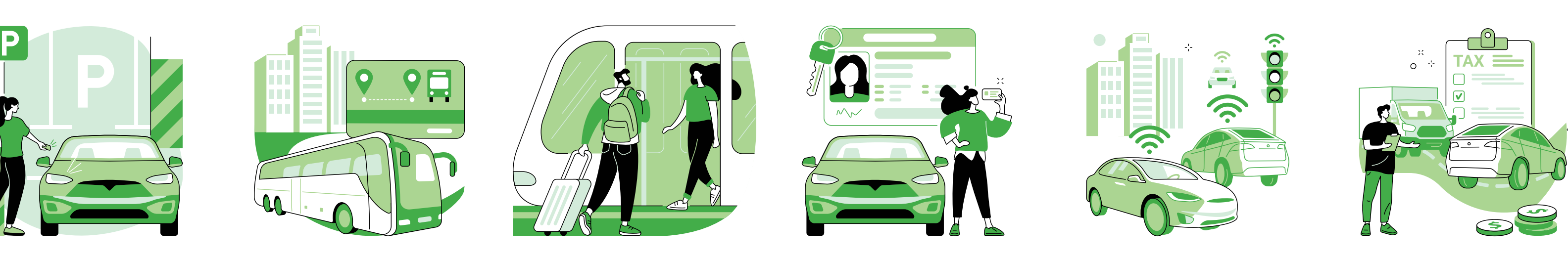
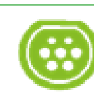
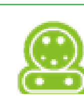
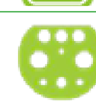


Table 7: Types of Chargers

S. No.	Charger Type	Charger Connectors	Rated Output Voltage (V)	No. of connector guns (CG)	Charging Vehicle Type (W=Wheeler)
1	Fast	Combined Charging System (CCS) (min 50 kW)	200-750 or higher	1 CG	4 W
2	Fast	CHArge de Move (CHAdeMO) (min 50 kW)	200-500 or higher	1 CG	4 W
3	Fast	Type 2 AC (min 22 kW)	380-415	1 CG	4 W, 3 W, 2 W
4	Slow/ Moderate	Bharat DC-001 (15 kW)	48	1 CG	4 W, 3 W, 2 W
5	Slow/ Moderate	Bharat DC-001 (15 kW)	72 or higher	1 CG	4 W
6	Slow/ Moderate	Bharat AC-001 (10 kW)	230	3 CG of 3.3 KW each)	4 W, 3 W, 2 W

Source: Ministry of Power

Apart from these chargers, other chargers can also be installed provided they meet the requisite standards set out by Bureau of Indian Standards. The types of EV Chargers are given below:

Charger Name	Image
Bharat AC 001	
Bharat DC 001	
Type 2 Charger	
CCS Charger	
GB/T Bus Charger	

2.2 Area Requirements

The area requirements for the setting up of EV charging station for e-2W, e-3W and e-4W are given in Table 8:

Table 8: Area requirements for EVCI

Type of Vehicle	Space Requirement for vehicle parking (length x width)	Space Requirement for charger installation (length x width)	Total Area Required
e-2W	2.5m x 1.4m	1m x 1.4m	4.90 sq. m.
e-3W	4m x 2m	1m x 2m	10 sq. m.
e-4W	5.5m x 2.5m	1m x 2.5m	16.25 sq. m.

Source: TERI Analysis and NITI Aayog report on EV

For e-buses, the chargers are proposed to be located in the bus depots only.

2.3 Existing Public Charging Infrastructure in Kolkata

E-buses

When the study was undertaken, Kolkata already had deployed Electric Vehicle Charging Infrastructure for 80 operating E-buses in the city. The Table 9 shows the existing Charging infrastructure for buses:

Table 9: List of existing E-bus chargers in Kolkata

S.No.	List of Charging Stations	Fast Chargers (120 kW)	Slow Chargers (60 kW)	DISCOM	Total Rating (kW)
1	Satragachi	1	0	WBSEDCL	120
2	Nabanna	1	0	WBSEDCL	120
3	Howrah Station	2	0	CESC	240
4	Korunamoyee	1	0	WBSEDCL	120
5	New Town	1	0	WBSEDCL	120
6	Raja Bazar	0	1	CESC	60
7	Gariya	1	0	CESC	120
8	Tollygunge	2	0	CESC	240
9	Airport	1	0	CESC	120
10	Digha*	1	1	CESC	180
11	Howrah Depot	1	6	CESC	480

Contd...

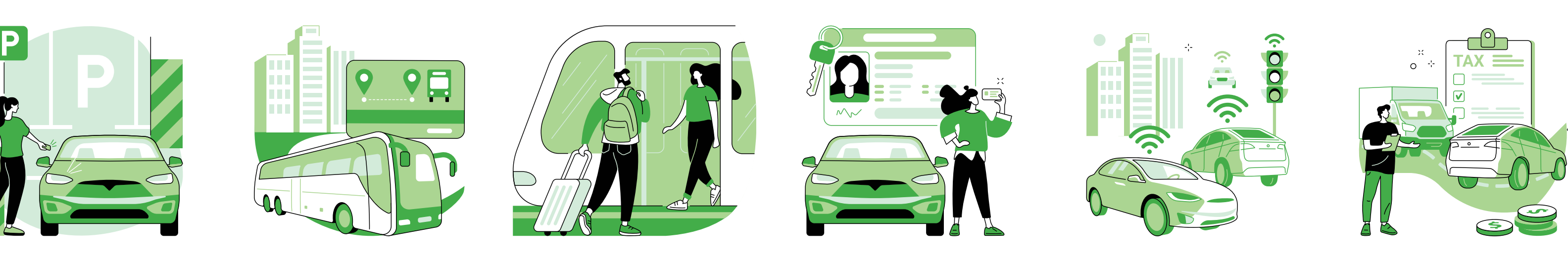


Table 9: *Contd...*

S.No.	List of Charging Stations	Fast Chargers (120 kW)	Slow Chargers (60 kW)	DISCOM	Total Rating (kW)
12	Belghoria Depot	1	6	CESC	480
13	Thakurpukur Depot	1	6	CESC	480
14	Lake Depot	1	6	CESC	480
15	Nonapukur Depot	1	7	CESC	540
16	Gariahat Depot	1	6	CESC	480
17	Kasba Depot	1	6	CESC	480
18	New Town Depot	1	6	WBSEDCL	480
19	Salt Lake Depot	1	6	WBSEDCL	480
	Total (for 80 E-buses)	**20**	**57**		**5820**

Source: WBTC

** Digha is outside city limits*

Public EV Charging

In the case of Public EV charging infrastructure, there are currently more than 125 chargers installed in over 70 locations in the city of Kolkata (including Howrah) which are under the supply area of WBSEDCL. The type of chargers used and the details are attached in the Annexure. Based on the information, it is seen that most of the chargers installed in the public charging station is either CCS type or Wall-socket type. In the CESC supply area, there are about 20 public EV charging stations.

2.4 Impact on Power Distribution Network due to Electric Vehicles

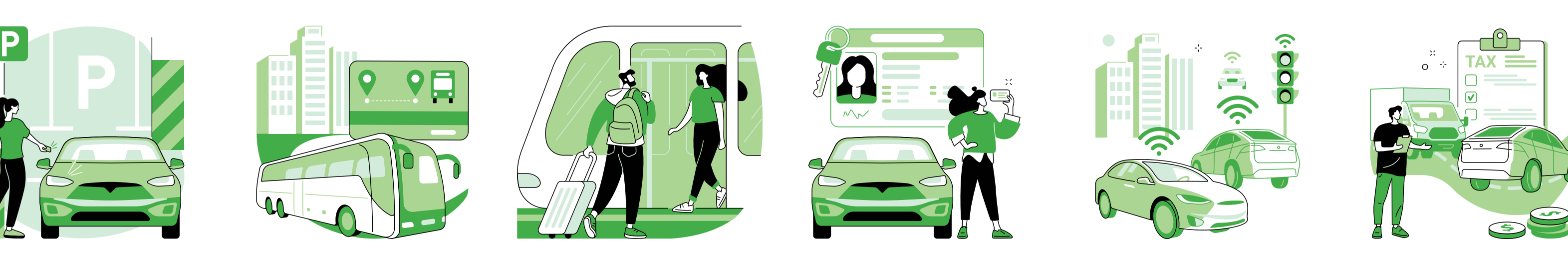
The EVs may be considered as active loads during charging, as they increase the demand on the power distribution network. This shall result in an impact on the network loading, voltage profile, phase imbalance and power quality. Hence, directly or indirectly, the EVs shall play an important role in augmented power consumption.

Network loading shall increase due to the charging load of EV, and sufficient line capacity needs to be maintained to cater to the increased demand. This shall prevent in network congestion and assist in smooth operation of all network loads. However, the use of BESS system or availing green energy open access exclusively for the Charging Infrastructure may be considered and a suitable feasibility study forms a part of further study.

Phase Imbalance may be caused due to EV Charging if the load is not evenly distributed across the three phases. It may occur due to voltage imbalance, current imbalance or due to both. However, by ensuring equal loading on all the three phases, the phase imbalance effect can be mitigated.

Voltage profile of the system may be affected due to impact of voltage dip that occurs while charging the electric vehicle. Suitable compensation methods need to be additionally deployed to overcome the dip, or the possibility of islanded operation may be explored, which forms a part of further study.

EV Charging can result in the formation of voltage and current harmonics. The level of current harmonic emission from EV charging depends on factors such as charger circuit topology, power level, on the supply voltage distortion (background distortion), and on the network impedance. EV charging can also contribute to formation of interharmonics and supraharmonics in the distribution network with charging infrastructure.



3. Methodology

The study was carried out in the following manner:

» Assessment of Electrification needs

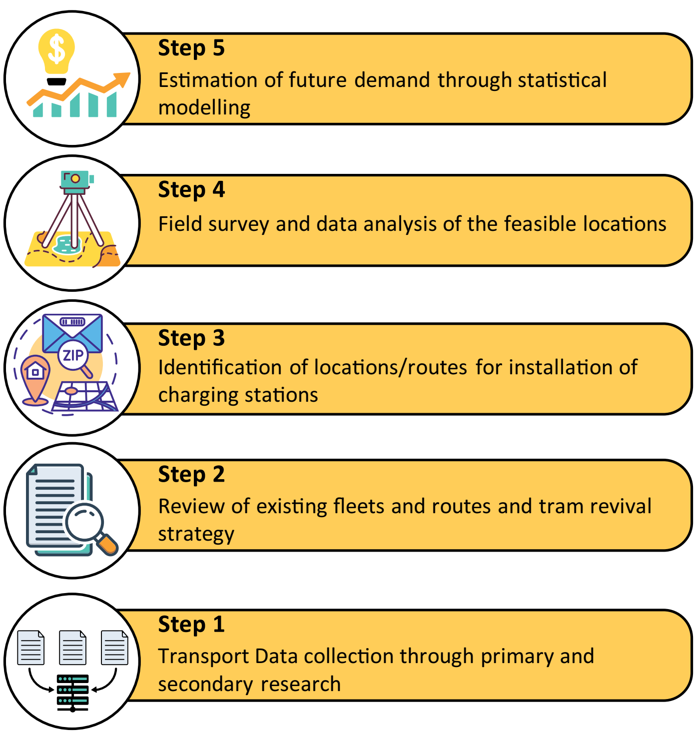
» Assessment of Power Demand

» Preparation of Public Transport Electrification Roadmap

» Stakeholder dialogues, Knowledge transfer & Recommendations

3.1 Assessment of Electrification needs

TERI carried out the following tasks for assessment of electrification needs:



The data for the fleet size and routes of the existing public transport was collected through primary & secondary research:

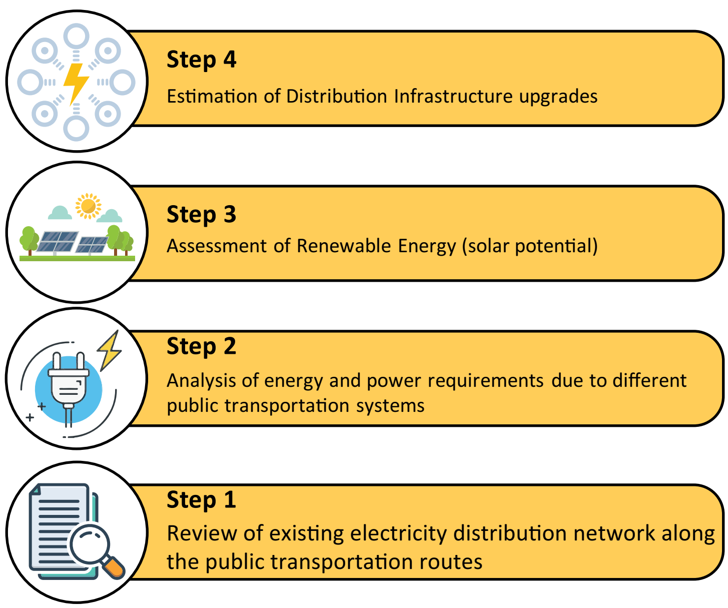
» The data for buses, 3-wheelers, ferries and trams were collected from the state transport authority (WBTC), and the Transport Department of West Bengal.

» The data for the number registered vehicles for 2013-2022 were taken from the Vahan database for each RTO under Kolkata city.

Upon analysis of the fleet size and the routes, 60 locations were identified which were feasible for the installation of charging stations for electric vehicles. After conducting site survey & traffic survey in these locations, we found out the feasible locations & technology for setting up the charging infrastructure. Further details in regard to the analysis are given in the chapter 5 of the report. Moreover, based on the surveys and stakeholder interactions with the transport authorities, we have estimated the future demand of electric vehicles through a statistical modelling till 2030.

3.2 Assessment of Power Demand

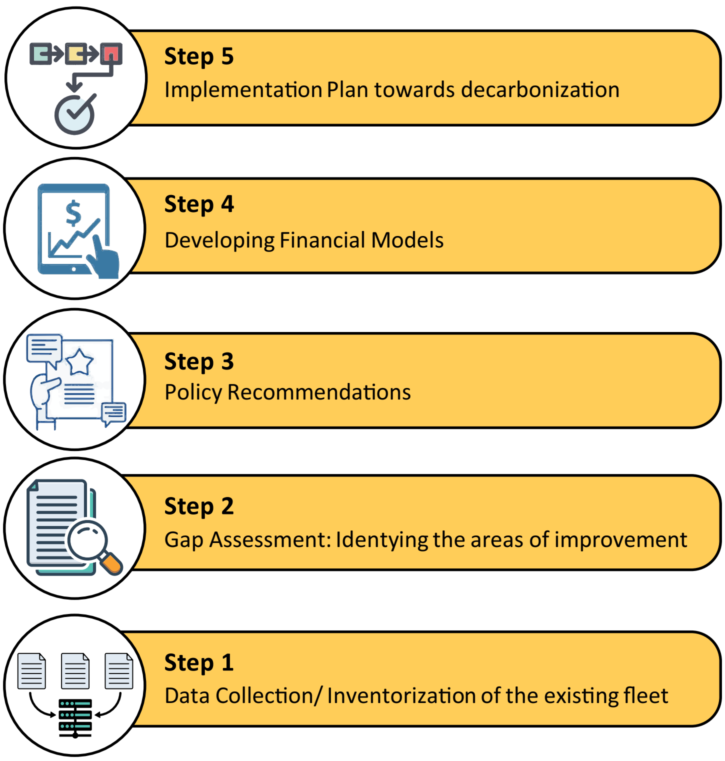
TERI carried out the following tasks for the assessment of power demand:



The single line diagrams, utility load curves and electricity bills for the chargers under WBTC collected from WBTC and CESC for the public transport routes framed the basis of assessment of power demand. For e-buses, the analysis of energy and power requirements was carried out by observing the daily load pattern due to charging of existing 80 e-buses and projecting the same for 1180 E-buses with different control mechanisms. For vehicles other than e-buses, the analysis for energy & power requirements was done after determining the sites & technology used for setting up the charging infrastructure. The assessment of Renewable Energy (solar) potential was also carried in the sites under WBTC bus depots and the 60 potential sites for EV charging infrastructure.

3.3 Preparation of Public Transport Electrification Roadmap

TERI carried out the following tasks for the preparation of public transport electrification roadmap:

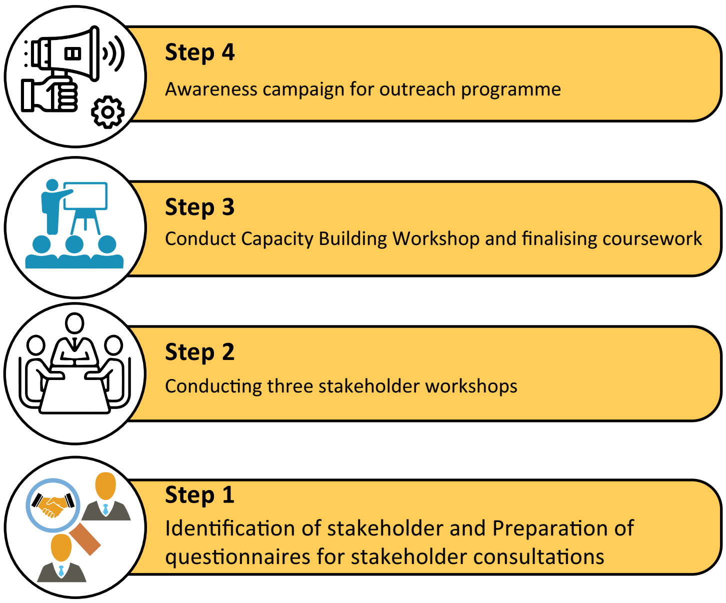


The data regarding the fleet size of the existing public transport was done through primary and secondary research as performed during the preparation of the GHG inventory. The existing policies and the future envisaged policies were identified which aimed towards decarbonization. An implementation/ deployment plan is prepared.

Further details in regard to the analysis are given in the chapter 6 of the report.

3.4 Stakeholder dialogues, Knowledge transfer & Recommendations

TERI carried out the following tasks for stakeholder dialogues, knowledge transfer:



The stakeholders were identified based on periodical interactions and consultations with WBTC during the field surveys and data collection. Regarding the same, three stakeholder workshops and one capacity-building workshop (for WBTC employees) were also conducted, the details of which are provided in Chapter 7 of the report. Moreover, an awareness campaign was also conducted as a part of the outreach programme of this project.

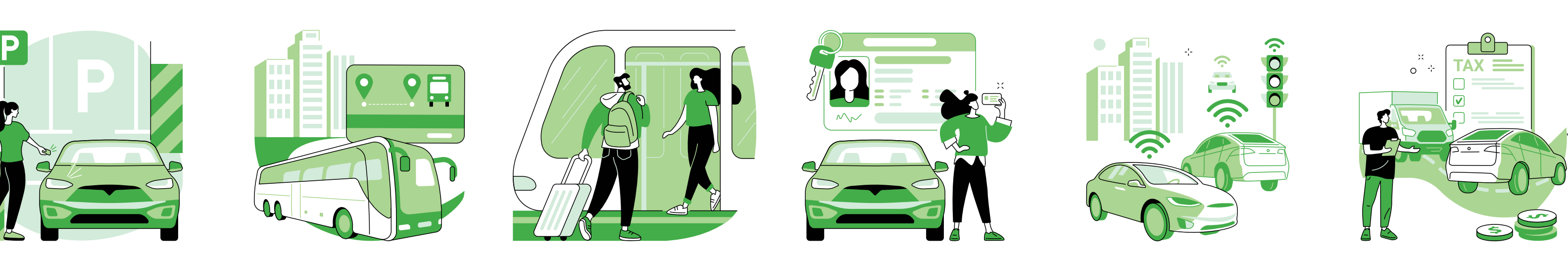
3.5 Criteria for Site Selection for Charging Stations and Swapping Stations

The following criteria was adopted while selecting the locations for Charging Stations and Swapping Stations for the city of Kolkata

General Considerations

» Available Land area must not be a private property

» Proposed land where chargers is set up should be easily accessible by the vehicles



Area Requirements

» For Battery Swapping Stations (BSS): Minimum area of 15.125 sq.m. is required

» For Charging Station (CS) Infrastructure: Minimum area of 105 sq.m. is required

» The area considered caters to the requirement of installation of ancillary equipment to the EV Charging Stations

» For Buses, the charging stations are considered to be installed in the bus depots only.

Traffic Considerations

» Traffic density of 2W, 3W and 4W are captured separately to individually identify the suitable location for setting up of BSS and CS.

» Adequate parking area for the vehicles is also considered

Power Infrastructure Requirements

» Mapping of Energy demand and Power Demand to ensure optimum loading of power infrastructure.

4. Charging Infrastructure for e-Buses

Buses are the prime means of public transportation in the city. These buses are operated from 28 depots whose infrastructure and operation is also managed by WBTC. Out of the 1633 buses that are operated by WBTC, 80 buses were deployed under FAME-I and being run throughout the state. In Kolkata, presently 75 E-buses are being operated for public transit. All the buses are manufactured by TATA Motors and delivered to the state on 2019. The 80 E-buses deployed with battery capacities of 125 kWh for 9m type and 187.5 kWh for 12m type. The seating capacity is 30 for 9m E-bus and 40 for 12m e-bus.

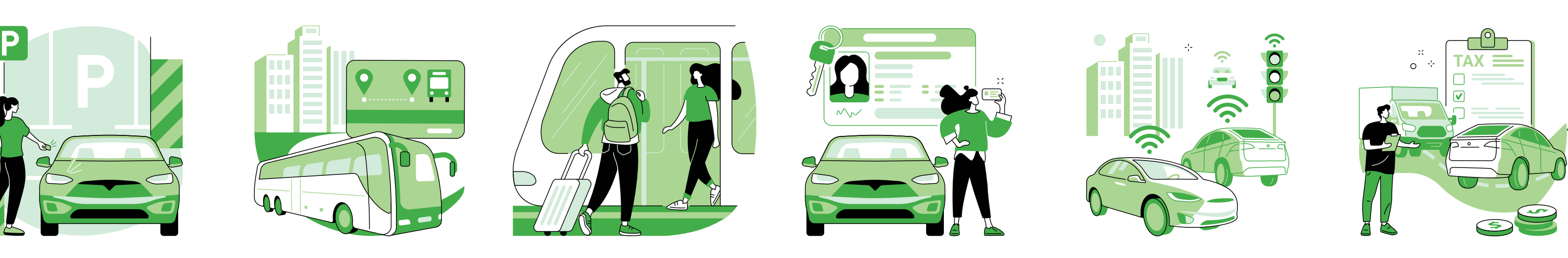
Table 10: List of e-bus types operating in Kolkata

Policy Framework	Bus Type	Number of Buses Plied	Battery Size (kWh)	Driving Range (km)
FAME-1	Type 1- 9m, 30 seater	40	125	125
	Type 2- 12m, 40 seater	40	187.5	160
FAME-2	12m, 40 seater	10/50	200	-

The distribution of e-buses to the various depots is given below;

Table 11: e-bus distribution in Kolkata

Sl. No	Depot	9m e-Bus	12m e-Bus	Total e-buses
1	Belgharia	8	0	8
2	Kasba	0	8	8
3	Nonapukur	0	5	5
4	Thakurpukur	4	4	8
5	Howrah	5	5	10
6	Salt Lake	0	8	8
7	Lake	8	0	8
8	Gariahat	10	0	10
9	New Town	0	10	10
10	Digha*	5	0	5
	Total	**40**	**40**	**80**



4.1 Bus Route Analysis

There are 348 routes being operated by WBTC out of which 215 routes (62%) are for intra-city movement and the rest (38%) are for inter-city movement. The average route length is between 6 – 55 kms, with the average of 22 km. Upon analysis, it was found that 76% or more than 3/4th of the routes fall under the range of 10-30 km per route. The average number of trips made by a bus is between 2 to 3. The average number of buses plied in a route is between 4 and 5. The total distance run each day by a diesel bus on an average is 120 km, the lowest being 55 km and the highest being 234 km. It was found that more than 80% of the buses covered a distance between 55-150 km/day.

The route analysis for 25 routes was also done in order to find out the peak hours of bus operation and the consumer behaviour. The details of the bus routes with time tables are specified in the table below. Upon analysis of the time table of the buses of 25 routes, where more than 100 buses are in operation, the peak hours of movement were found to be from 7-10 AM and 2-6 PM. The average duration of these routes (one-way) was 1 hour and 21 minutes with an average speed of 20 km/hr.

Table 12: Route analysis of buses in Kolkata

Sl. No.	Route Number	Route Length (km)	Origin	Destination	Route Duration (hrs)	Speed (km/hr)
1	AC-4A	29	Parnashri	Sapoorji	01:27	20
2	AC-12	25	New Town (Sapoorji)	Howrah	01:15	20
3	AC-12D	21	Joka	Howrah	01:03	20
4	AC-14	39	Baruipur	Karunamoyee	01:39	24
5	AC-20	41.5	Santragachi	Barrackpore	01:03	40
6	AC-24	21	Patuli	Howrah	01:10	18
7	AC-37A	33	Garia	Air Port	01:39	20
8	AC-43	32.5	Golf Green	Air Port	01:38	20
9	AC-47	27	Kundghat	Sapoorji	01:50	15
10	S-3W	31	Joka	Eco Space	01:45	18
11	S-4	29	Parnashree	Karunamoyee	01:30	19
12	S-5C	21	Nayabad	Howrah	01:28	14
13	S-9A	21	Dunlop	Ballygunge	01:24	15
14	S-10	22	Airport	Nabanna	01:13	18
15	S-11	40	Neilgunj	Esplanade	01:35	25
16	S-12	20.5	New Town	Howrah	01:00	21

Table 12: *Contd...*

Sl. No.	Route Number	Route Length (km)	Origin	Destination	Route Duration (hrs)	Speed (km/hr)
17	S-12E	27.5	Howrah Station	Ecospace	01:20	21
18	S-16	27.50	Thakurpukur	Salt Lake	01:24	20
19	S-17A	24	Ariadaha	Kundghat	01:02	23
20	S-21	21.00	Garia	Baghbazar	01:03	20
21	S-23A	31.50	Rajchandrapur	Karunamoyee	01:18	24
22	S-24	21.5	Kamalgazi	Howrah	01:07	19
23	S-32	28.50	Barrackpore	Howrah	01:33	18
24	S-46	28.00	Karunamoyee	Akra/ Rabindranagar	01:24	20
25	S-47	22.5	Eden City	Howrah	01:08	20

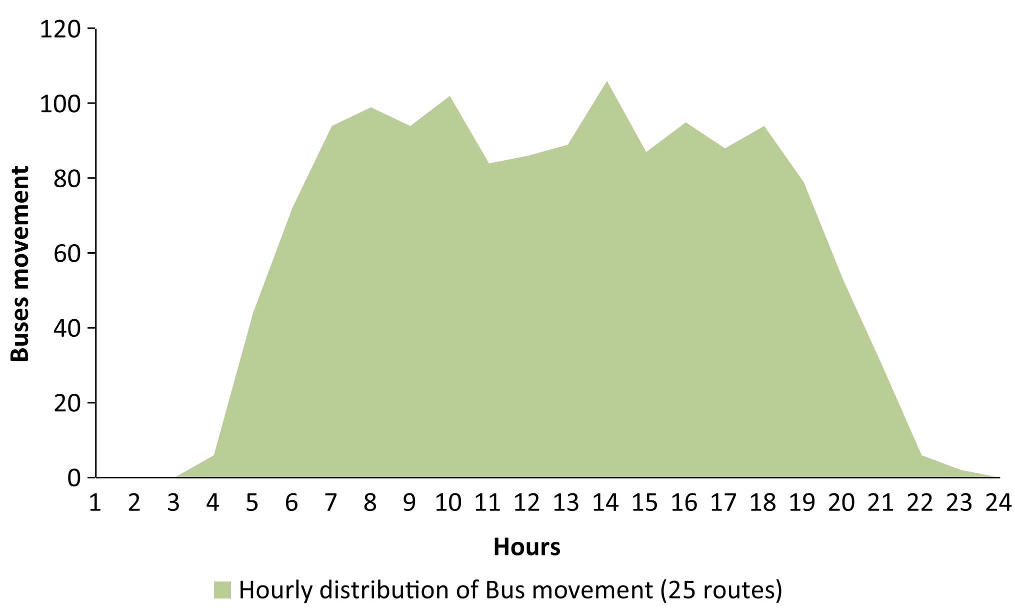
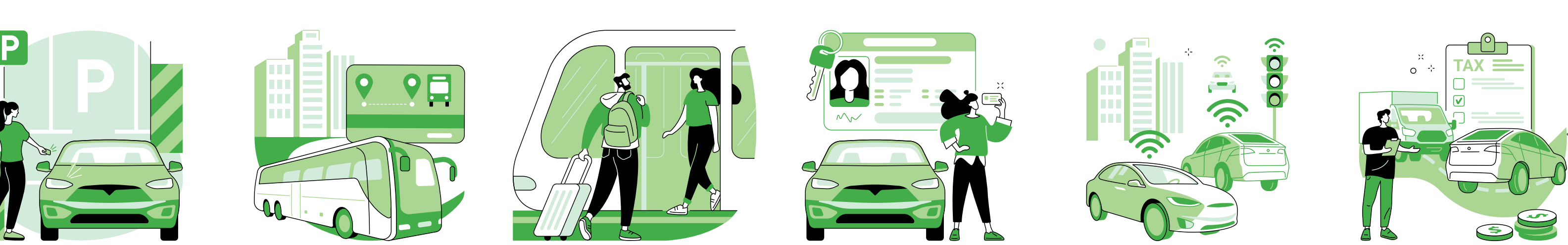
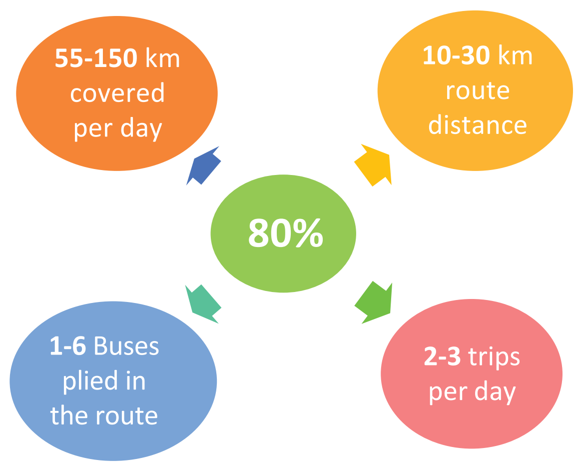


FIGURE 5: **Hourly distribution of bus movement (25 routes)**



Out of the 215 Bus routes under WBTC in Kolkata, the 75 E-buses in the city presently operate only at 12 routes. The details of E-bus routes are provided in the annexure. The average route length of E-bus routes lies between 13 km and 35 km, with the average being 25 km. There are 2-4 trips made by each bus on its route. The number of buses plied in a route varies between 4 and 10. The average distance covered by an E-bus per day is 133 km. The maximum distance covered is 210 km, whereas the minimum distance covered is 78 km.



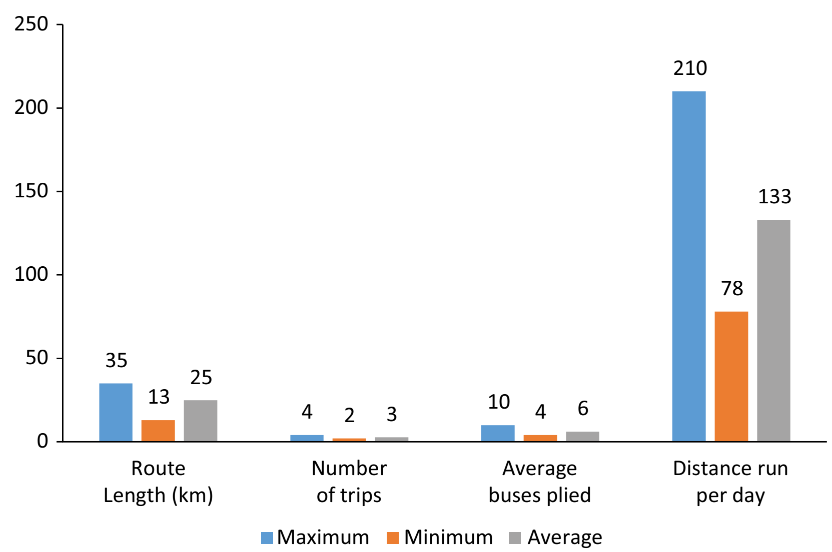


FIGURE 6: Route analysis of E-buses & Diesel buses

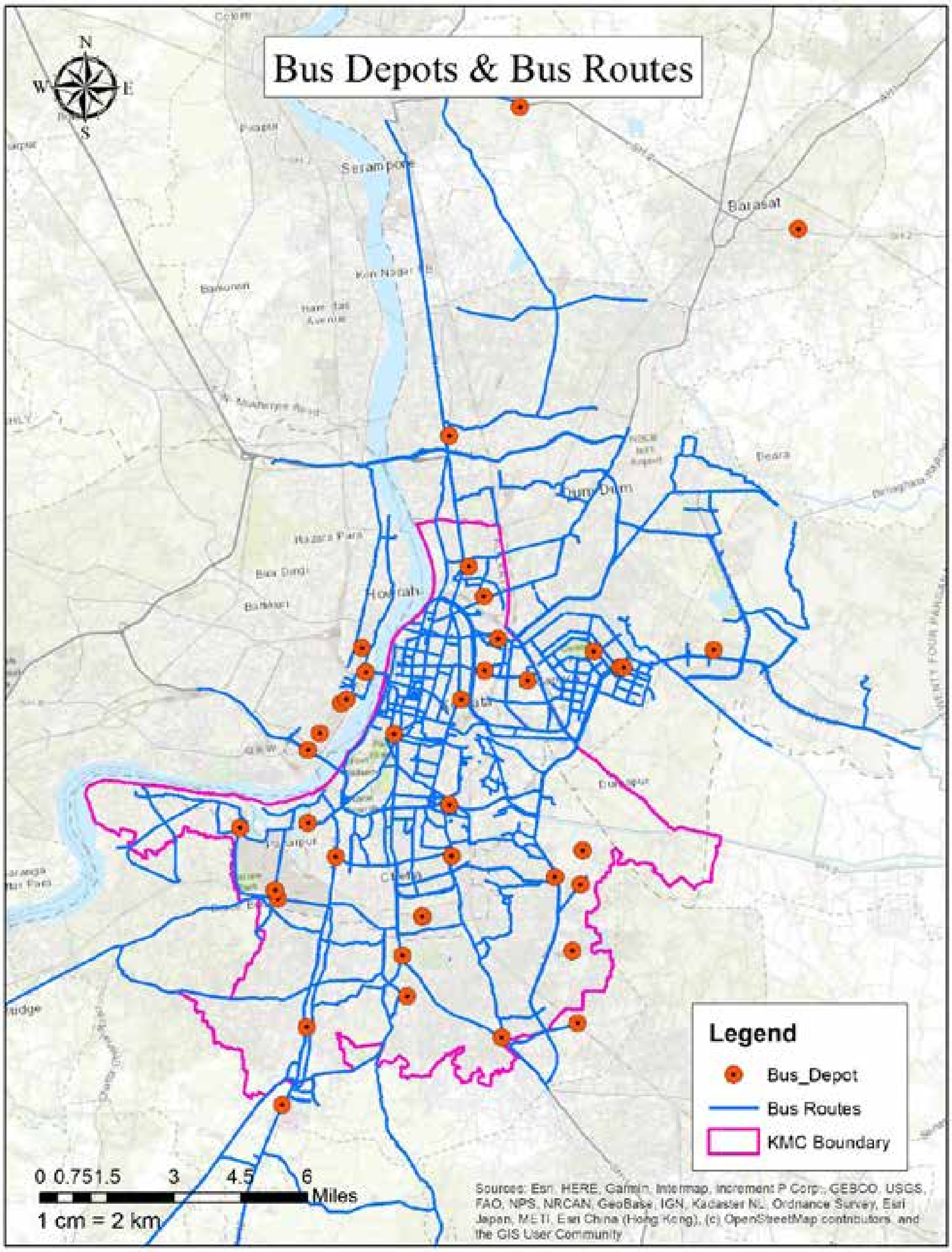
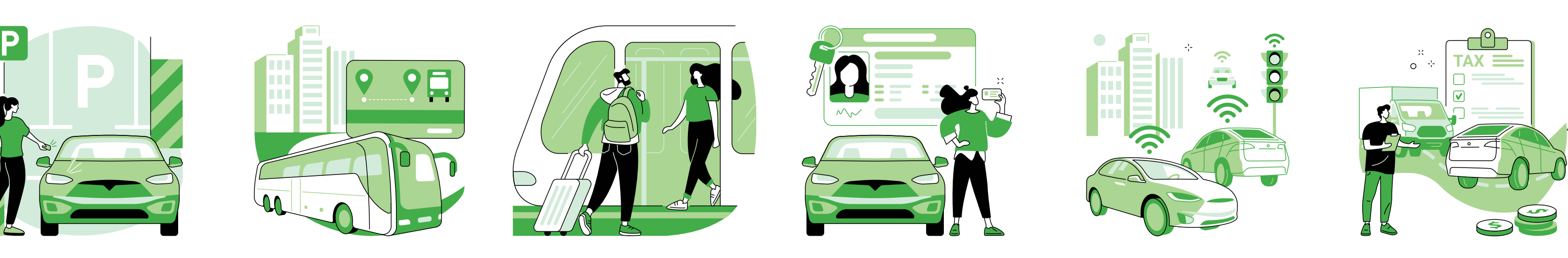


FIGURE 7: E-bus routes operating in Kolkata



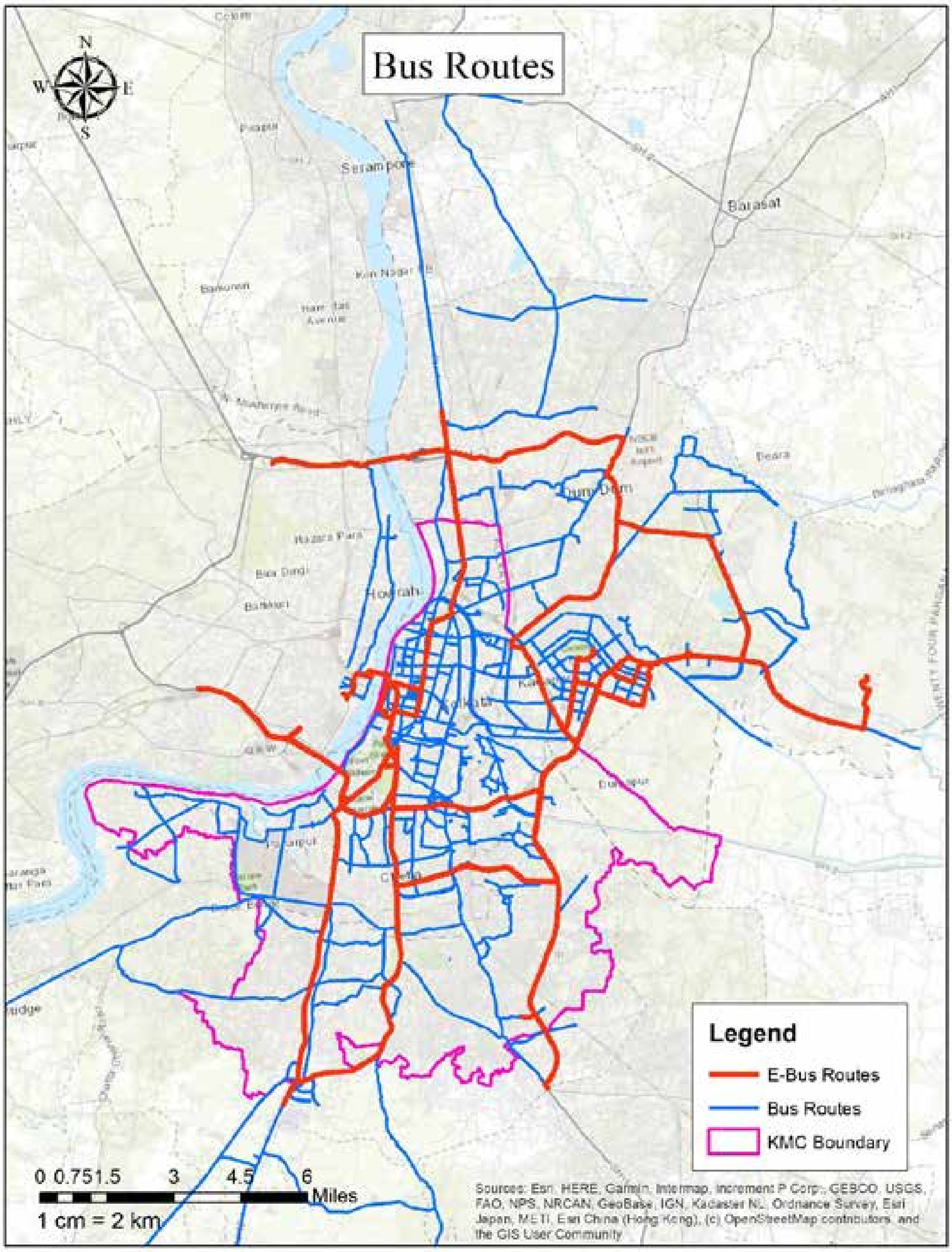
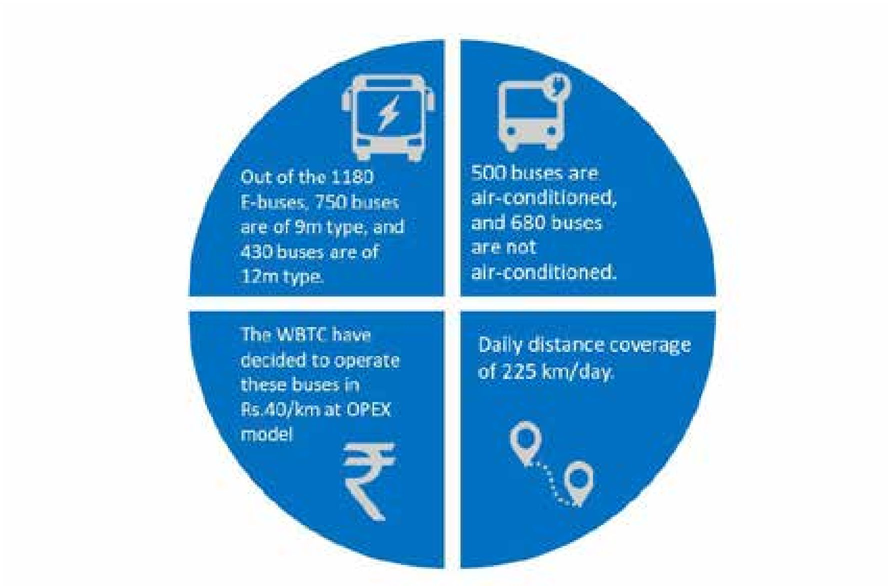


FIGURE 8: Operating Bus Routes & E-bus Routes in Kolkata

4.2 Expansion Plans

The WBTC is planning to deploy 1180 more E-buses by 2025 in addition to the already operating 80 E-buses in their fleet. The total number of E-buses in the WBTC fleet by the end of 2025 will be 1260. The bifurcation of the buses based on the bus type (9m/ 12m) and depot are presented below. Some of the specifications of this planned are:



The other details of these buses such as battery capacity, operating routes, frequency of operation are yet to be specified by the WBTC in the public domain.

Table 13: Allocation of 1180 E-buses in Kolkata

Sl. No	Depot	9 Mtr AC	9 Mtr NAC	12 Mtr L/F AC	12 Mtr NAC	Total
1	Maniktala	20	34	21	5	80
2	Kasba	0	0	24	36	60
3	Paikpara	8	50	0	22	80
4	Thakurpukur	34	48	18	0	100
5	Salt Lake CSTC	39	15	0	46	100
6	Belghoria	42	39	0	39	120
7	Taratala	10	38	18	34	100
8	Lake	27	15	25	33	100
9	Garia	19	27	24	0	70

Contd...

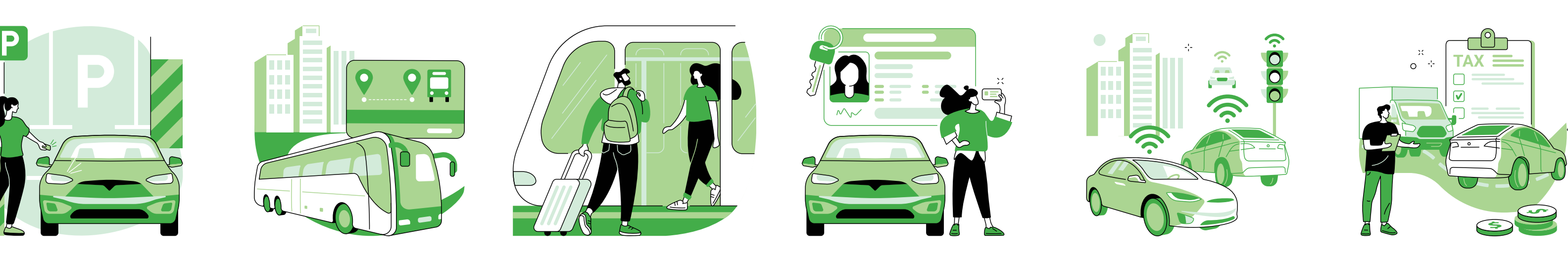


Table 13: *Contd...*

Sl. No	Depot	9 Mtr AC	9 Mtr NAC	12 Mtr L/F AC	12 Mtr NAC	Total
10	Park Circus	25	28	0	22	75
11	Joka	17	0	10	23	50
12	Belgachia	44	41	0	20	105
13	Rajabazar	35	45	0	0	80
14	Ghasbagan	30	20	10	0	60
	TOTAL	**350**	**400**	**150**	**280**	**1180**

4.3 Power Demand Analysis for e-buses

The analysis of the present energy required for the operation of the E-buses was conducted based on the data provided by the WBTC. The Single Line Diagram of the conventional charging station in a WBTC bus depot is shown below in the Figure 9.

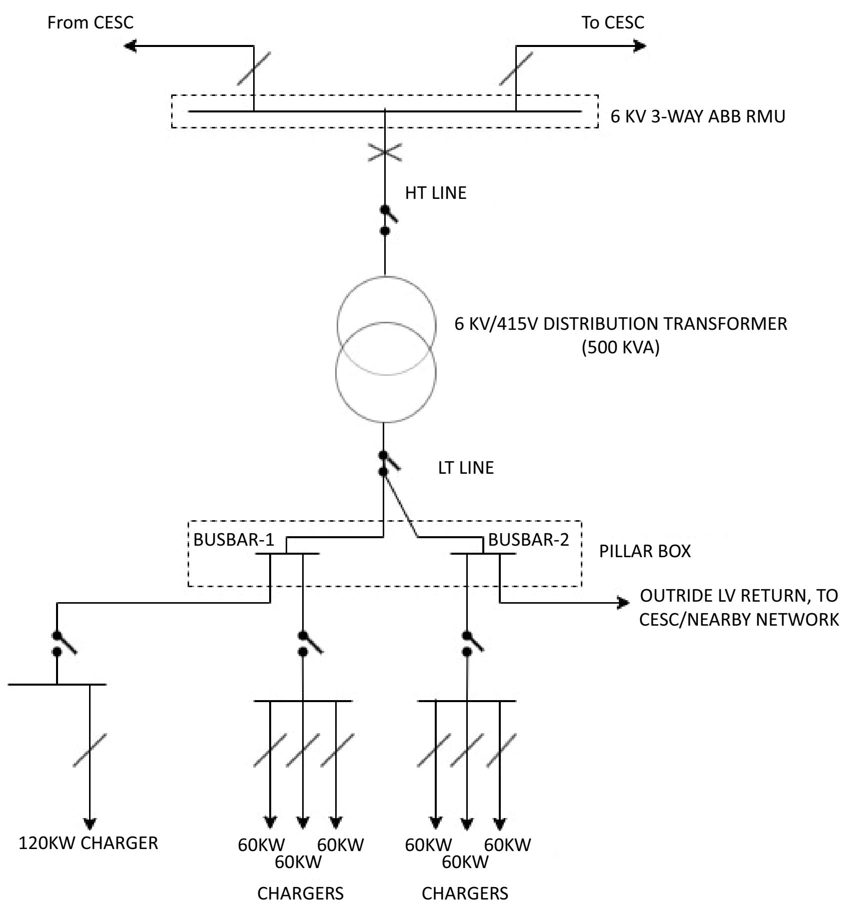


FIGURE 9: **Single Line Diagram for E-bus charging in a depot**

The daily charging pattern of the e-buses for a week in August 2022, when the field study was undertaken, is shown in Figure 10.

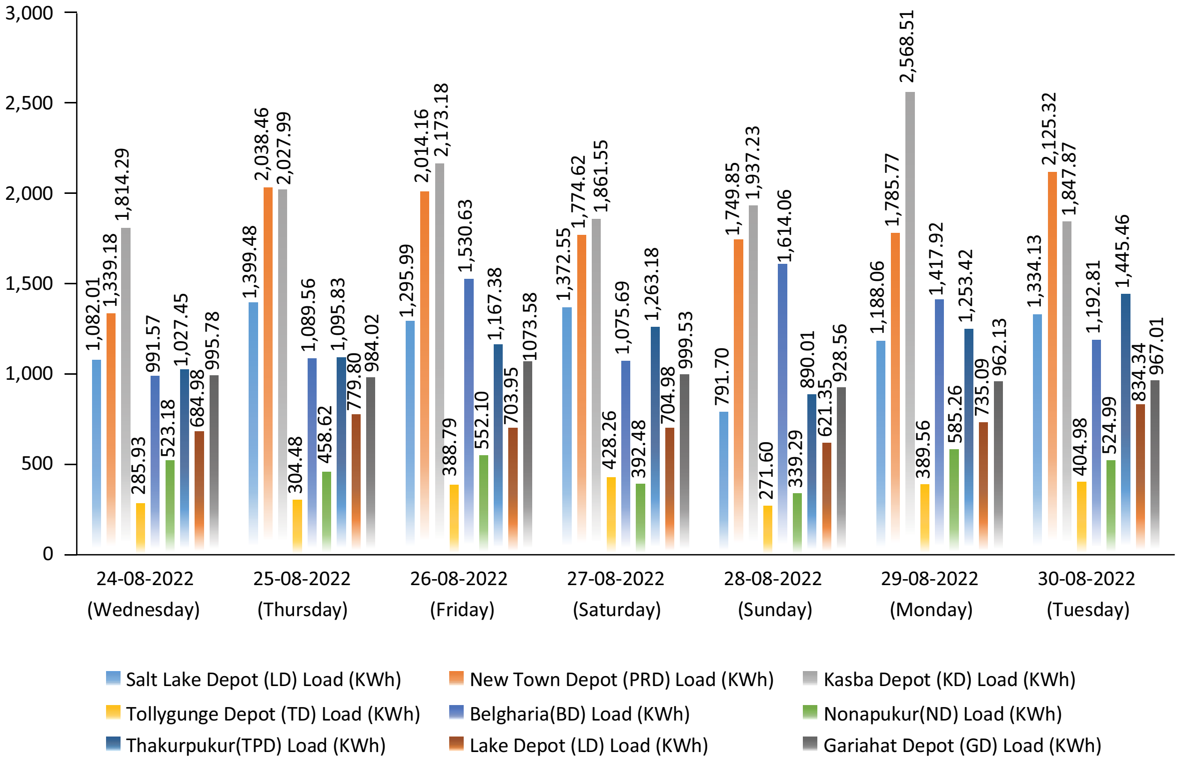


FIGURE 10: Weekly charging pattern of E-buses

Load Curve for e-buses

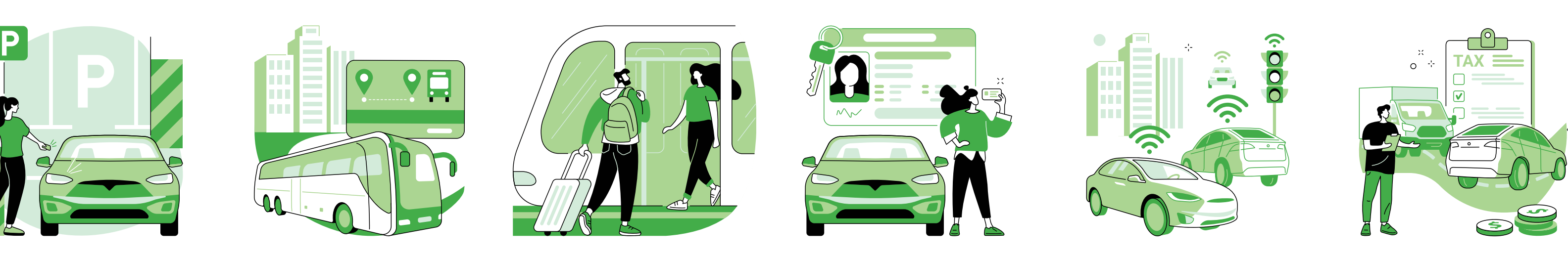
The assumptions considered for analysis of the load curve are presented below;

» At each Depot, which will be allotted new Electric Buses, it was assumed that the charging machine will have a rating of 240 kW consisting of two charging guns. A single charging gun can charge an Electric Bus at 120 kW. Charging gun used is GB/T Type.

» The details of the battery capacity for 1180 Electric Buses are given in Table 14.

Table 14: Battery capacities of planned buses

Type of EBuses	Number of e-Buses	Battery Capacity (kW)
9 Mtr AC	350	200
9 Mtr NAC	400	200
12 Mtr L/F AC	150	300
12 Mtr NAC	280	400



» Two types of charging situations are considered while the estimation of charging load curves for Electric Buses,

a) Night Charging (Conventional Charging)

b) Top-up charging (Opportunity Charging)

Charging after operational hours is assumed to occur between 22:00 hours and 10:00 hours. Electric Buses will be fully charged during this period for their next day/ shift operation. The initial State of the Charging (SoC) of arrived Electric bus is taken as 15% at the point at which charging is started. It is based on the existing data on charging old Electric Buses. All the Electric Buses are assumed to get fully charged during this period.

On the other hand, it is assumed that top-up charging last from 45 to 50 minutes approximately. It would mostly occur during day time considering the normal operational time duration for Electric Buses in the day time. Based on this charging period, along with the existing data of charging old Electric Buses, battery capacities of Electric Buses and charging machines rating, the initial SoC at the start of charging for arrived Electric Buses is taken as 25%.

The charging guns assumed at each Depot are approximately 1:2 with respect to the total number of new Electric Buses along with the old ones allotted at each Depot. Based on the assumptions, the estimated charging guns at each depot are shown in Table 15.

Table 15: Number of charges required and power demand of E-buses

S.No.	Depots Name	Charging Guns (Old + New)	Demand by Depot (Approx. Value in kW)
1	Belghoria *	60	4000
2	Belgachia	52	3467
3	Garia	32	2133
4	Ghasbagan	28	1867
5	Joka	24	1600
6	Kasba *	32	2133
7	Lake *	52	3467
8	Maniktala	40	2667
9	Paikpara	40	2667
10	Park Circus	36	2400
11	Rajabazar	40	2667
12	Salt Lake CSTC *	52	3467
13	Taratala	48	3200
14	Thakurpukur *	52	3467

** indicate the depots which also have old Electric Buses along with new ones.*

The analysis of the present energy required for the operation of the E-buses was conducted based on the data provided by the WBTC. The primary data source included the charging sheets from various E-bus depots in Kolkata.

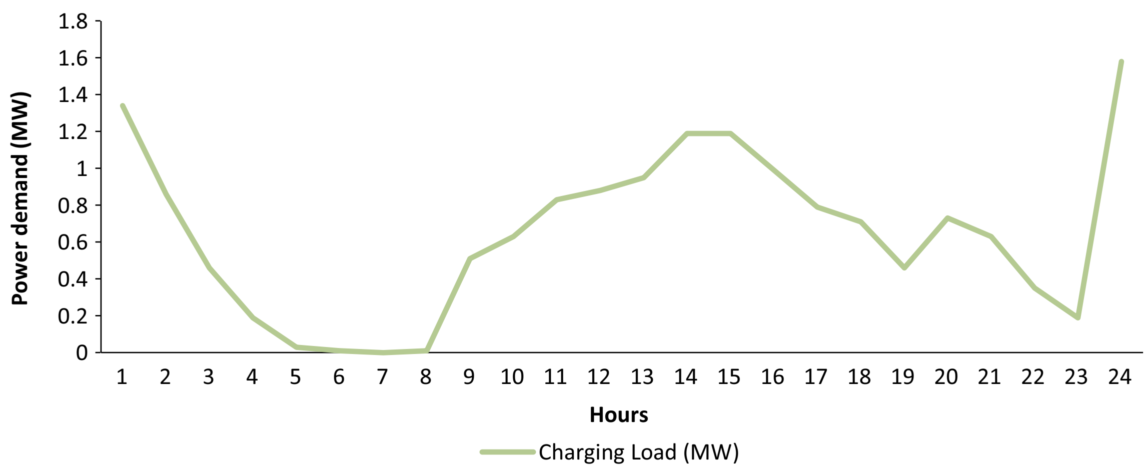


FIGURE 11: Load curve due to charging of existing E-buses

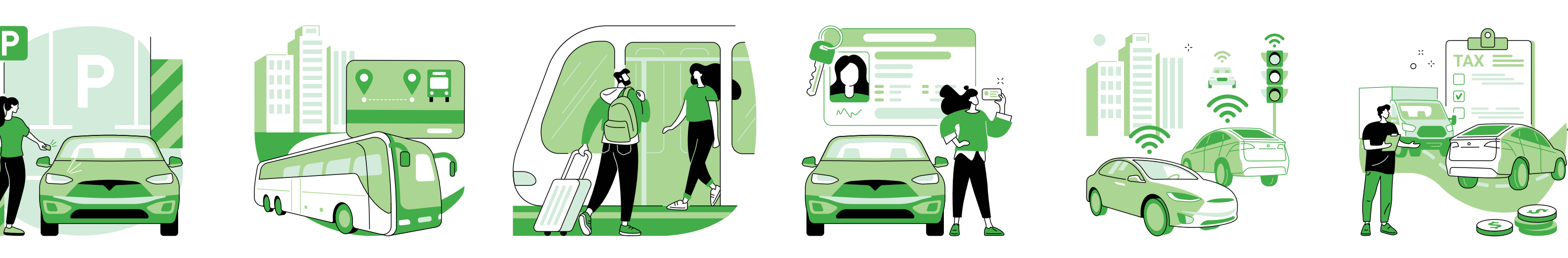
4.4 Renewable Energy Potential Assessment

During site survey it was observed that the depot rooftop had the potential for installation of solar panels for the generation of electricity. The Table 16 shows the solar energy potential.

Table 16: Outputs of RE potential analysis for E-buses

Parameters	Values
Average Annual Global Horizontal Irradiance (GHI)	907* W/m²
Rooftop area under WBTC which can be used for Solar PV installation	66965 m²
Total number of PV Modules required	26199
Nominal Power of Solar PV installed	14.2 MW_p
Maximum Output Power (AC)	13 MW
Average Performance Ratio	0.865
Energy Produced per day	63.35 MWh
Energy Produced per year	5701 MWh

*Source: *NREL Database; TERI Analysis*



It is observed that the potential for solar energy generation is 5.70 GWh, considering that solar generation per day is done only for 6 hrs.

The energy demand is approx 500 MWh, and the renewable energy potential is 63MW, which is 12% of the daily energy requirement at all depots combined for 1180 e-buses. To achieve net zero in this case, suitable power procurement mechanisms such as from open access or import from other areas may be analysed.

Financial Aspects of Solar Rooftop generation

The cost for installation of Roof Top System (RTS) for general category states is given below;

RTS System Capacity/ Range	Upto 1 kW	>1kW upto 2 kW	>2 kW upto 3 kW	>3 kW upto 10 kW	>10 kW upto 100 kW	>100 kW upto 500 kW
Benchmark Cost (Rs./kW), excl GST	46923	43140	42020	40991	38236	35886

Source: https://solarrooftop.gov.in/notification/130_notification.pdf

The solar panels are to be installed on the rooftop area available in the bus depots, which shall provide supply for charging of the e-Buses. The area available in each bus depot is given below, along with solar plant size). The commercial cost of electricity is taken to be Rs. 8/kWh.

Table 17: Solar Rooftop potential under each WBTC depot

Bus Depot	Area (sq.m.)	Proposed Solar Panel Capacity (kWp)	Output Power (kW)	kWh/day
Belghoria	3,374	712.8	651.84	3,150.58
Belgachia	6,809	1,438.56	1,315.10	6,372.82
Garia	1,242	262.44	239.90	1,191.48
Gariahat	3,435	725.76	663.27	3,244.15
Ghasbagan	2,045	432	394.62	1,874.88
Howrah	1,342	283.5	259.28	1,281.42
Joka	358	75.6	69.01	336.42
Kasba	3,108	656.64	599.99	2,974.58
Lake	3,681	777.6	710.64	3,491.42
Maniktala	2,715	573.48	524.16	2,569.19
Nonapukur	9,125	1,927.80	1,763.40	8,732.93
Paikpara	6,262	1,323.00	1,209.17	5,913.81
Park Circus	3,374	712.8	651.84	3,250.37
PRD	1,554	328.32	299.69	1,444.61

Contd...

Table 17: *Contd....*

Bus Depot	Area (sq.m.)	Proposed Solar Panel Capacity (kWp)	Output Power (kW)	kWh/day
Rajabazar	3,681	777.6	710.64	3,506.98
Salt Lake	3,885	820.8	749.83	3,636.14
Taratala	1,104	233.28	213.25	1,052.09
Thakurpukur	3,313	699.84	639.74	3,156.28
Tollygunge	4,818	1,017.90	929.75	4,570.37
New Town	654	138.24	126.56	590.28
Karunamoyee	1,086	229.5	210.19	1,012.10
Total	66,965.00	14,147.46	12,931.86	63,352.90

As per the benchmark cost provided by MNRE, the total investment to install 14MW of solar power plant is estimated to be Rs. 46.65 Crores across all the bus depots. Considering the life of solar panels to be 25 years, the gross lifetime saving is calculated to be Rs. 358.80 Crores.

(Source: https://solarrooftop.gov.in/rooftop_calculator)

4.5 Recommendations

The load pattern for the 1180 new deployed Electric Buses along with the old ones, is estimated considering the assumptions described in the previous section. Three different Charging Scenarios are considered for the estimation of load pattern at all depots for Electric Buses.

Recommendation 1: Having Charging Point Utilization within 50%

Two cases are envisaged:

» Case 1A: Uncontrolled Charging

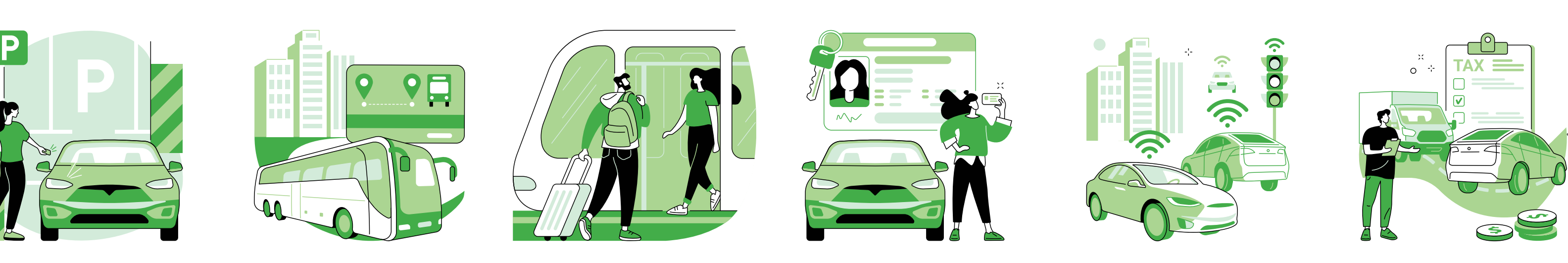
» Case 1B: Controlled Charging

Case 1A: Uncontrolled Charging: In this case it is assumed that the buses get charged in a random manner depending on the availability of buses in the depot. The pattern of arrival and departure of e-buses is not available is this case. However, it is assumed that most of the buses will available at night and during the afternoon for charging.

The load pattern is shown in Figure 12.

It is observed, in this case, there was a sudden ramping up of load demand in the night (10:00 PM to 11:00 PM), indicating close to full charging capacity utilization at the depots. In this case the charger utilization (i.e. ratio of how many hours per day is the charger charging the vehicle and the total hours in the day) is 35%.

The energy demand for this case is given in the table below. It is calculated to be 551 MW, considering 548 chargers installed for 9m length and 12m length e-buses.



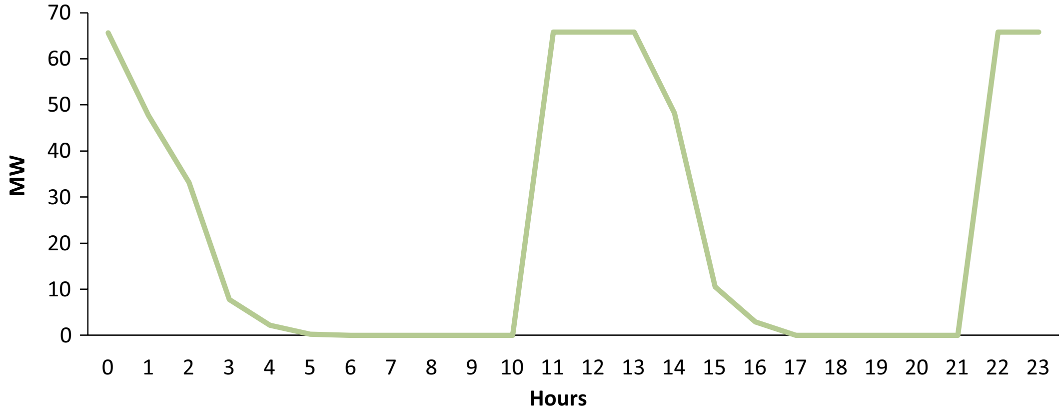


FIGURE 12: Load curve due to E-bus charging (Case 1a)

Case	Type of e-bus	Proposed Charger Type	Proposed Charger rating	Number of Chargers	Power Demand (MW)	Hours of operation of charger	Energy Demand (MWh)
Case 1a	9 mtr	Fast Charger only	120 kW (Fast)	548	65.7	8.4	551.88
	12 mtr	Fast Charger only	2*120 kW (Fast)				

Case 1B: Controlled Charging: In this case it is assumed that the buses get charged in a predefined manner such that the buses are allocated specific slots in the depot. It is based on the arrival time of Electric Buses. The arrival and departure timings of the buses is given in Figure 13.

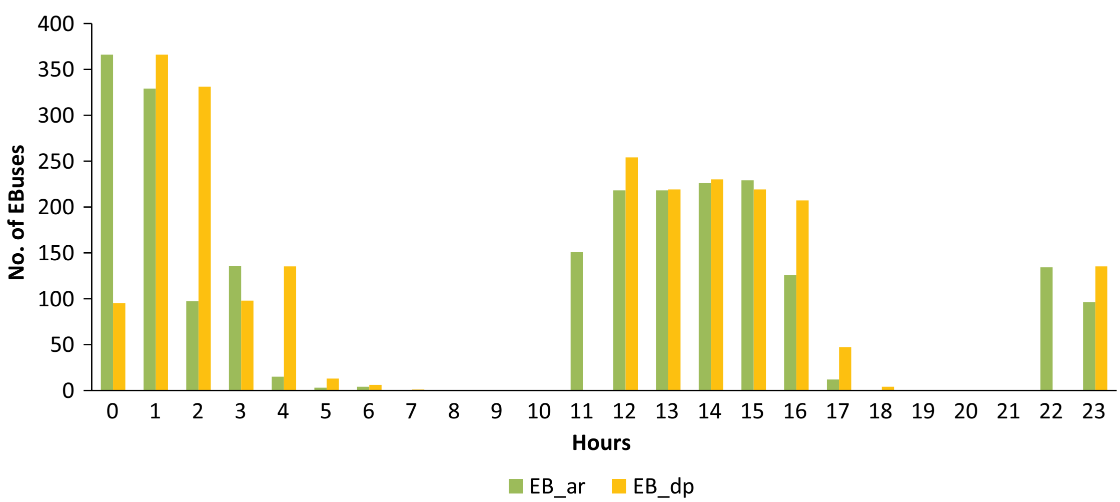


FIGURE 13: Arrival & Departure pattern of E-buses (Case1b)

The utilization of charging guns hence can be estimated as arrival times of the buses is known. It is presented in the table below.

Time (in hours)	Charging guns to be used per hour
22:00 to 1:00	(80 to 90) % of available charging guns
1:00 to 8:00	(20 to 40) % of available charging guns
8:00 to 10:00	(10 to 20) % of available charging guns
13:00 to 17:00	(up to 30) % of available charging guns
17:00 to 22:00	(60 to 80) % of available charging guns

The load pattern in this case is depicted in Figure 14.

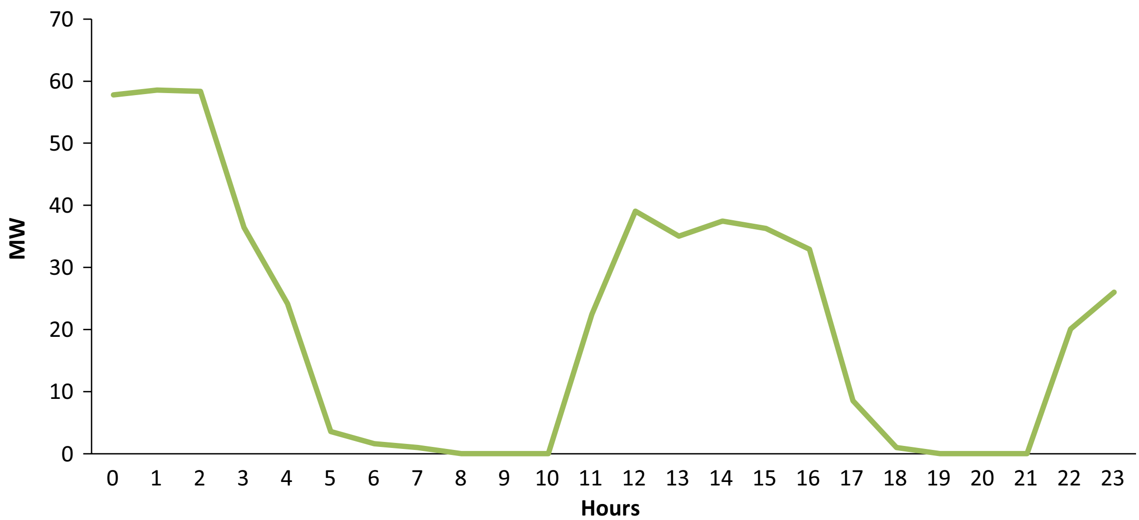
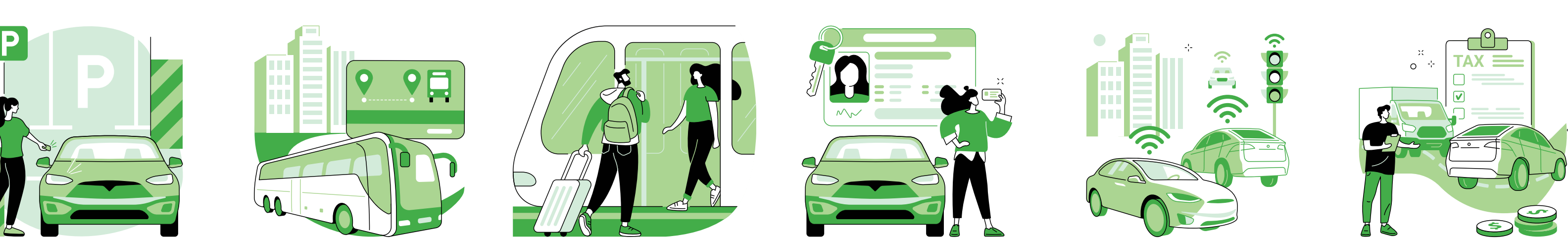


FIGURE 14: Load curve due to E-bus charging (Case2)

In this case the charger utilization is 34%.

Case	Type of e-bus	Proposed Charger Type	Proposed Charger rating	Number of Chargers	Power Demand (MW)	Hours of operation of charger	Energy Demand (MWh)
Case 1b	9 mtr	Fast Charger only	120 kW (Fast)	548	58.5	8.4	491.4
	12 mtr	Fast Charger only	2*120 kW (Fast)				



Recommendation 2: Having Charging Point Utilization above 50%

Case - 2: Optimized Charging: In this case, it is assumed that the buses primarily get charged during the night time and multiple buses can get charged with a single charger. However, the buses can also get charged intermittently during the daytime at depots. It is observed from Figure 15 that predominantly the buses arrive during the night and during the afternoon at the depots.

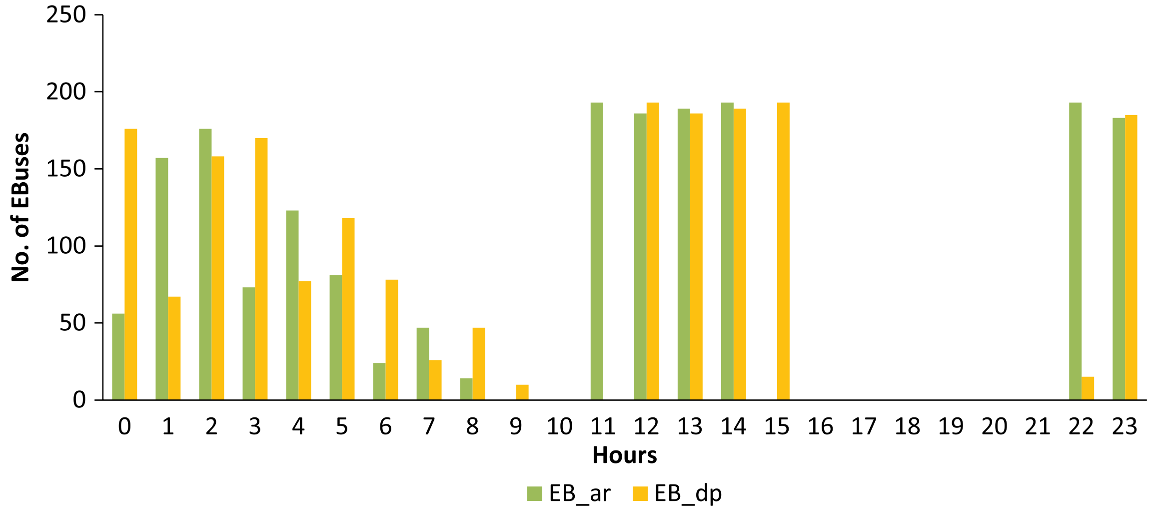


FIGURE 15: Arrival & Departure pattern of E-buses (Case 2)

The load pattern formed in this case is shown below;

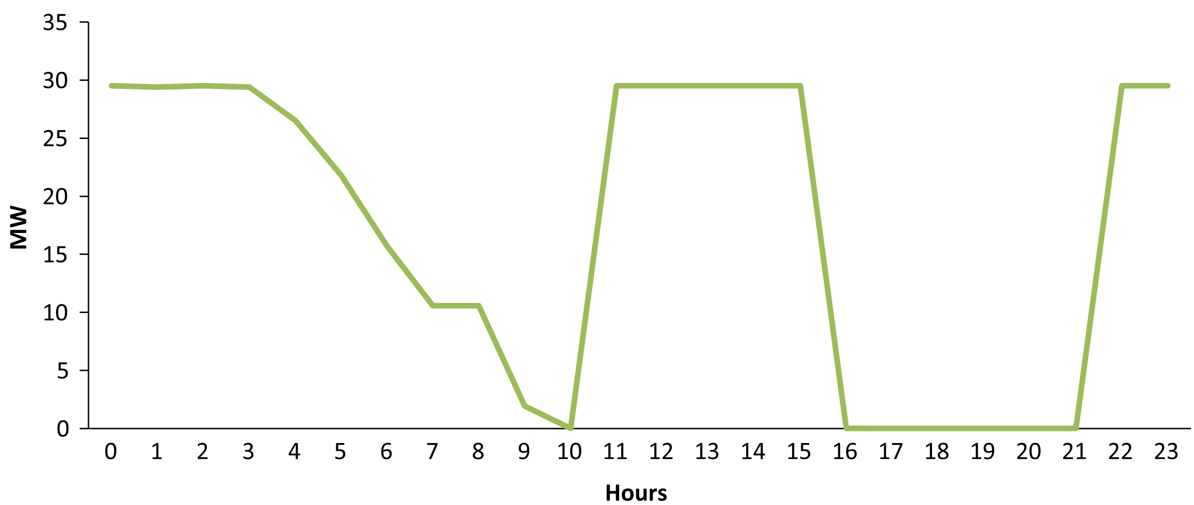


FIGURE 16: Load curve due to charging of e-buses (Case 2)

In this case the charger utilization is 58%.

The energy demand for this case is shown below;

Case	Type of e-bus	Proposed Charger Type	Proposed Charger rating	Number of Chargers	Power Demand (MW)	Hours of operation of charger	Energy Demand (MWh)
Case 2	9 mtr	Fast Charger only	120 kW (Fast)	246	29.5	13.9	410.05
	12 mtr	Fast Charger only	2*120 kW (Fast)				

Summary of recommendations

The table below shows the inferences of the three charging scenarios with respect to the existing load pattern of Electric Buses. It can be seen from the Table that the estimation of peak load hours in Case 1b and Case 2 is in accordance with the existing peak load of the operational Electric Buses.

Inferences	Case 1a	Case 1b	Case 2
Load due to e-bus charging (MW at hours)	65.7 MW	58.5 MW	29.5 MW
% of city's peak load demand	2.52%	2.24%	1.13%

It also specifies a substantial rise in the peak load demand. The average load demand of charging Electric Buses has also increased between 1.13% and 2.52% of total city's load demand of 2606 MW.

The electricity demand at each depot is shown in Table18:

Table 18: Chargers required and energy demand due to E-bus charging (Case 2)

S.No.	Depots Name	Station Code	e-buses (old+new)	Charging Guns (Old + New)	Demand by Depot (Approx. Value in kW)
1	Belghoria*	BD	128	60	4000
2	Belgachia	BHD	105	52	3467
3	Garia	GHD	70	32	2133
4	Ghasbagan	GBD	60	28	1867
5	Joka	JD	50	24	1600
6	Kasba*	KD	70	32	2133

Contd...

Table 18: *Contd...*

S.No.	Depots Name	Station Code	e-buses (old+new)	Charging Guns (Old + New)	Demand by Depot (Approx. Value in kW)
7	Lake*	LD	108	52	3467
8	Manicktala	MD	80	40	2667
9	Paikpara	PD	80	40	2667
10	Park Circus	PCD	75	36	2400
11	Rajabazar	RBD	80	40	2667
12	Salt Lake CSTC*	SLD	107	52	3467
13	Taratala	TD	100	48	3200
14	Thakurpukur*	TPD	108	52	3467

** are old depots in which old e-Buses are also considered while load estimation*

The load pattern for charging is shown in Figure 17:

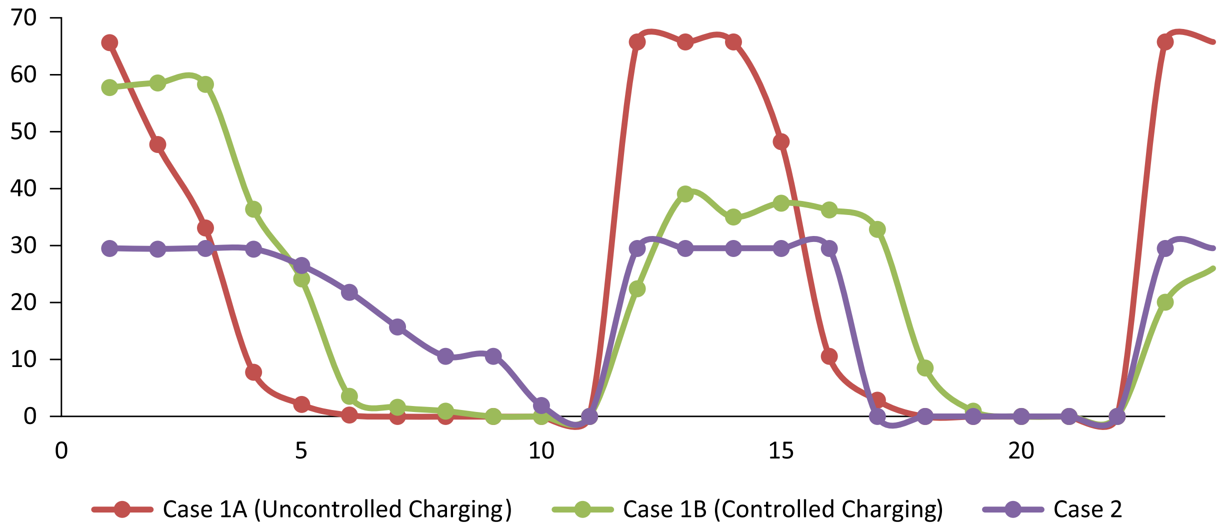
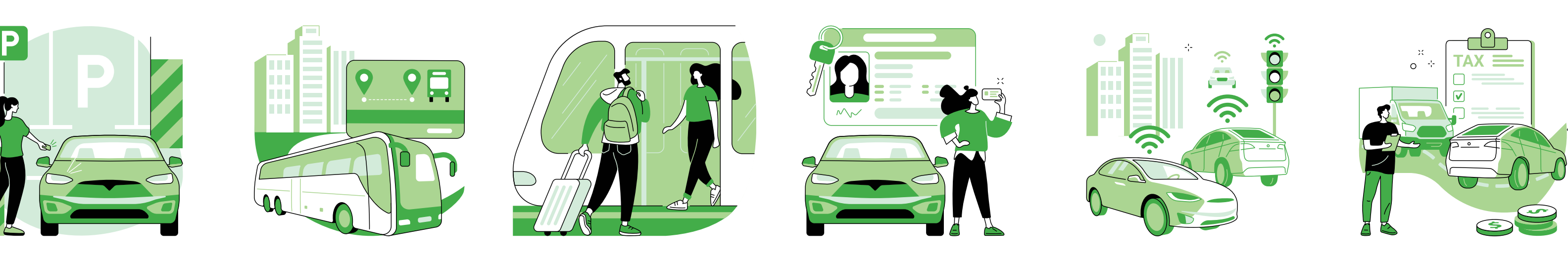


FIGURE 17: Comparison of Load curves due to e-bus charging (Case 1a, 1b, 2)

The charger utilization scenarios for the three cases are shown in Table 19:

Table 19: Comparison of different charging schedules for E-buses

Sl. No.	Parameters	Case 1A- Uncontrolled Charging	Case 1B- Controlled Charging	Case 2- Optimized Charging
1	Number of Bus depots	14	14	14
2	Number of E-buses/ depot	85	85	85
3	Number of chargers available (guns)	548	548	246
4	Type of Charger	CCS	CCS	CCS
5	Rating of Charger/gun	120 kW	120 kW	120 kW
6	Single gun/ Double gun	9m- single gun 12m- double gun	9m- single gun 12m- double gun	9m- single gun 12m- double gun
7	Battery capacity of buses	9m- 200 kWh 12m NAC- 300 kWh 12AC- 400 kWh	9m- 200 kWh 12m NAC- 300 kWh 12AC- 400 kWh	9m- 200 kWh 12m NAC- 300 kWh 12AC- 400 kWh
8	Assumed charging time per bus	2 hrs. (conventional) + 45 mins. Opportunity	2 hrs. (conventional) + 45 mins. (Opportunity)	2 hrs. (conventional) + 45 mins. (Opportunity)
9	Time of maximum utilization of charger (in hrs. or specify time)	6 hrs.	3 hrs.	11 hrs.
10	Peak Demand	65.76 MW	58.56 MW	29.52 MW
11	Charger Utilization	35%	34%	58%



5. Charging Infrastructure for other Transportation Modes

The other modes of transportation in Kolkata include two wheelers, three wheelers, four wheelers, trams for land connectivity and ferries for water connectivity.

5.1 Route Analysis

3-Wheelers

There are 489 permissible routes for 3-wheeler in Kolkata where more than 37 thousand 3-wheelers are permitted to operate. As per Vahan database, there are currently around 9,000 electric 3-wheelers registered between 2013-2022 in the 7 RTOs surrounding Kolkata which are- Kasba, Behala, Alipore, Salt Lake, PVD Kolkata, Barrackpore and Barasat. It was seen that almost all of the registrations are from Barrackpore & Behala RTOs which fall outside the KMC boundary. During a stakeholder interaction, it was found that currently no electric 3-wheelers operate within the KMC boundary. But, outside the boundary, the fleet is mixed of LPG based and electric 3-wheelers. The map in Figure 17 shows the 3-wheeler operating routes in Kolkata. About 46% of the routes operate within the KMC boundary and hence don't have electrified 3 -wheelers operating in them. The routes outside the KMC boundary i.e. 54% operates both electric and LPG 3-wheelers.

The three wheelers are a mode of public transport operated by private owners on routes permitted by the Road Transit Authority (RTA) on specified routes. The details are given below:

Table 20: Route Analysis of 3-wheelers

Parameter	Numbers
Total road distance covered by 3-Wheelers (km)	2542
Average distance covered by a 3-Wheeler (km)	5.25
Number of three wheelers/km	14.6
Number of Locations with 3 –wheeler operations	152
Number of hotspots (permits more than 1000)	3
Contribution of hotspots in terms of number of permits	25%

Out of the 489 routes, there are 152 common locations identified based on the start and the end points of each route. The locations are provided in the figure below. Some of the locations such as: Ultadanga, Baguiati, Barrackpore station, have the highest number of permits (more than 1000) and can be classified as hotspots for three-wheelers. The three hot-spots account for more than a quarter of total three-wheeler permits in the city, as given in the map below:

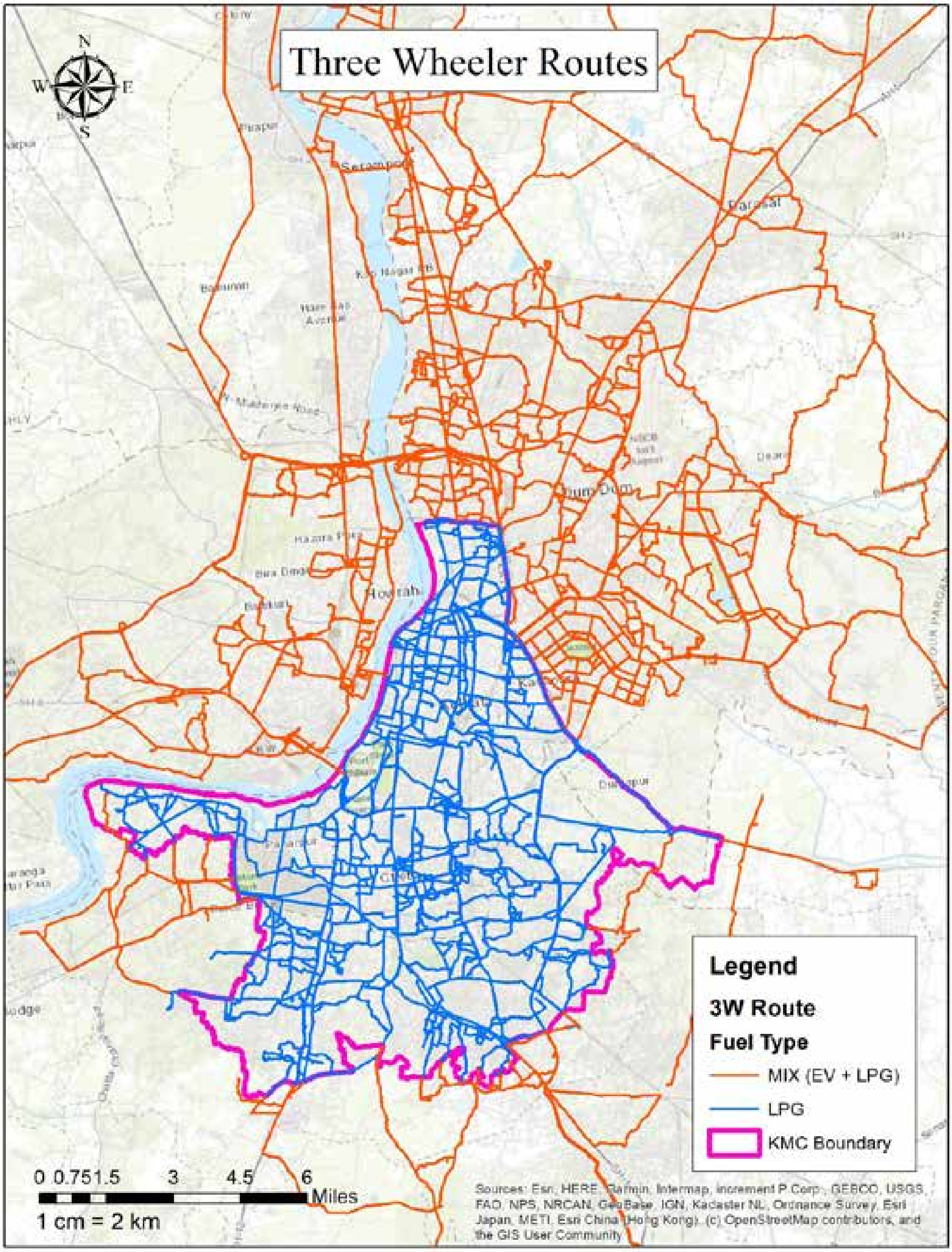
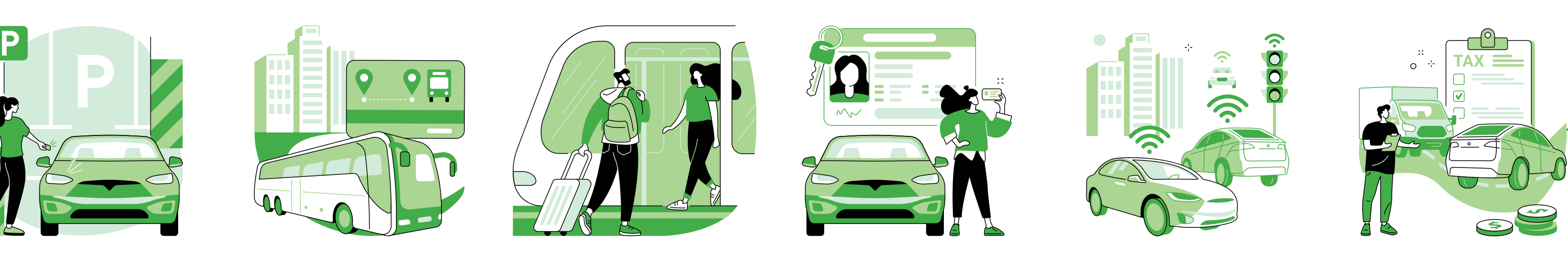


FIGURE 18: 3-wheeler permitted routes in Kolkata

Source: Transport Department of West Bengal



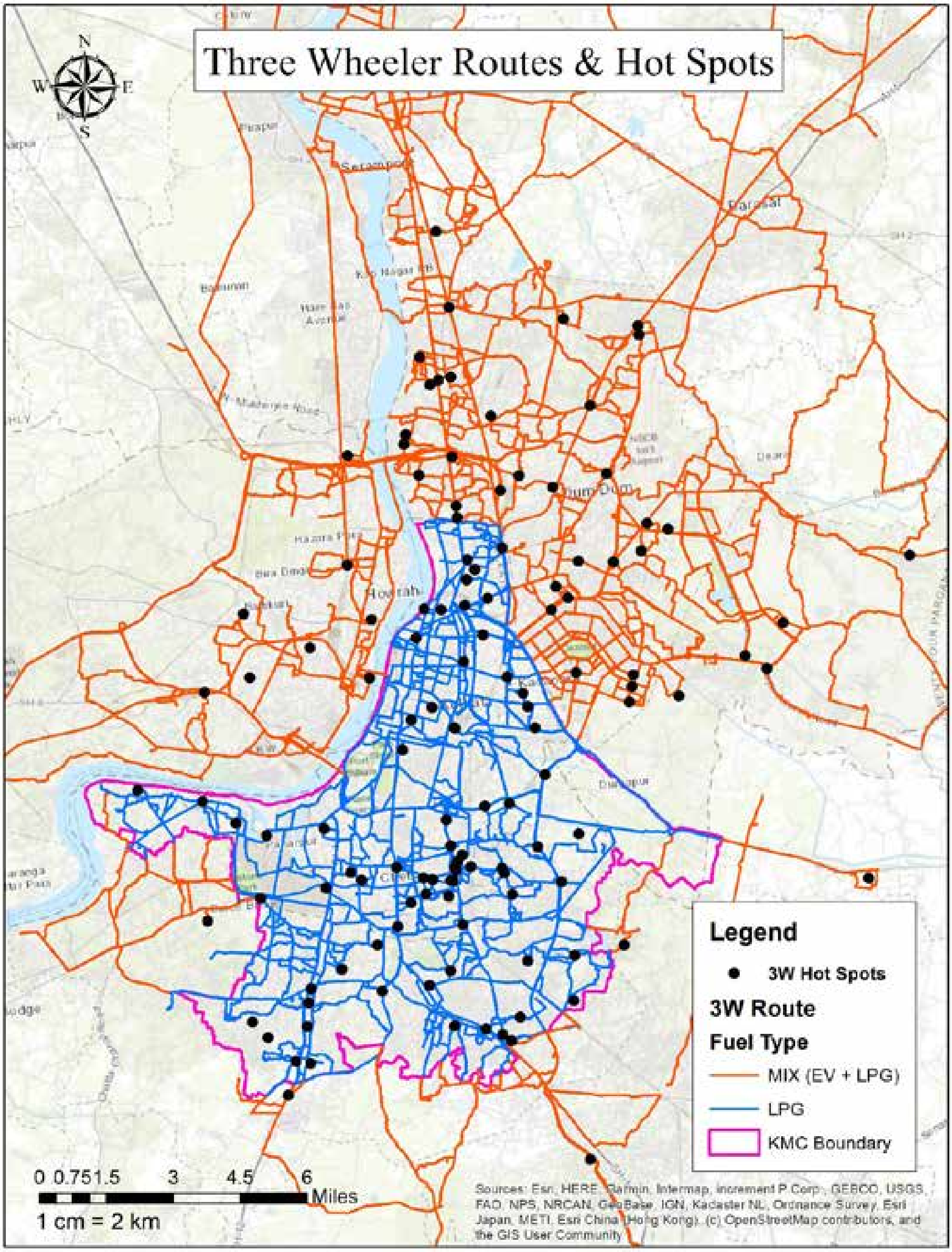


FIGURE 19: **Major locations of 3-wheelers in Kolkata**

Source: Transport Department and TERI analysis

Trams

The trams are another popular mode of transport in the city. However, with an average speed of 10 km/hr, the trams are considered to be a slow mode of transport compared to other available means. The primary reason for the significant decrease in trams is because there have been no concrete steps taken for their revival which have ultimately resulted in the upkeep of tram bogeys and the decline of ridership. The operating network for trams is presented below:

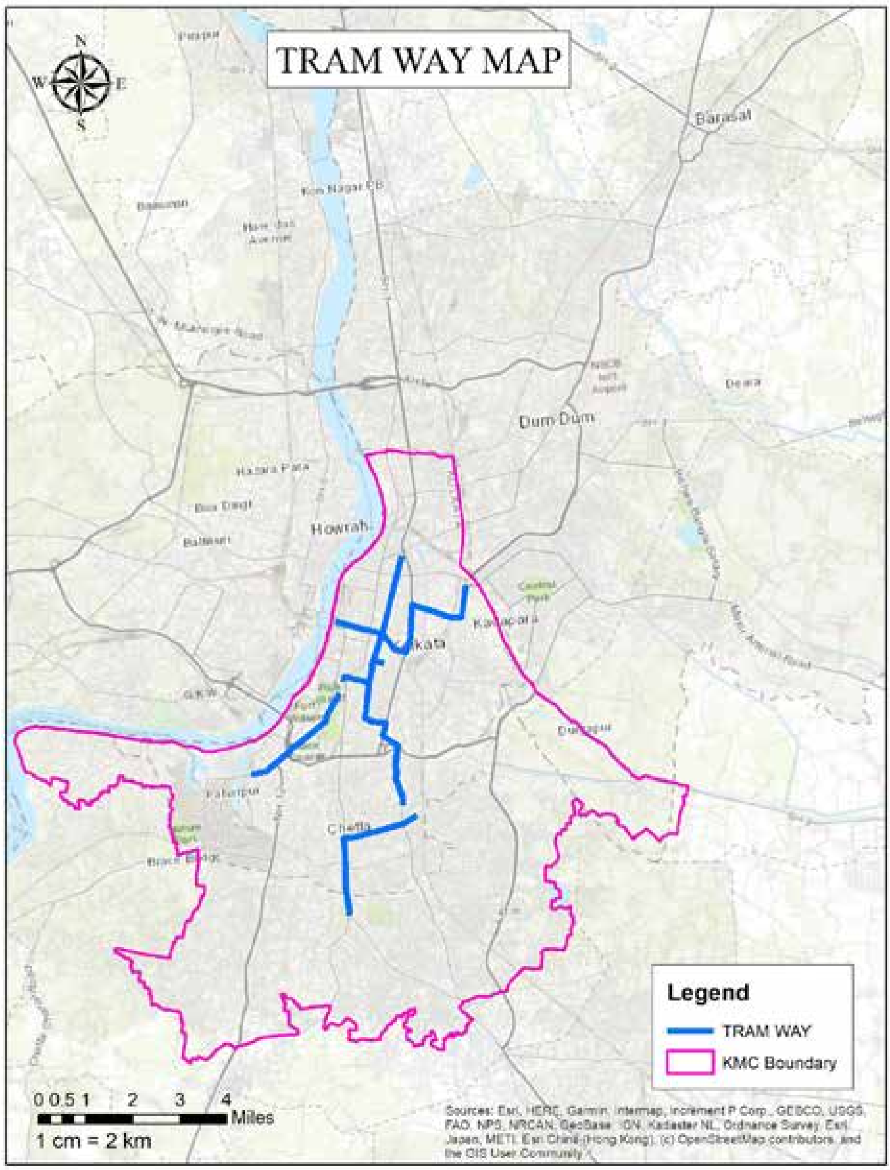
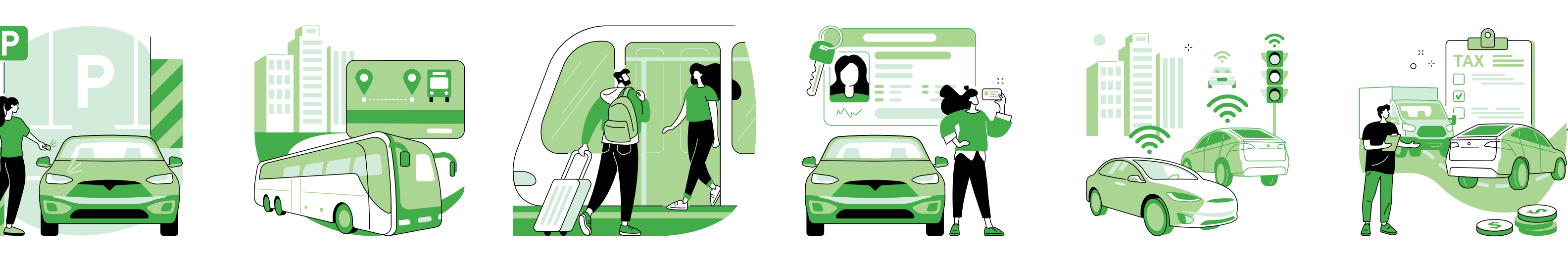


FIGURE 20: Tram routes in Kolkata

Source: WBTC



As part of this study, the revival strategy for trams is presented based on the following approaches:

» **Optimistic Approach-** Expanding the tram network by focusing on upgrading it with newer technologies, and constructing dedicated corridors.

a) **Upgrading the brake system:** By replacing mechanical and drum brakes with disc and dyanamic brakes, we can increase the operating speeds of the trams, thus help in increasing ridership.

b) **Move to Catenary-Free trams:** By using new bogeys for trams with APS (Alimentation Par le Sol) or SRS (Système de Recharge statique par le sol) technology, we can reduce the infrastructural requirements associated with the trams.

c) **Utilization of ICT:** By utilizing information & communications technology, we can enhance the traffic coordination an management between trams and other vehicles on road. Also, one card system for using different modes of transport can be viewed upon.

d) **Construct Dedicated corridors:** Dedicated routes for trams can serve as a better way to decongest the existing road traffic and also help in enhanced level of safety for the consumers.

» **Pessimistic Approach-** Closing down all the existing routes of trams i.e. 138 bogeys in holding & 13 km of operating network and looking towards other means of public transport such as metros or trolley buses.

» **Equanimous Approach-** Finding out new and efficient ways of operating the present trams in the network and serving the purpose of general passenger movement in the existing operational routes.

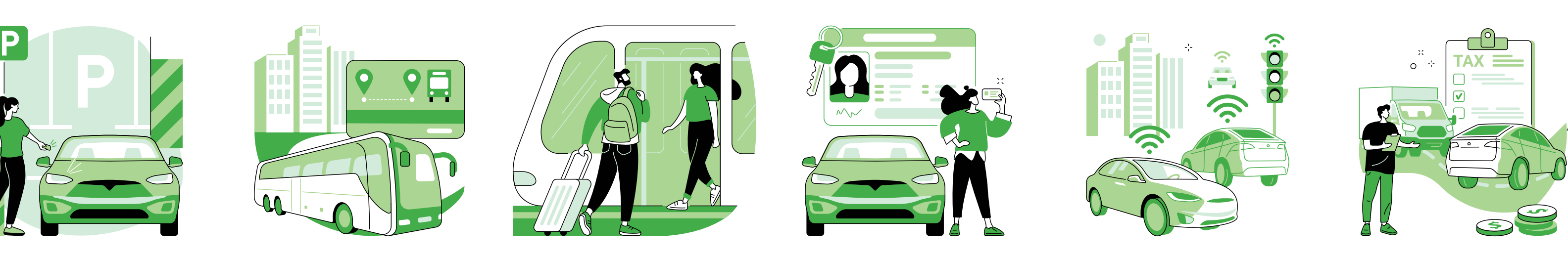
a) **Improvement in Aesthetics:** WBTC's current holding of rolling stocks is 138 which mostly consists of old-generation tram and recently improved bogeys. Remaining trams could be improved in terms of overall aesthetics, providing low floors, upgradation of exiting bogeys, and make use of the "Pathadisha" application for providing an app-based journey plan through the multi-model network of public transportation (similar to a Delhi Metro app).

b) **Priority Signalling:** Introduction of "Priority Signaling" for trams would help in maintaining the traffic and interoperability between the vehicles operating on the road. An example of strict traffic rules by the management bodies and a strong communication network between the bogeys is shown. It is observed that implementation of 100% priority signaling increases the speed by 20%. The first step towards this mechanism is to form a new set of laws such as "Right of way" which includes all vehicle segments, pedestrians, and trams as well. Installing remote sensing units in the bogeys and across the routes a few meters apart from the nearest traffic signal. Then, creating a centralized monitoring system that would control the traffic movement based on the sensor indication between roadside unit sensors and the vehicle intelligent terminal.

c) **Incentivize/De-incentivize:** In order to promote the use of trams, "Incentivization" or subsidizing the ticket prices of trams is essential. Strictness in parking by application of fines and rotations to reduce the private vehicles on the sides of the road. This would allow more free space on the roads and allow the operation of the trams in a hassle-free manner.

d) **Interconnected Networks:** An overall "Tram + Bus + Metro" network should be focused upon to interconnect among the major metro as well as bus routes, Integration of different modes of public transport with a larger focus on trams will help in expanding the network. A total of about 22 Km of Tram infrastructure is required to connect the segregated metro line networks considering that the closed routes are made operational again. But it is also suggested that the tram routes are planned in the areas which are newly developed.

From	To	Via	Distance (kms)
Behala Chourasta Metro Station	Rabindra Sarobar Metro Station	New Alipore Petrol pump, Tollygunge circular road	3.31
Ballygunge Tram Depot	Hemendra Mukherjee Metro Station	Rashbehari Avenue	3.56
Howrah Maidan	Mominpur Metro Station	Upper Foreshore Road, Avni mall, Vidyasagar setu, Hastings, Diamond Harbour Road	9.85
Maniktala Main Road	Salt Lake sector 5 Metro Station	Bengal Chemical, Salt Lake H Block, National Institute of Homeopathy	4.93



e) **Heritage Routes:** Connect all the areas of "historical/heritage importance" with trams, and make these areas pedestrian only. Interestingly, this decision has also been considered by some of the administrative authorities as the future of the trams. This is due to the assumption that the city is being forwarded towards a car-centric policy. Four routes including the current operational routes are classified as heritage routes. This includes route no 5 (Shyambazar-Esplanade) and route number 36 (Khidirpur-Esplanade). The revival of these two routes would not require much work as a layer of bitumen has to be pulled off for the tracks. One of the prime outcomes would be that it could be used for tourism purposes

f) **Selecting Appropriate Business Models:** Various business models such as "Build-Lease-Transfer" (BLT) or "Build-Transfer-Lease" (BTL) could be used in the tram networks. In this case, the asset is leased, either by the public entity to the private partner or vice-versa. The role of the private partner is to bear the cost of CAPEX and manage the operations. Performance-based incentives to the operating firm and its employees could be provided.

Table 21: Revival Strategies for trams

Sl. No.	Approach	Method	Type of Strategy	Outcomes	Expenditure
1.	Optimistic	Upgrading the Brake system	Technical	» Reduce braking distance » Better speed control » Achieve higher speeds » Increase in ridership	High
		Move to Catenary-free trams	Technical	» Avoid construction of overhead catenaries » Simultaneous operation as well as charging possible » Safe "Third rail" or Static Chargers » Regenerative braking possible	High
		Sharing of the Electrical Infrastructure	Technical	» Operation of Tram & charging of EV simultaneous » Vehicle-to-Grid options possible » Regenerative braking possible	High

Contd...

Table 21: *Contd..*

Sl. No.	Approach	Method	Type of Strategy	Outcomes	Expenditure
		Utilization of ICT	Technical + Operational	» Better coordination & traffic management » Online ticket management system » “One-card” for multi-mode transportation	Medium
		Construct Dedicated Corridors	Technical + Operational + Planning	» “Hassle-free” movement for trams » Achieve high speeds » Possibility of automatization of bogeys in future	High
2.	Equanimous	Improvement in aesthetics	Technical + Operational	Improved bogeys Increased safety Increased comfort Better ticket management	Medium
		Priority Signalling	Technical + Operational	» Better traffic control » Achieve higher speeds in trams » Increase in ridership	Medium
		Incentivize/ Deincentivize	Operational	» Less money spent on infrastructure » Promote the use of trams » Demote the use of private vehicles » More space on roads	Minimal
		Interconnected Network	Technical + Operational + Planning	» Feeder routes between Trams, Buses, and Metros » Tram Network expansion » Increase in ridership	High

Contd...

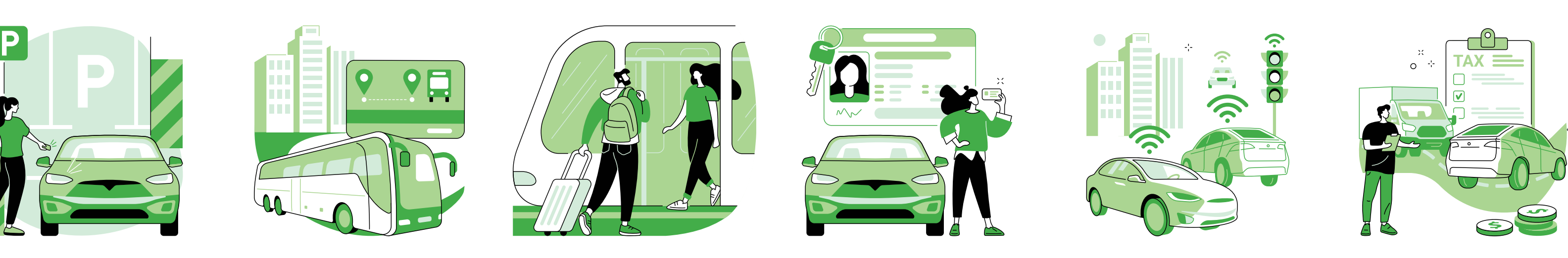


Table 21: *Contd..*

Sl. No.	Approach	Method	Type of Strategy	Outcomes	Expenditure
		Heritage Route	Operational	» Very less investment required » Focus on the tourism aspect for trams and the city as a whole	Minimal
		Selecting Appropriate Business Models	Planning	» Open the floor for private parties for operating/ manage the trams » Possibilities for investment in tram expansion	-
3.	Pessimistic	No Expansion, no approach	Planning	» Look at other modes of public transport » Use tram infrastructure for other purposes	Minimal

Ferries

In Kolkata, the ferries on the Hooghly river, which bifurcates the city, is another major mode of transport. The WBTC started its ferry services post-colonial era and it increased thereon as a means to help in traffic decongestion on the roads. All the ferries are fueled once every day at the fueling station which is located at Babughat. Details are given below:

Table 22: Ferry details under WBTC

Parameters	Values
Passenger Capacity of Cross Ferry Vessels	100, 150, 200, 250, 300, 384, 400
Passenger Capacity of Cruise vessels	30, 150, 200
Average Diesel Consumption of Cross Ferry Vessels	1300 L/day
Operational Hours per day of Cross Ferry Vessels	130 Hours

5.2 Power Demand Analysis

The cumulative power demand for EV Charging Stations at each individual location is given in Figure 21:

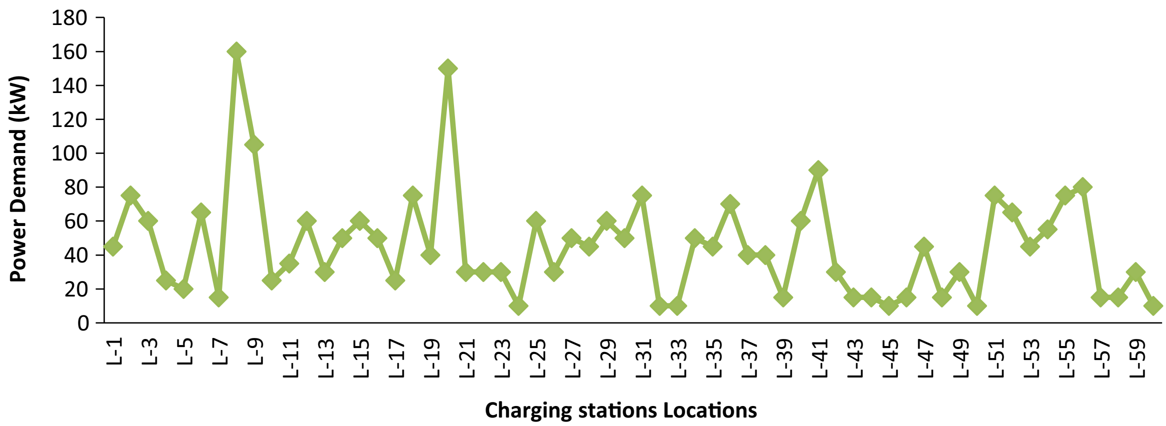


FIGURE 21: **Estimated Power Demand due to Public EV charging (60 Locations)**

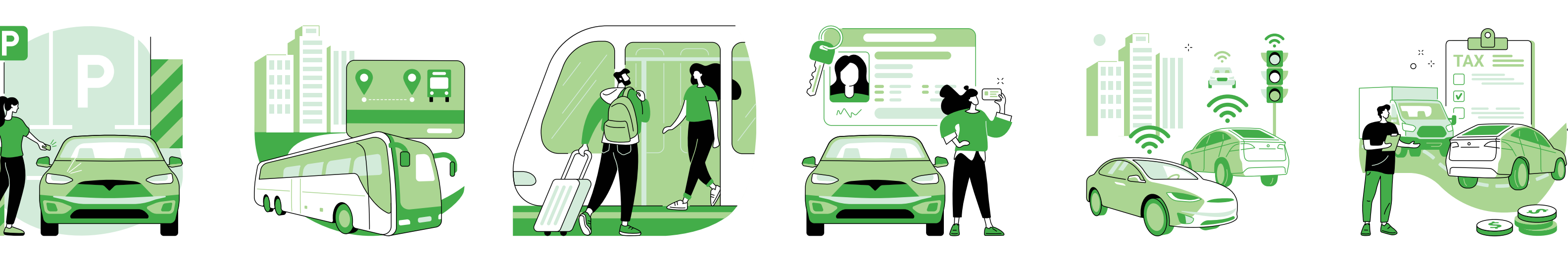
5.3 Renewable Energy Potential Assessment

During site survey, it was observed that the buildings rooftop (i.e. in case of malls, residential apartments, etc.) had the potential for installation of solar panels for the generation of electricity. The Table below shows the solar energy potential considering 6 hrs. of solar generation potential per day:

Table 23: Analysis of Solar Potential in 60 locations

Parameters	Values
Average Annual Global Horizontal Irradiance (GHI)	907 W/m^2
Rooftop area under WBTC which can be used for Solar PV installation	7.2 km^2
Total number of PV Modules required	2916261.60
Nominal Power of Solar PV installed	5400484.44 MW_p
Maximum Output Power (AC)	13 MW
Average Performance Ratio	0.865
Energy Produced per day	6609.12 MWh
Energy Produced per year	603.08 GWh

Source: PVsyst Software



5.4 Recommendations

The criteria for selection of EV charging locations and the charging technology have been described in Section 3.5. The site suitability analysis was conducted based on the area available, and vehicle density, the charging stations have been proposed. For battery swapping stations, a minimum of 15.125 m^2 is required, while for EV charging stations, the minimum area requirement is 105 m^2.

The site suitability analysis was conducted as described below.

Preliminary Survey	Site Survey and Traffic Survey
» Primary Road Network and Bus routes under WBTC were analysed and the bus routes with high frequency were shortlisted. » A circular boundary of 2km radius around the existing EV stations was created » In the vicinity of the shortlisted routes and outside the circular boundaries, the available areas such as: open area and parking facilities near commercial spaces, metro stations, malls, residential buildings, etc. were considered.	» Land area available and its accessibility was surveyed. » Road connectivity and distance from mass transit hubs and amenities were also checked. » Availability of Electrical Infrastructure near these locations. » The average number of 2-wheelers, 3-weelers, and 4-wheelers parked during the day and their duration of parking was recorded. Also the traffic density and movement of vehicles for 60 locations was recorded from 40 locations
Outcome	**Outcome**
» Mapping of 60 locations throughout the city were identified for setting up of EV Charging infrastructure for e-2W/ e-3W/e-4W	» Mapping of feasible locations for installation of EV chargers based on the e-2W, e-3W, and e-4W traffic survey.

Based on the above survey, the chargers/battery swapping systems are proposed for the identified feasible locations. They are presented in Table 24.

Table 24: Proposed Chargers for various locations

Location	Landmark near the Location	Available Area (Sq. m.)	Charger Technology Selected			
			Battery Swapping System (BSS) 30 kW	Slow Charger (10 KW)	Slow Charger (15 kW)	Fast Charger (50 kW)
L-1	CPC Ground, Hastings	7,095	1		1	
L-2	Park Street Metro Station	1,571		1	1	1
L-3	Maidan	1,834		1		1
L-4	Millenium Park	2,160		1	1	
L-5	Writers' Building	840		2		
L-6	Sealdah Station	2,184			1	1
L-7	Sapoorji	5,991			1	
L-8	HIDCO Bhawan	17,231			4	2
L-9	Ecopark	10,211	1	1	1	1
L-10	City Centre 2	3,964		1	1	
L-11	New Town Bus Stand	2,882		2	1	
L-12	Central Park Metro	4,662		6		
L-13	Dumdum Metro	95	1			
L-14	Airport	4,811				1
L-15	Baguiati	2,437	1		2	
L-16	Bangaon-Kulpi Highway	1,320				1
L-17	Star Mall, Barasat	2,104		1	1	
L-18	City Centre 1	1,240		1	1	1
L-19	Salt Lake sector 5 metro	3,113		1	2	
L-20	Dakshineshwar Temple	5,904				3

Contd...

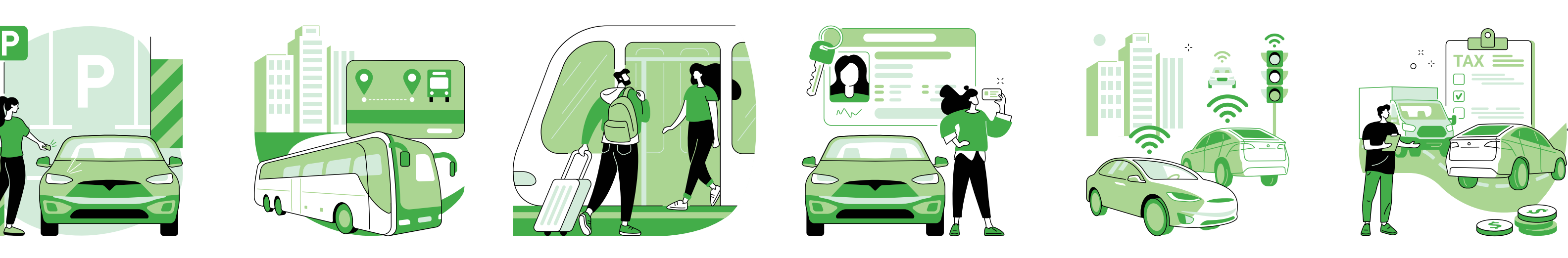


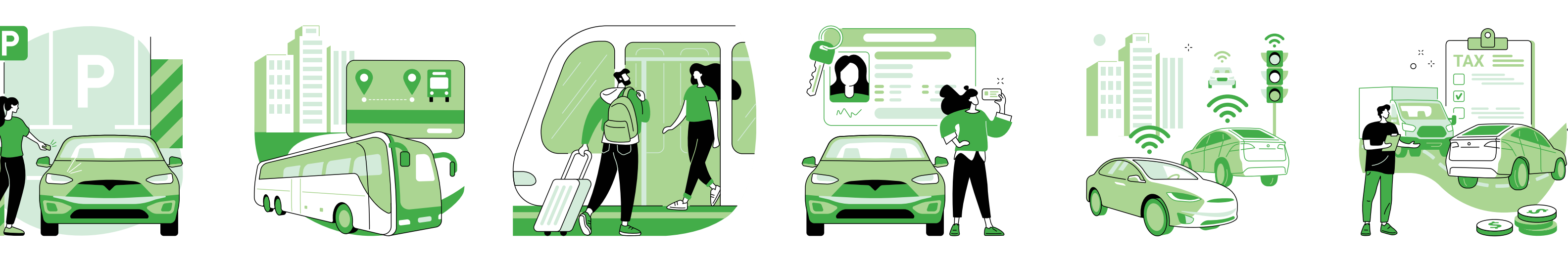
Table 24: *Contd...*

Location	Landmark near the Location	Available Area (Sq. m.)	Charger Technology Selected			
			Battery Swapping System (BSS) 30 kW	Slow Charger (10 KW)	Slow Charger (15 kW)	Fast Charger (50 kW)
L-21	Kharda Industrial Area	6,068	1			
L-22	Noapara Metro	260	1			
L-23	Mani Square	1,499		3		
L-24	Salt Lake Stadium	801		1		
L-25	Shyambazar	138	2			
L-26	Girish Park	116	1			
L-27	Science City	4,940				1
L-28	Fortis Hospital	13,614			3	
L-29	Ruby General	9,898	1		2	
L-30	Spencer’s Ruby	403				1
L-31	Metropolis Mall, Garia	794		1	1	1
L-32	New Garia Metro	4,680		1		
L-33	Kavi Nazrul Metro	2,174		1		
L-34	Dhakuria	316				1
L-35	South City mall	10,027			3	
L-36	Tollygunge	1,277	1	1	2	
L-37	Netaji Metro	3,298	1	1		
L-38	Behala Chowrasta	1,034	1	1		
L-39	Joka	343			1	
L-40	Majerhat	855		1		1
L-41	Taratala	451	3			
L-42	Garden Reach	3,206			2	
L-43	Khiderpore	2,673			1	
L-44	Ballygunge	548			1	
L-45	Lake mall	114		1		

Contd...

Table 24: *Contd...*

Location	Landmark near the Location	Available Area (Sq. m.)	Charger Technology Selected			
			Battery Swapping System (BSS) 30 kW	Slow Charger (10 KW)	Slow Charger (15 kW)	Fast Charger (50 kW)
L-46	Ladies Park, Mullick Bazar	19,487			1	
L-47	Quest Mall	724			3	
L-48	Alipore	12,192			1	
L-49	Golpark Gariahat	41	1			
L-50	Beltala	501		1		
L-51	Barasat	1,824	2		1	
L-52	Kalyani Highay	1,380			1	1
L-53	Howrah Maidan	2,411	1		1	
L-54	Avani Riverside Mall	5,127	1	1	1	
L-55	Shalimar Station	1,298		1	1	1
L-56	Howrah Station	5,565			2	1
L-57	Jadavpur University (Lake Campus)	720			1	
L-58	KPC Medical College	519			1	
L-59	Bansdroni	299	1			
L-60	Thakurpukur	2,587		1		
Total		**206344**	**22**	**34**	**48**	**20**



The locations of the sites are given in the map shown in Figure 22

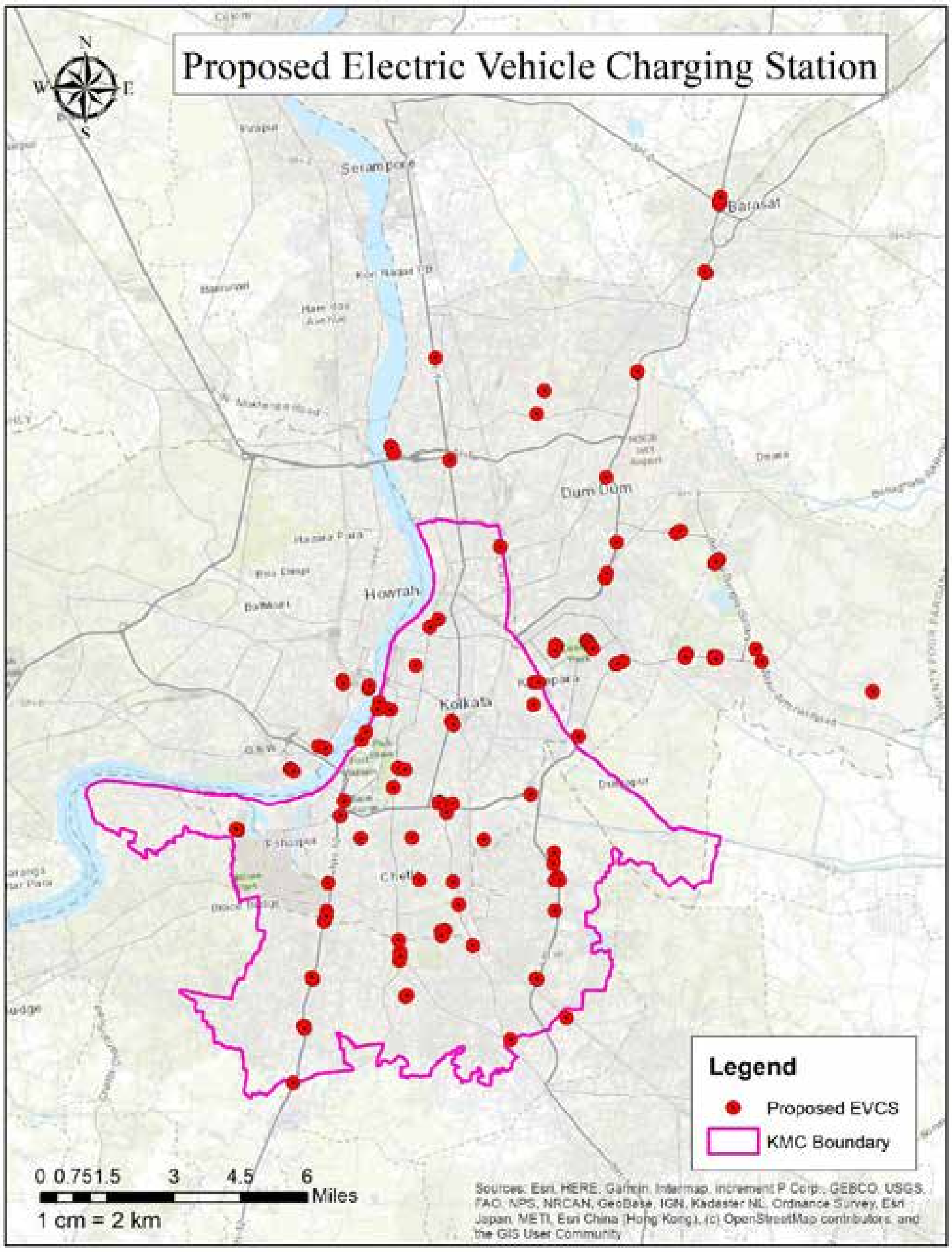


FIGURE 22: Map view of 60 locations for public EV charging

Source: TERI analysis

All sites have adequate space for installation of transformers, and for required civil works.

Considering that the Chargers will be operated for 12 hrs a day, the energy demand envisaged due to the charging stations is 32.64 MW. The breakup is given below in Figure 23.

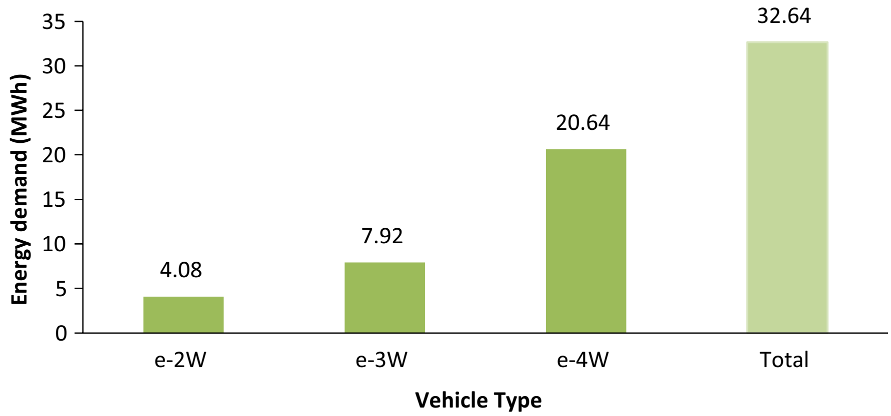
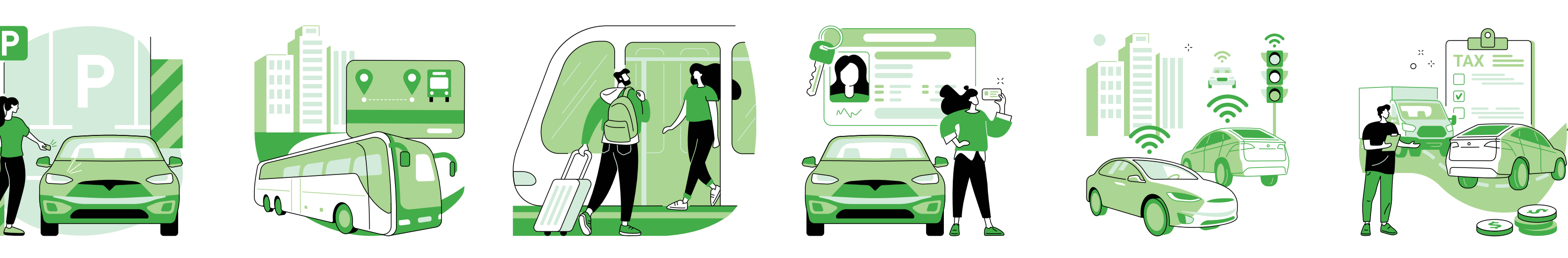


FIGURE 23: Estimated Energy Demand due to public EV charging



6. Public fleet Decarbonization Strategy for Kolkata

The city of Kolkata has six modes of transportation such as Buses, Three wheelers, Taxi, Metro, Tram, and Waterways. Current fuel mix of these modes are given below:

Mode	Fuel	Decarbonization
Buses	Diesel	Fuel Shift: Electricity partly powered through solar energy
Three Wheelers	Petrol, LPG, Diesel	Fuel Shift: Electricity partly powered through solar energy
TAXI / Four Wheelers	Petrol, LPG, Diesel	Fuel Shift: Electricity partly powered through solar energy
Metro	Electricity	Not Applicable under the current study
Tram	Electricity	Efficiency improvement
Waterways / Ferries	Diesel	Fuel Shift: Electricity partly powered through solar energy

The vehicle inventory in the city is given in detail in Chapter 1, corresponds to 820 tons of CO2e per day in the base year. The comparison of 'business as usual' scenario vs decarbonization path is given in the below figure and with the successful implementation of public transportation decarbonization over the next two decades city will be avoiding approximately 0.29 million tons of CO2e each year compared to the base year.

A detailed GHG inventory is developed for the city public transportation fleet considering the following:

» Base year as 2022

» Decarbonisation pathway 2022 to 2050

» Annual GHG savings would be 0.29 million tons of CO2e per annum.

» Total GHG emission reductions, over the next two decades accounts to 8.4 million tons of CO_2e.

In the below section, we have presented the detailed strategy / plan aiming towards the decarbonization / achieve the avoidance of 8.41 million tons of CO2 reductions from 2022 to 2050. Savings are aimed to be achieved through fuel switch / deployment of EV in various public transport options up to 2050.

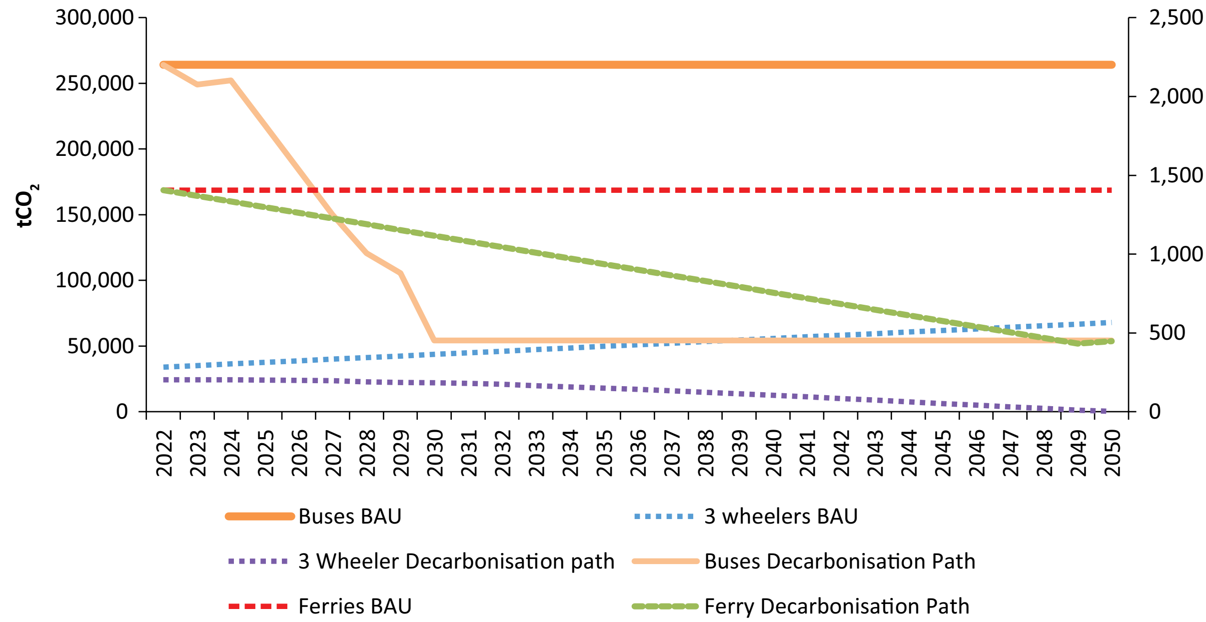
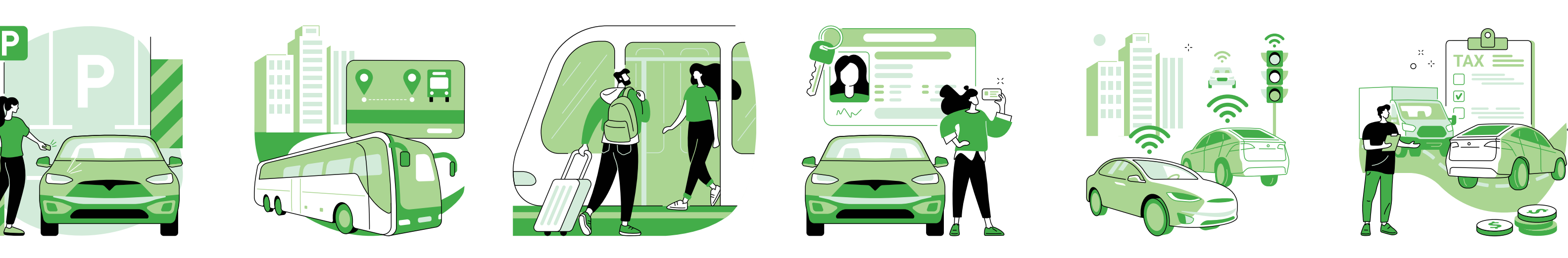


FIGURE 24: Decarbonization Pathway for Public Transport in Kolkata

Source: WBTC, Transport Department and TERI analysis

This section presents a comprehensive plan to decarbonize public transportation in Kolkata, focusing on the electrification of three key modes: three-wheelers, buses and ferries. Through engaging narratives and data-driven insights, this section highlights the transformative potential of this initiative and its significant contribution towards building a greener future for Kolkata. Deployment schedule is broadly considered under 6 phases and the time frame is given below:

Phase 1: 2022 - 2026 → **Phase 2: 2027 - 2031** → **Phase 3: 2032 - 2036** → **Phase 4: 2037 - 2041** → **Phase 5: 2042 - 2046** → **Phase 6: 2047 - 2050**



Phase 1 (2022-26)	**Three Wheelers:** the strategy invollves a shift of 4% towards the purchase of electric three wheeler alongside the retrofitting of existing 500 ICE three wheelers to electric 3W each year	**Public Buses:** deployment of 1260 electric buses during this phase and reducing the diesel buses from 1553 to 853.	Ferry: gradual retrofittment process will be followed with one ferry being converted to electric propulsion each year (4 Ferry).
Phase 2 (2026-31)	**Three Wheelers:** similar to phase 1 the shift in purchasing trend and retrofittment will remain the same	**Public Buses:** Deployment of remaining 373 Electric buses and remove all the operational diesel busses	**Ferry:** the retrofittemnt plan will continue and each year one ferry will retrofitted to electric propulsion
Phase 3 (2032-36)	**Three Wheeler:** this phase strategy involves continuation of strategy followed in phase 1, & 2, alongside retrofitting 1500 ICE 3W to electric	**Public Buses:** during this phase all the bus fleet in the city will be transitioned to electric buses. No more buses will be purchased	**Ferry:** the retrofittemnt plan will continue and each year one ferry will retrofitted to electric propulsion
Phase 4 (2037-41)	**Three Wheeler:** this phase strategy involves continuation of strategy followed in phase 1, & 2, alongside retrofitting 1500 ICE 3W to electric	**Public Buses:** during this phase all the bus fleet in the city will be transitioned to electric buses. No more buses will be purchased	**Ferry:** the retrofittemnt plan will continue and each year one ferry will retrofitted to electric propulsion
Phase 5 (2042-46)	**Three Wheeler:** this phase strategy involves continuation of strategy followed in phase 1, & 2, alongside retrofitting 1500 ICE 3W to electric	**Public Buses:** during this phase all the bus fleet in the city will be transitioned to electric buses. No more buses will be purchased	**Ferry:** the retrofittemnt plan will continue and each year one ferry will retrofitted to electric propulsion
Phase 6 (2047-50)	**Three Wheeler:** this phase strategy involves continuation of strategy followed in phase 1, & 2, alongside retrofitting 1500 ICE 3W to electric	**Public Buses:** during this phase all the bus fleet in the city will be transitioned to electric buses. No more buses will be purchased	**Ferry:** the retrofittemnt plan will continue and each year one ferry will retrofitted to electric propulsion

Under each phase we have elaborated the possible intervention which could be adopted aiming towards decarbonization path. In the subsequent sections, the detailed decarbonization of individual modes is explained.

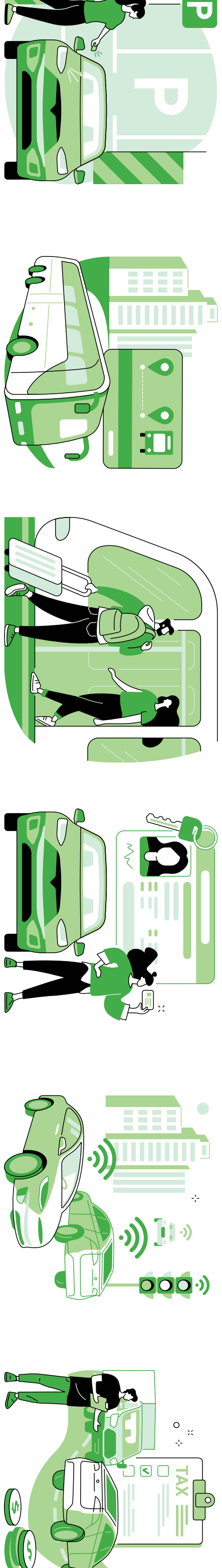


Table 25: Phase wise decarbonization plan (2022-50)

Mode		Phase	1		2	3	4	5	6
		Description	**2022**	**2026**	**2031**	**2036**	**2041**	**2046**	**2050**
Three Wheelers	BAU	Total number of vehicles	33,308	38,284	44,504	50,724	56,944	63,164	68,140
		ICE	24,376	28,144	32,854	37,564	42,274	46,984	50,752
		Electric power	8,932	10,140	11,650	13,160	14,670	16,180	17,388
		GHG Emissions (tCO_2)	33,972	1,48,024	2,12,335	2,42,675	2,73,014	3,03,353	2,64,527
		CO (in tonnes)	355	4,794	5,654	6,514	7,373	8,233	7,206
		Nox (in tonnes)	388	724	838	953	1,067	1,182	1,028
		PM (in tonnes)	36	40	45	50	55	60	51
		NH3 (in tonnes)	19	201	256	311	367	422	377
	Decarbonization Path	Total number of vehicles	33,308	38,723	43,988	49,636	56,105	62,325	67,534
		ICE	24,376	25,849	25,630	20,021	13,267	5,767	0
		Electric power	8,932	12,874	18,358	29,615	42,838	56,558	67,534
		GHG Emissions (tCO_2)	9,562	51,384	99,813	1,47,906	2,04,544	2,65,543	2,56,763
		CO (in tonnes)	355	219	1,297	2,820	4,868	8,227	1,297
		Nox (in tonnes)	388	79	315	579	815	1,017	315
		PM (in tonnes)	36	10	206	51	56	60	206
		NH3 (in tonnes)	19	48	48	322	378	422	48
Buses	BAU	Total number of vehicles	1,633	1,633	1,633	1,633	1,633	1,633	1,633
		ICE	1,553	1,553	1,553	1,553	1,553	1,553	1,553
		Electric power	80	80	80	80	80	80	80
		GHG Emissions (tCO_2)	2,64,033	10,56,131	13,20,164	13,20,164	13,20,164	13,20,164	10,56,131
		CO (in tonnes)	890	3,904	5,654	6,514	7,373	8,233	7,206
		Nox (in tonnes)	588	136	838	953	1,067	1,182	1,028
		PM (in tonnes)	8	33	45	50	55	60	51
		NH3 (in tonnes)	36	166	256	311	367	422	377

Contd...

Table 25: *Contd...*

Mode		Phase	1		2	3	4	5	6
		Description	2022	2026	2031	2036	2041	2046	2050
Buses	Decarbonization Path	Total number of vehicles	1,633	2,113	1,633	1,633	1,633	1,633	1,633
		ICE	1,553	853	0	0	0	0	0
		Electric power	80	1,260	1,633	1,633	1,633	1,633	1,633
		GHG Emissions (tCO_2)	0	1,52,505	8,35,555	10,49,028	10,49,028	10,49,028	839,222
		CO (in tonnes)	890	3,685	4,693	4,077	2,933	1,601	303
		Nox (in tonnes)	588	509	523	418	301	164	31
		PM (in tonnes)	8	23	7	0	0	0	0
		NH3 (in tonnes)	36	118	51	0	0	0	0
Ferry	BAU	Total number of vehicles	27	27	27	27	27	27	27
		ICE	27	27	27	27	27	27	27
		Electric power	0	0	0	0	0	0	0
		GHG Emissions (tCO_2)	1,406	5,623	7,028	7,028	7,028	7,028	5,623
		CO (in tonnes)	1	6	7	7	7	7	6
		Nox (in tonnes)	28	113	141	141	141	141	113
		PM (in tonnes)	1	6	7	7	7	7	7
		NH3 (in tonnes)	0	0	0	0	0	0	0
	Decarbonization Path	Total number of vehicles	27	27	27	27	27	27	27
		ICE	27	23	18	13	8	3	0
		Electric power	0	4	9	14	19	24	28
		GHG Emissions (tCO_2)	0	361	1,262	2,164	3,066	3,968	3,771
		CO (in tonnes)	1	6	7	3	0	0	0
		Nox (in tonnes)	28	102	104	78	52	26	3
		PM (in tonnes)	1	6	7	3	0	0	0
		NH3 (in tonnes)	0	0	0	0	0	0	0

Source: TERI analysis

To achieve a successful 4% transition rate towards electric three-wheelers in Kolkata, the government must undertake a comprehensive and well-coordinated approach. The following measures should be implemented to facilitate this shift effectively:

1. **Financial Incentives:** The government should substantially increase demand-side subsidies and financial incentives for the purchase of electric three-wheelers in addition to the existing ones. By doing so, the upfront cost of these vehicles will significantly reduce, making them more affordable and enticing for potential buyers. This step will play a pivotal role in encouraging a larger number of people to convert to electric three-wheelers, thus accelerating the transition process.

2. **Awareness Campaigns:** Conducting extensive and targeted awareness campaigns is crucial to educate the public about the manifold benefits of electric three-wheelers. These campaigns must emphasize the substantial reduction in harmful emissions, lower operational costs, and their positive impact on the overall air quality and climate. By effectively communicating these advantages, the government can instill confidence and enthusiasm among prospective buyers, creating a growing demand for electric three-wheelers.

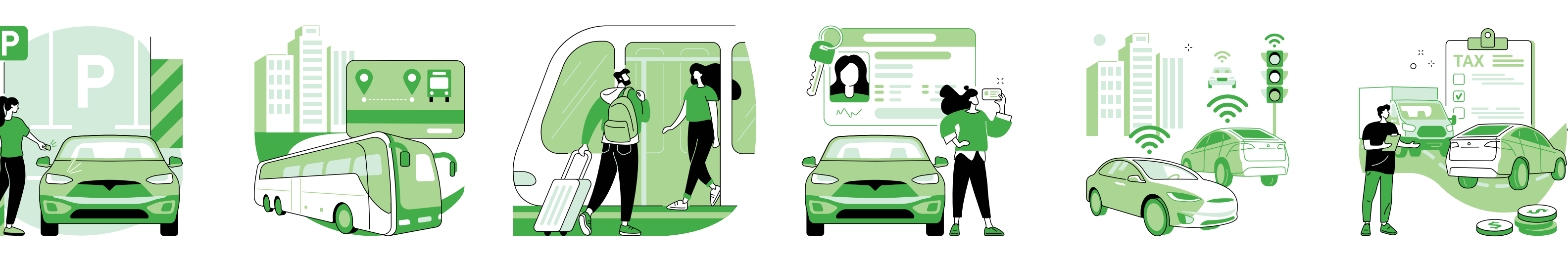
3. **Capacity Building:** Focusing on comprehensive capacity-building initiatives for vehicle manufacturers, dealers, and service providers is essential. By offering technical training, knowledge enhancement, and necessary resources, the government can ensure the availability of electric three-wheelers adhering to BIS, ARAI, and/or relevant standards in the market. A well-supported supply chain and efficient support systems will further bolster the adoption of these eco-friendly vehicles.

4. **Charging Infrastructure Development:** To address range anxiety and promote a seamless transition, the government should prioritize the establishment of robust charging infrastructure across the city. A dense network of accessible charging stations will instill confidence among drivers and fleet operators, eliminating concerns related to vehicle charging and range limitations.

5. **Collaboration with Industry Stakeholders:** Active engagement and collaboration with private sector players, non-governmental organizations (NGOs), and environmental organizations are crucial for a cohesive approach to address challenges related to electric vehicle adoption. By working together, these stakeholders can identify and resolve potential bottlenecks and streamline the transition process.

6. **Regulatory Support:** Implementing favorable policies and regulations, such as tax exemptions and simplified registration processes, will provide a strong impetus for the switch to electric three-wheelers. These measures will lower the overall cost of ownership and operation, making electric vehicles even more attractive to consumers and businesses alike.

7. **Public Transport Integration:** Collaborating with public transport authorities to integrate electric three-wheelers into their fleets can be a game-changer in accelerating adoption. Electric three-wheelers can complement existing public transportation services, providing



a greener and more sustainable option for short-distance travel. This integration will also positively influence public perception, driving further interest and demand for electric three-wheelers.

In conclusion, the successful shift towards electric three-wheelers in Kolkata hinges on a well-rounded and determined effort from the government. Such strategic interventions are vital to combat air pollution, mitigate climate change, and foster a sustainable and eco-friendly urban mobility ecosystem for a greener and cleaner future.

6.1 Pathway to Decarbonize Three-Wheelers

In Kolkata, three-wheelers play an important role in public transportation, offering convenient and accessible mode of travel for thousands of commuters. The electrification of three-wheelers in Kolkata is a vital step towards achieving a carbon-neutral public transportation system. Our deployment schedule showcases a well-planned transition that gradually eliminates the use of fossil fuel-powered ICE three-wheelers and replaces them with environmentally friendly electric vehicles. Recognizing the need for sustainable urban mobility, our project sets forth an electrification strategy that aims to replace all conventional three-wheelers with electric models by 2028.

Current Scenario and Business as usual (BAU)

As of 2022, Kolkata has 33,308 three-wheelers on the road and out of which; 19,788 are LPG autos; 4,557 are diesel autos, and 31 are CNG autos. City has 8,932 electric three wheelers' vehicles. The electrification process involves acquisition of new electric three-wheelers and to retrofitting of old three-wheelers as EV. As part of our strategy, 500 three-wheelers will be retrofitted each year till 2031 after which number will increase to 1500, ensuring a smooth and sustainable transition to electric mobility. This data provides the foundation for a strategic deployment plan that aims to gradually transition to a fully electric fleet while reducing the reliance on fossil fuel-powered vehicles.

In the baseline scenario the number of three-wheelers running on LPG, diesel, and CNG is projected to steadily increase over the years. By 2050, the baseline scenario shows a significant rise in the number of vehicles, with 42,300 running on LPG, 7,749 on diesel, and 17,388 on CNG. This substantial growth in ICE three-wheelers would have several negative implications for the city's environment and public health.

It would lead to increased emissions of greenhouse gases and air pollutants, contributing to air pollution and worsening the overall air quality in Kolkata. Additionally, the reliance on fossil fuels in the baseline scenario would perpetuate the city's dependency on non-renewable energy sources, hindering efforts to transition to cleaner and more sustainable transportation alternatives. Implementing the deployment plan for electric three-wheelers becomes crucial to mitigate these negative consequences and achieve a cleaner, greener, and more sustainable transportation system in Kolkata.

The plan's phased approach (as shown in figure 24), modal shifts, and retrofitting efforts aim to gradually replace conventional three-wheelers with electric models, reducing emissions, improving air quality, and promoting the adoption of clean energy technologies. By embracing this deployment plan, Kolkata can work towards a future where three-wheelers contribute to a carbon-neutral public transportation system, fostering a healthier and more liveable city for its residents.

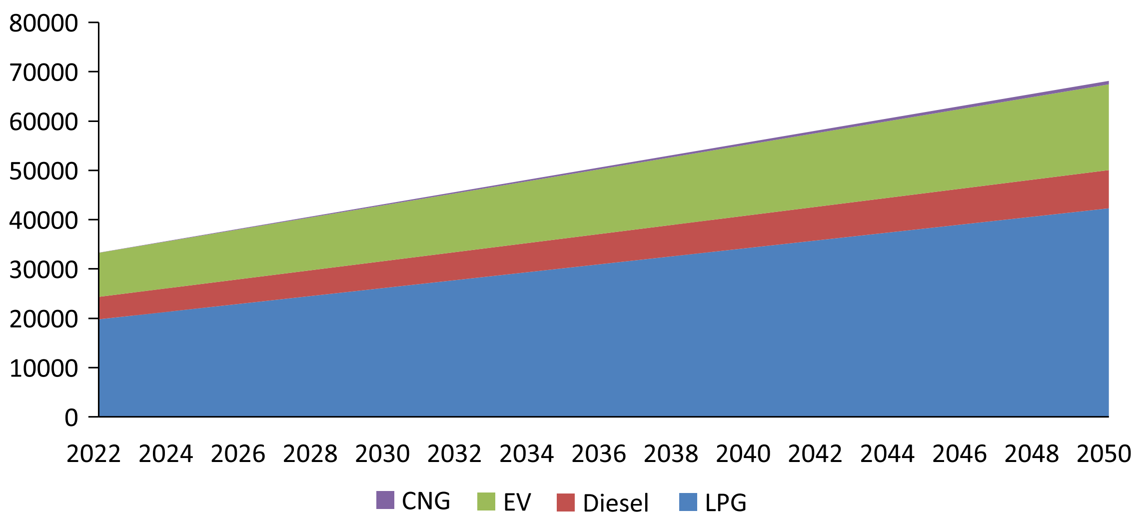
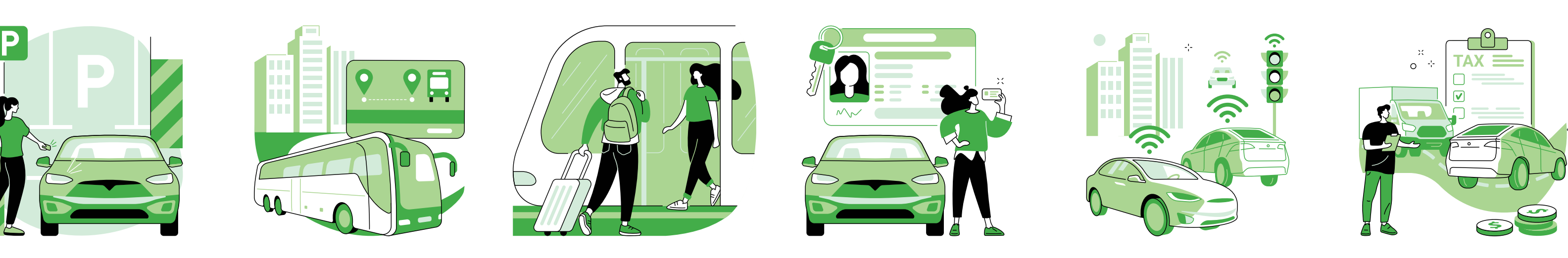


FIGURE 25: Decarbonization Plan for 3-wheelers

Source: Transport department of West Bengal and TERI analysis

Decarbonisation Plan for Three Wheelers

The electrification of three-wheelers in Kolkata is a vital step towards achieving a carbon-neutral public transportation system. Our visionary deployment schedule showcases a well-planned transition that gradually eliminates the use of fossil fuel-powered three-wheelers and replaces them with environmentally friendly electric vehicles. By 2050, Kolkata's streets will be transformed into a cleaner, greener, and more sustainable transport network.



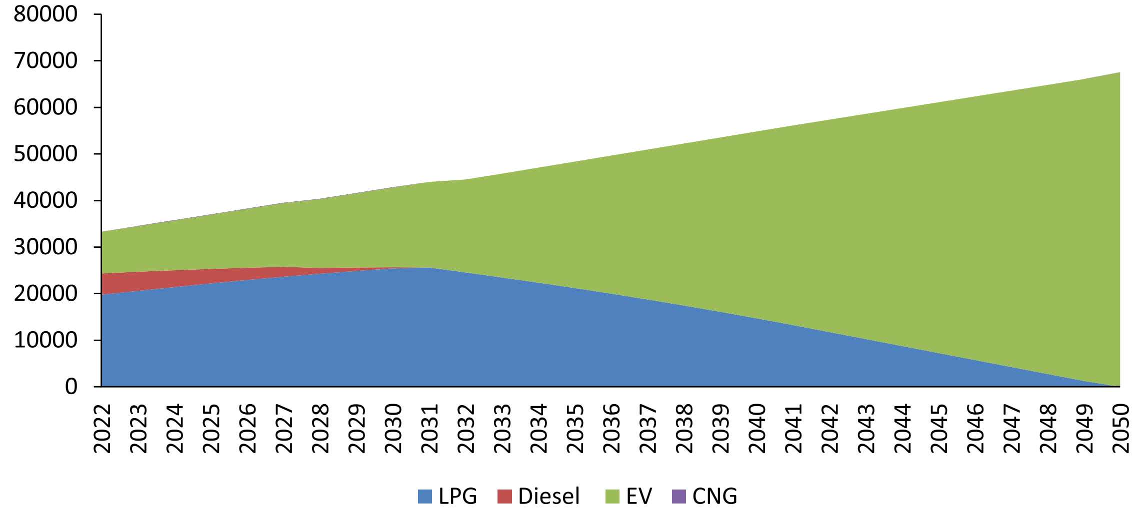


FIGURE 26: Deployment schedule of EV Three wheelers

Source: TERI analysis

GHG Emission Reduction - Decarbonisation of Three Wheelers

Figure 27 shows the GHG emissions reduction over 2022 to 2050. Based on the emissions reduction model developed, compared to the BAU by end of 2050 a total 10,35,514 tCO2e will be avoided through the deployment schedule; the Three-Wheeler Decarbonisation Pathway is given below:

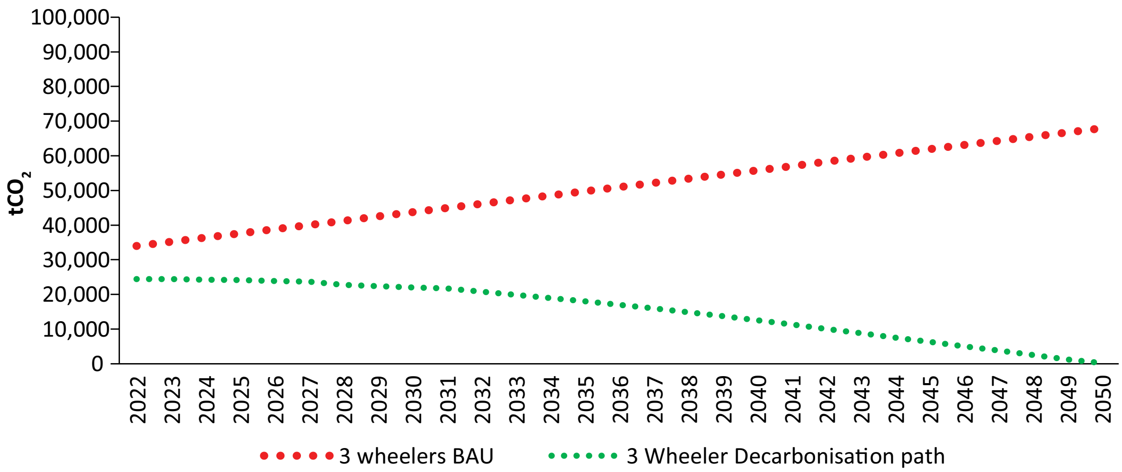


FIGURE 27: GHG Emissions Three-Wheeler BAU vs Decarbonization Pathway

Source: TERI analysis

6.2 Pathway to Decarbonize Buses

The electrification of buses stands as a cornerstone of the mission to decarbonize Kolkata's public transportation system. This section outlines a strategic pathway to replace conventional diesel buses with electric buses, revolutionizing the city's public transit and significantly reducing carbon emissions.

Current Scenario and **Business as usual (BAU)**

As of 2022, Kolkata operates a fleet of 1,553 diesel buses, contributing to air pollution and greenhouse gas emissions. WBTC has already deployed 80 electric buses on the road.

In the baseline scenario (as shown in Figure 28) the number of diesel buses remains constant throughout the projection period, with no transition to electric buses. By 2050, the baseline scenario shows a stagnant fleet of 1,553 diesel buses and 80 electric buses, resulting in a total of 1,633 buses.

Diesel buses are known for their high emissions of pollutants and greenhouse gases, contributing to air pollution and climate change. The absence of a transition to electric buses in the baseline scenario means that Kolkata would continue to rely on fossil fuels, exacerbating air quality issues and hindering efforts to achieve sustainability goals. By gradually replacing diesel buses with electric models and investing in sustainable transportation infrastructure, the city can significantly reduce emissions, improve air quality, and promote the use of renewable energy sources.

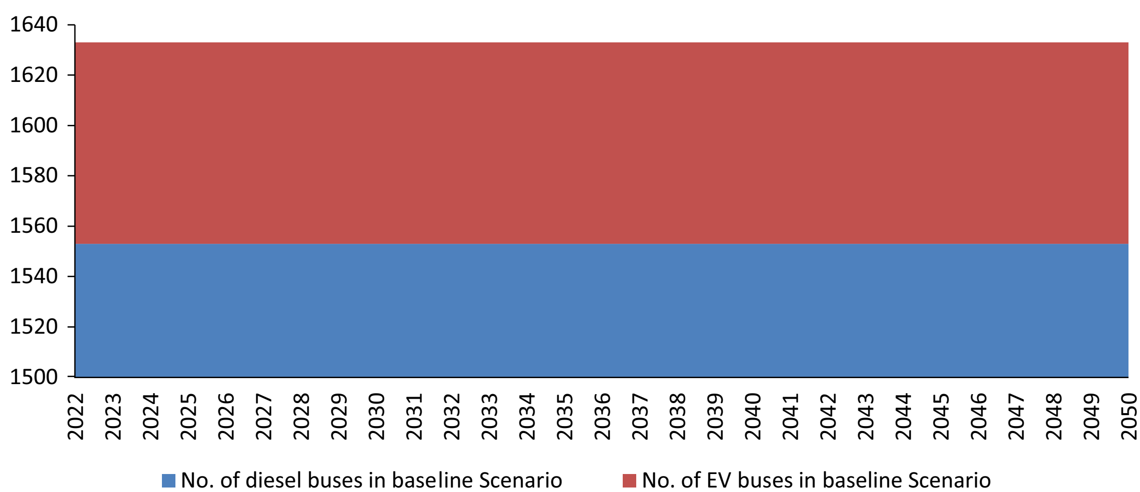
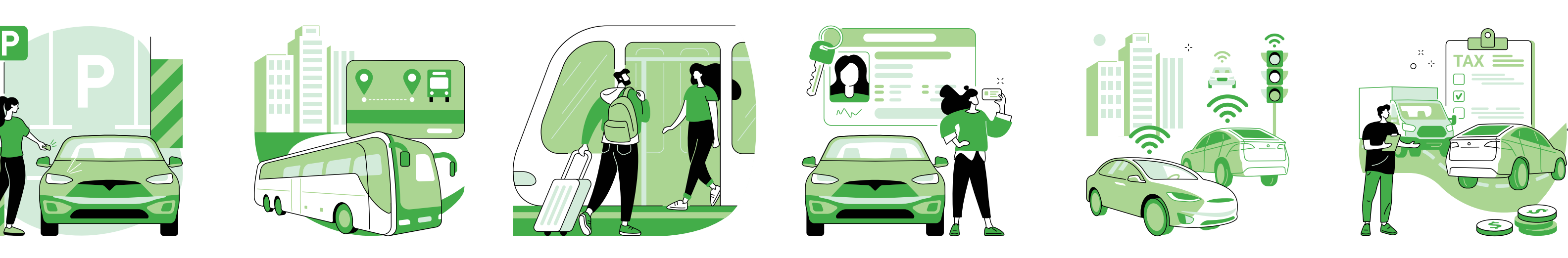


FIGURE 28: Baseline scenario projected Number of Buses (BAU)

Source: WBTC



Decarbonization Plan for Buses

Figure 29 presents the projected pathway to decarbonize Kolkata's bus fleet under WBTC, emphasizing the gradual replacement of diesel buses with electric alternatives:

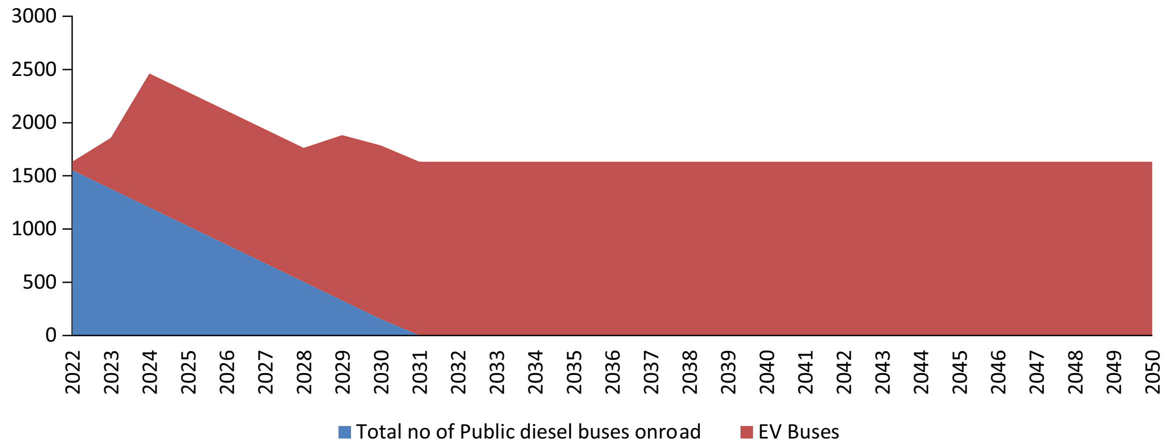


FIGURE 29: Deployment schedule of EV Buses

Source: TERI analysis

This ambitious pathway to decarbonize buses aligns with Kolkata's commitment to sustainability and cleaner air. By embracing electric buses, the city aims to improve air quality and create an eco-friendlier transportation system. The systematic replacement of diesel buses with electric alternatives showcases Kolkata's dedication to providing clean, efficient, and sustainable public transportation for its residents. Through this comprehensive plan, Kolkata is poised to become a leader in sustainable urban mobility, setting an example for other cities to follow. By transitioning to an all-electric bus fleet, the city demonstrates its commitment to a greener future and a more liveable environment for its citizens.

GHG Emission Reduction - Decarbonization of Buses

The following phases showing how the GHG emissions are reducing over a period of time and are reducing to 80% from BAU by the end of 2050 a total 49,74,366 tCO2e will be saving from following the deployment schedule for the projected period as shown in the Figure 30:

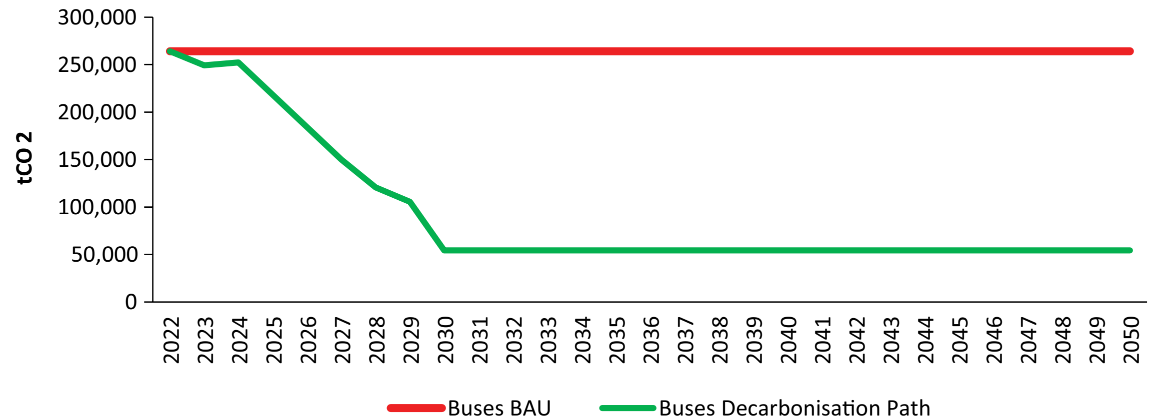


FIGURE 30: **GHG Emissions, Buses BAU vs Decarbonization Pathway**

Source: TERI analysis

6.3 Pathway to Decarbonize Ferries

The decarbonization of ferries plays a vital role in Kolkata's comprehensive plan to create a sustainable and eco-friendly public transportation system. This section outlines a strategic pathway for the transition from diesel-powered ferries to electric vessels, aiming to reduce emissions and promote a cleaner water transport network.

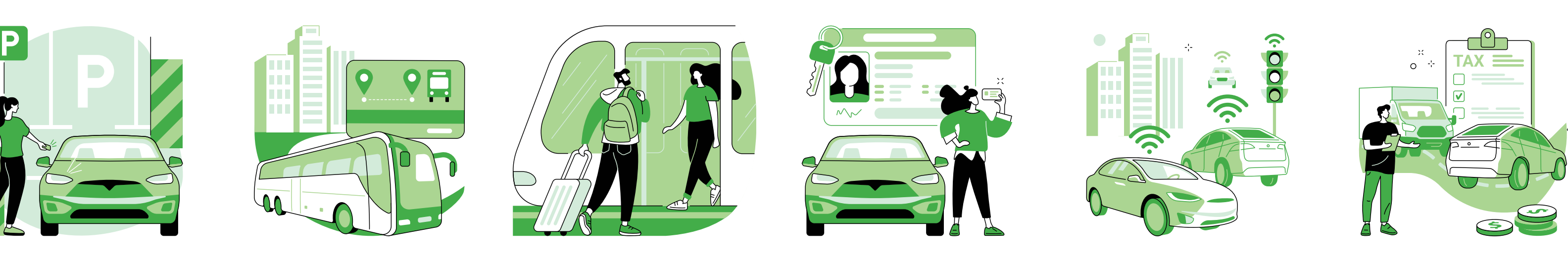
***Current Scenario and* Business as usual (BAU)**

As of 2022, Kolkata operates 27 diesel ferries, contributing to air pollution and carbon emissions. However, the retro fitment plan aims to gradually replace these diesel ferries with electric alternatives, providing a greener alternative for commuters and tourists alike, and leading to a cleaner and more sustainable water transport system.

In the baseline scenario (as shown in Figure 31) we considered the 27 diesel ferries till 2050. Diesel ferries are known for their high emissions of pollutants and their contribution to water pollution. Implementing the deployment plan for electric ferries is crucial for Kolkata to improve water quality, reduce emissions, and promote sustainable practices in the transportation sector. By gradually replacing diesel ferries with electric alternatives and investing in clean energy infrastructure, Kolkata can create a more environmentally friendly and efficient water transportation network.

Decarbonisation Plan for Ferries

The following schedule presents the projected pathway for the decarbonization of ferries, highlighting the gradual replacement of diesel ferries with electric vessels as also shown in the Figure 32:



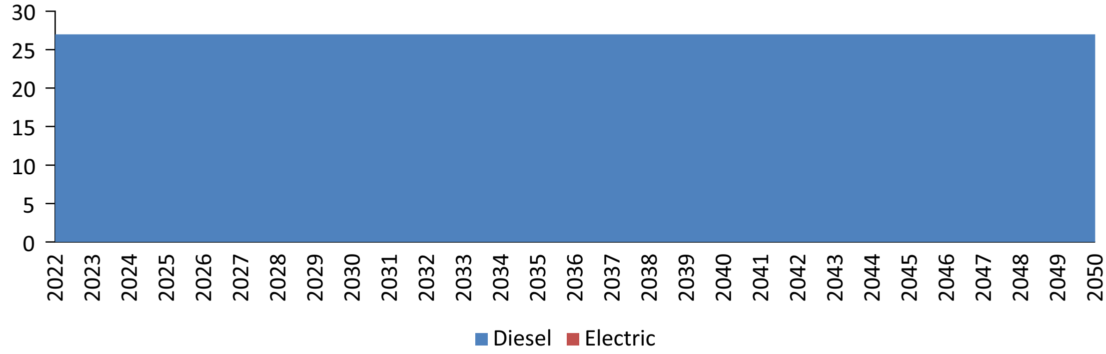


FIGURE 31: Baseline scenario projected Number of Ferry (BAU)

Source: WBTC

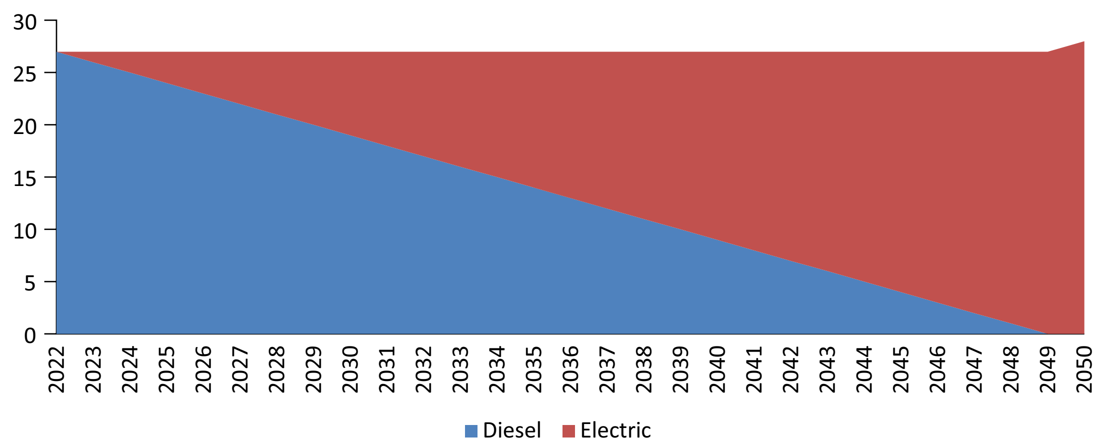


FIGURE 32: Deployment schedule of EV Ferries

Source: TERI analysis

Through a carefully planned deployment schedule, Kolkata aims to achieve a fully decarbonized ferry fleet by 2050. This ambitious initiative contributes to a cleaner and more sustainable water transport network, reducing pollution and improving the overall environmental quality of Kolkata's waterways. The gradual replacement of diesel ferries with electric vessels signifies Kolkata's commitment to sustainable development and reducing its carbon footprint. The electrification of ferries not only enhances air quality but also promotes a more enjoyable and environmentally conscious experience for commuters and tourists. By embracing the pathway to decarbonize ferries, Kolkata showcases its determination to lead in sustainable transportation solutions. The transition to electric vessels will inspire other regions and cities to prioritize eco-friendly alternatives.

GHG Emission Reduction - Decarbonisation of Ferries

The following phases showing how the GHG emissions are reducing over a period of time and are completely reducing to 100% from BAU by the end of 2050 a total 14,592 tCO2e will be saving from following the deployment schedule for the projected period as shown in the Figure 33:

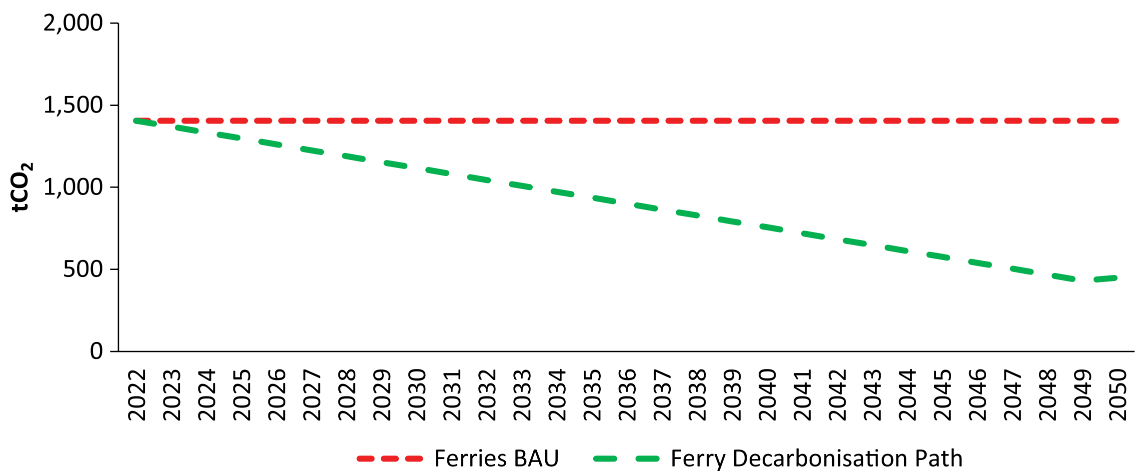


FIGURE 33: GHG Emissions, Ferry BAU vs Decarbonization Pathway

Source: TERI analysis

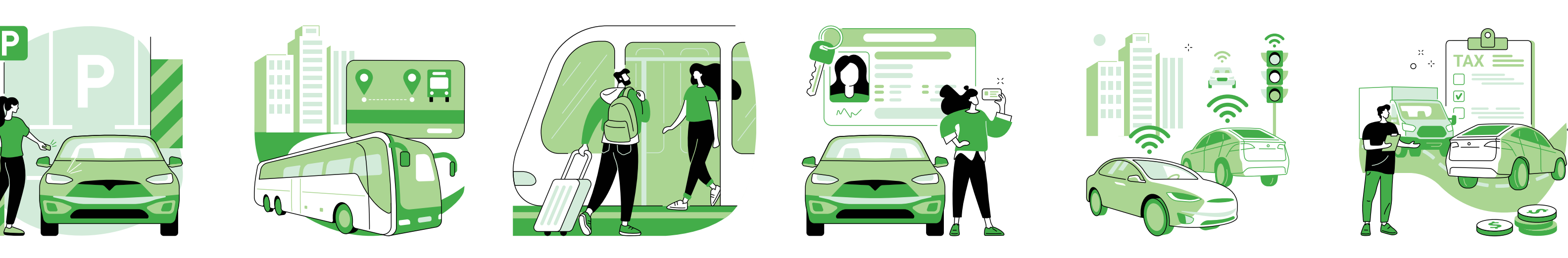
6.4 Reduction of Air Emissions through decarbonization plan

Decarbonisation has dual benefits on the macro level and we have studied the impact is Carbon Monoxide, Nitrogen Oxide, Particulate Matter, and Ammonia reduction and detailed information can be found below.

Reduction of Carbon Monoxide (CO)

Our study focuses on quantification of the reduction of carbon monoxide emissions from public transportation in Kolkata City by implementing a decarbonization plan. The Figure 34 showcases the reduction in CO emissions over the years from 2022 to 2050.

The reduction of carbon monoxide emissions will be gradual each year, with the largest reduction predicted in 2040. We can expect the CO emissions to drop by 60 tonnes, 122 tonnes, 186 tonnes, and 251 tonnes by the year 2023, 2024, 2025, and 2026, respectively. The reduction will continue to increase each year, providing a safer and cleaner environment for the residents of Kolkata.



By 2050, we can expect a total reduction of 30,159 tonnes CO emissions, which is a significant number that will contribute to the sustainable development of Kolkata City. The implementation of this decarbonization plan is crucial, as it improves the air quality in the city, reducing the health hazards associated with air pollution and climate change.

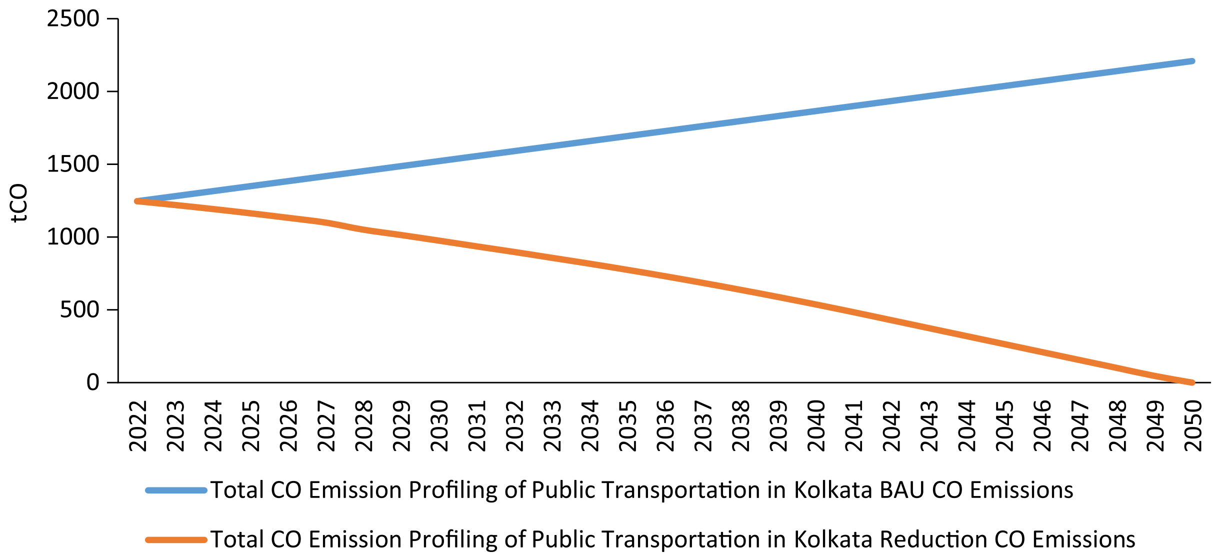


FIGURE 34: Total CO Emission Profiling of Public Transportation in Kolkata

Source: TERI analysis

Reduction of Nitrogen Oxide (NOx)

The reduction of nitrogen oxide emissions from public transportation in Kolkata City is a crucial step towards building a clean air environment. Our study estimates that adopting a decarbonization plan that involves deploying electric three-wheelers, buses, and ferry's, and retrofitting current ICE engines with electric will lead to a significant reduction of NOx emissions.

As per the calculations, its expect a total reduction of 13,472 tonnes of NOx emissions by 2050 with the decarbonization implementation(as shown in Figure 35). The reduction will be gradual over the years but will increase significantly at 2028, reduction of 324 tonnes. The implementation of this plan will also contribute towards mitigating climate change and achieving a sustainable and equitable future.

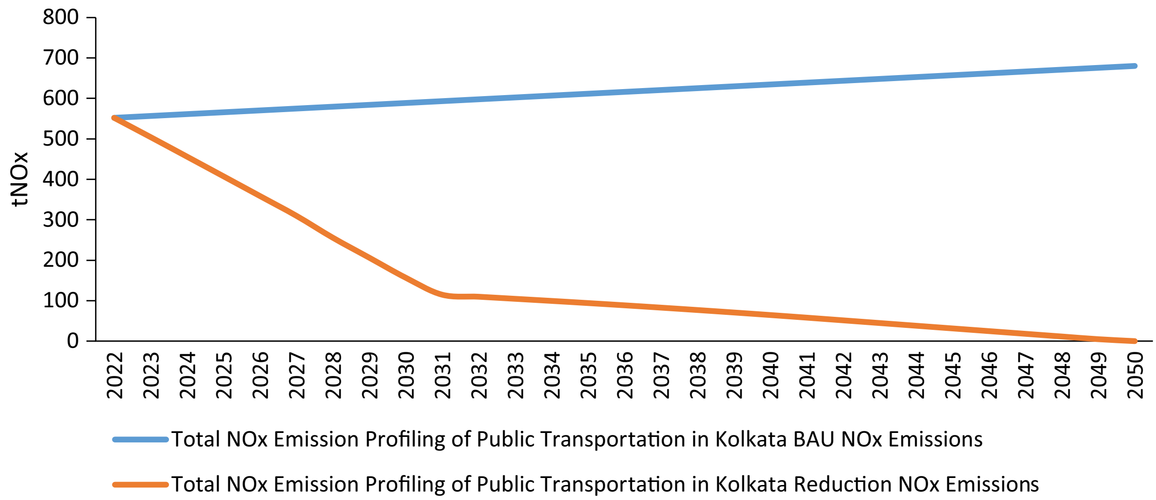


FIGURE 35: Total NOx emission profiling of Public Transportation in Kolkata

Source: TERI analysis

Reduction of Particulate Matter (PM)

Reducing particulate matter emissions from public transportation in Kolkata City is crucial for improving air quality and public health.

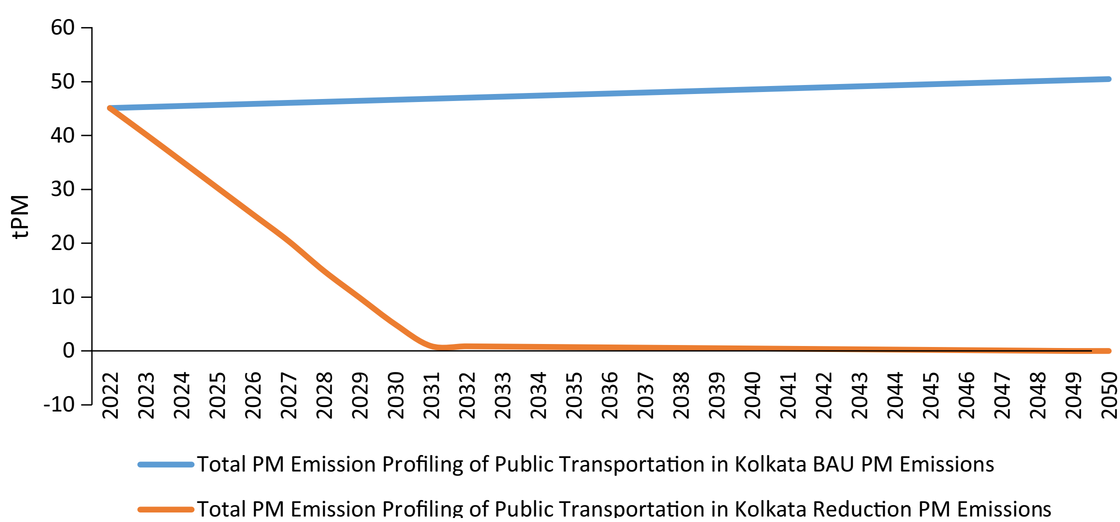
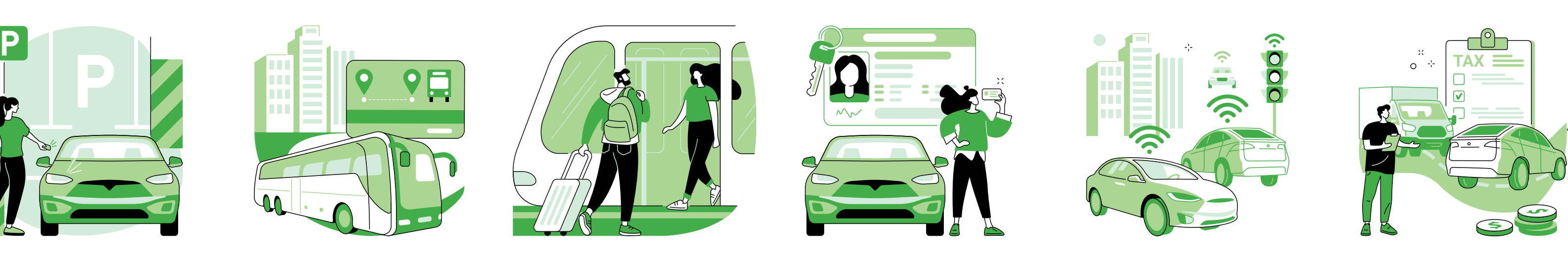


FIGURE 36: Total PM emission profiling of Public Transportation in Kolkata

Source: TERI analysis



As shown in the Figure 36, its expected a gradual reduction in PM emissions over the years and with the implementation of decarbonization, its estimated a total reduction of 1,151 tonnes of PM emissions by 2050. The reduction in PM emissions starts with 5 tonnes in 2023 and increases incrementally each year. The reduction is consistent and ranges from 10 to 50 tonnes from 2024 to 2050.

Reduction of Ammonia (NH_3)

Our study accounts the reduction of ammonia (NH_3) emissions from public transportation in Kolkata city along with GHG emission reduction. To achieve this, we have developed a decarbonization plan that involves the deployment of electric three-wheelers, buses, and ferries, as well as the retrofitting of current internal combustion engines (ICE) with electric technology. The Figure 37 showcases the estimated reduction of NH_3 emissions over the years, if our plan is adopted. Beginning in 2022, with no reduction in NH_3 emissions, we anticipate a gradual decrease in the subsequent years.

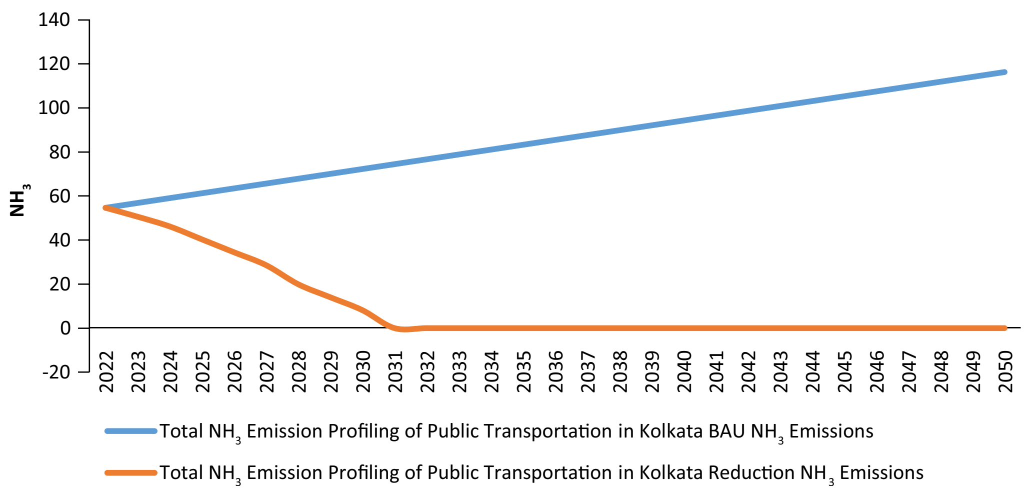


FIGURE 37: Total NH_3 emission profiling of Public Transportation in Kolkata

Source: TERI analysis

The total reduction in NH_3 emissions over the entire period is estimated to be 2,182 tonnes. This reduction signifies improvement in air quality and a positive step towards reducing pollution in the city.

Through the adoption of our study's decarbonization plan, Kolkata can pave the way for other cities to follow suit in reducing ammonia emissions and promoting sustainable transportation practices. The data provided showcases the potential positive impact our plan can have on the city, both in terms of reducing pollution and improving air quality.

6.5 Financial Requirements for Decarbonization

Decarbonization of public transportation in Kolkata over the next 28 years will require finance around INR 73,294 million. This includes:

» INR 68,249 million for deploying electric public buses

» INR 4,790 million for electric three-wheelers. The three-wheeler decarbonization plan covers swapping stations, retro fitment, and solar infrastructure development at a cost of INR 200 million, INR 2016 million, and INR 2574 million respectively.

» INR 255 million for electric ferries. The ferry decarbonization plan involves retrofitting one ferry each year with an electric engine, along with installing renewable charging stations at a total cost of INR 224 million. Additional costs include INR 14 million for chargers and INR 17 million for developing solar infrastructure for charging the electric ferries.

These investments will not only reduce greenhouse gas emissions but also improve air quality in Kolkata.

Possible funding sources

Below table presents the various funding streams, WBTC (West Bengal Transportation Corporation) can access finance to implement the suggested decarbonization plan at large scale.

Table 26: Potential Funding Sources

Funding Source	Eligibility	Requirements	Limitations	Revenue Stream	Financing Mechanism
Green Climate Fund	Open to projects that reduce greenhouse gas emissions and promote sustainable development	Application for funding	Funding available on a competitive basis	Repayment of loan with interest	Grant / Loan
National Clean Energy Fund	Open to projects that promote clean energy and reduce greenhouse gas emissions	Application for funding	Funding available on a first-come, first-served basis	Repayment of loan with interest	Grant

Contd...

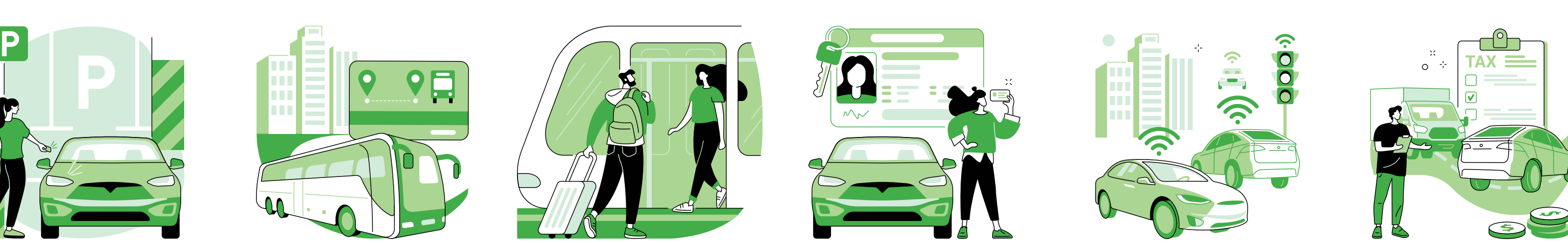


Table 26: *Contd...*

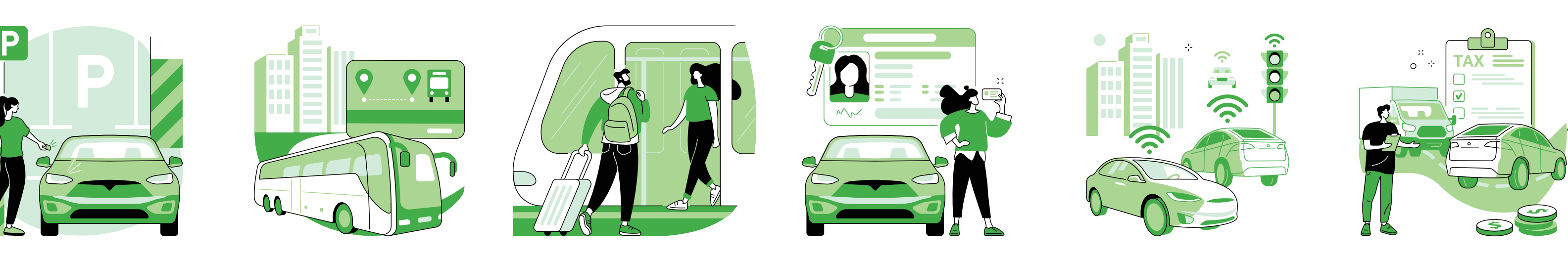
Funding Source	Eligibility	Requirements	Limitations	Revenue Stream	Financing Mechanism
Multilateral Development Banks	Open to projects that promote sustainable development	Application for loans	Loans available at concessional rates	Repayment of loan with interest	Loan
Carbon Market	Open to projects that reduce greenhouse gas emissions	Implementation of emission reduction projects and sale of certified emission reduction credits	Funding available based on the number of credits earned	Sale of certified emission reduction credits	Market-based mechanism
State Budget	Open to projects that are included in the state budget	Inclusion in the state budget	Funding available based on the availability of funds	None	Grant
Public-Private Partnerships (PPP)	Open to projects that involve collaboration between the public and private sectors	Development of PPP projects	Funding available based on the terms of the PPP agreement	Revenue-sharing or profit-sharing	Partnership
Municipal Bonds	Open to municipalities that want to raise funds for infrastructure projects	Issuance of municipal bonds	Funding available based on the demand for the bonds	Repayment of bond with interest	Bond
Impact Investing	Open to investors who want to support social and environmental causes	Investment in impact projects	Funding available based on the terms of the investment	Repayment of investment with interest or equity	Investment

Contd...

Table 26: *Contd...*

Funding Source	Eligibility	Requirements	Limitations	Revenue Stream	Financing Mechanism
State EV Policy	Open to WBTC for the purchase of electric buses and chargers	Meeting the eligibility criteria of the policy	Maximum amount of finance available is up to 50% of the cost of the vehicle or charger	Subsidies or incentives for the purchase of electric vehicles	Policy-based mechanism
Swachh Bharat Mission	Open to WBTC for the installation of waste-to-energy plants and other clean energy projects	Meeting the eligibility criteria of the mission	Maximum amount of finance available is up to 50% of the project cost	Sale of electricity or certified emission reduction credits	Mission-based mechanism
Smart Cities Mission	Open to WBTC for the implementation of smart transportation projects	Meeting the eligibility criteria of the mission	Maximum amount of finance available is up to 50% of the project cost	Sale of services or products	Mission-based mechanism
Atal Mission for Rejuvenation and Urban Transformation (AMRUT)	Open to WBTC for the construction of bus depots and other infrastructure projects	Meeting the eligibility criteria of the mission	Maximum amount of finance available is up to 50% of the project cost	None	Mission-based mechanism

The above stated policies and programs can help in generating finance for the decarbonization transportation opportunities. Overall, these policies aim to encourage and support the transition towards cleaner and more sustainable public transportation in Kolkata by providing financial support.



7. Stakeholder discussions and capacity building workshop

7.1 Creation of a State-level public e-mobility stakeholder consultation group

Kolkata was one of the first cities in India to implement an electricity-run public transport system with the introduction of the electricity-driven tram in 1902. For an easier technology shift and the integration in public transportation networks, it is suggested that WBTC officials participate in the capacity-building programme. Capacity building programme is a significant step to involve stakeholders and experts who would provide inputs to decarbonize the public transport in a more resource efficient ways and also by adopting low hanging fruits which would aim resource optimization.

Therefore, in order to decarbonize the public transport, TERI in support with WBTC has conducted various capacity building workshop for the employees of WBTC to address key challenges & gaps related to technology implementation, charging infrastructure, possible revenue streams for successful implementation of electrified vehicles transition.

This section mainly focuses on creating public transport electrification stakeholders consultation group comprising primary and secondary beneficiary of the project. The aim of stakeholder consultation and capacity building workshop were:

» Develop a comprehensive understanding of the technological, financial, and administrative measures required to transition to electric vehicles

» Address ground-level infrastructural implementation challenges and find ways to finance them

» Exchange information and best practices for electrifying public transportation, including technological, financial, and administrative measures

» Discuss cross-cutting issues like charging optimization, asset utilization, and innovative business models

» Foster stakeholder cooperation to promote sustainable public transport in Kolkata.

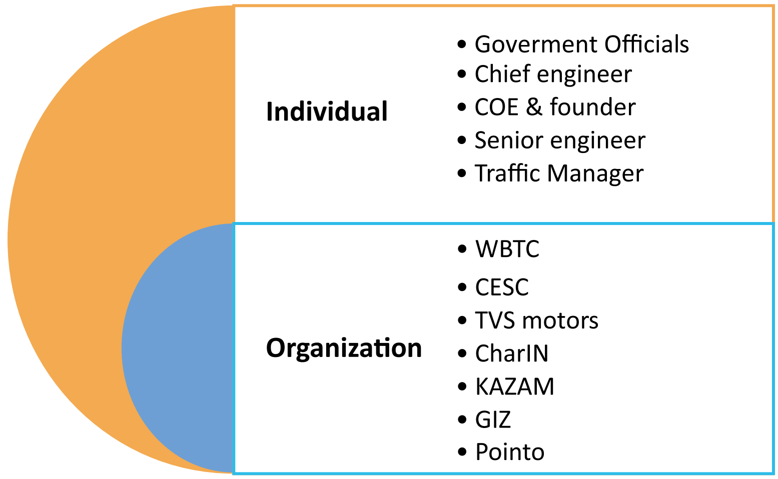


FIGURE 38: Stakeholder Mapping

7.2 EV forum-Need of accelerator cell; Nodal person in charge of WBTC

In Kolkata, WBTC and Govt. of West Bengal are responsible for the execution of the electric mobility. In order to expedite deployment, the EV Accelerator Cell/ forum is required which will function as a central entity and its necessary to develop such a EV accelerator cell/forum which will create capital, foster innovation, establish policies, bring the latest technology, establish charging infrastructure and develop grievance cell.

The major responsibilities of the EV Accelerator Cell/forum would also be to identify potential areas of collaboration between local and international firms, such as the development of battery manufacturing units, battery swapping stations and EV charging infrastructure. The cell also aims to bring together national and international investors to develop investment hubs. Also, the draft EV policy, the state of West Bengal has aided through the production of electric vehicles, battery storage, and related components, localization will increase investments.

Stakeholder consultations

As part of the study we have done multiple Stakeholder consultations and the details with respective outcome is given below:

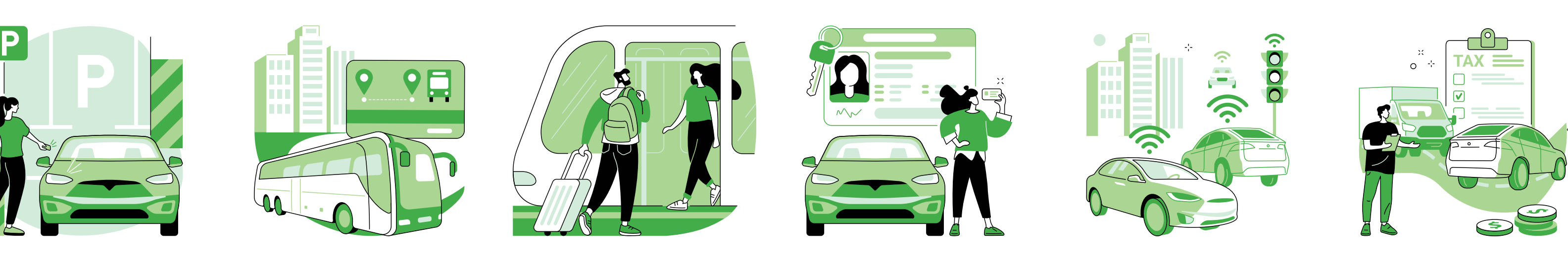


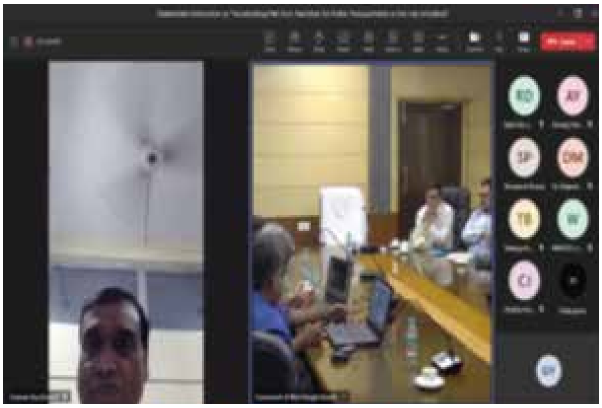
Table 27: List of Stakeholder Interactions

Date	Consultation	Outcome
6th May 2022	Inception Meeting	A broad number of strategies were formulated to accelerate net zero transition of public transportation in Kolkata. TERI has promised to engage stakeholder consultation, opt for quality-oriented approach and planned to represent West Bengal as number one in building a sustainable public transportation using clean energy
14th June, 2022	Stakeholder consultation with Tramway officials	A detailed discussion about the challenges faced by the trams, routes travelled, stoppage points, daily fares, revenue generated, daily operation and revival strategies of tramways were addressed by the tramway officials.
29th August 2022 – 2nd September 2022	Stakeholder consultation with the Ferry officials	The launching of E-vessels were proposed in the routes connecting Salkia - Fairlie – Shipping. Charging spots were identified to charge the vessels.
31st August 2022	Stakeholder consultation with the WBSEDCL	The requirement to build new charging depots at Nilgunge Depot and Shapoorji Bus Stand were emphasized during the consultation. Cost-effective bus routes were identified. Further, it was addressed that the efficiency of charging E-buses can be improved by using opportunistic charging rules.
26th September,2022	Stakeholder consultation with Navalt Solar and Electric Boats, Team Sustain and CharIN	In the stakeholder discussion the production of solar-powered boats and other electric vessels, various technological interventions relating to e-ferries, alternatives for retrofitting and costing along with financing possibilities, charging technologies, and charging optimisation were majorily discussed. The manufacturing of solar boats were proposed and various technological intervention were discussed to increase the efficiency of the E-ferries.
13th March 2023	Stakeholder engagement with CESC, TVS Motors and Map my India	The discussion were primarily based on the safety issues with charging, creating maps of charging stations for easy location, budgeting, charging methods, peak demand, and government stakeholder participation. All of the issues raised will be addressed by TERI, and it will take any additional actions necessary moving forward. Additionally, TERI has consented to include stakeholder comments in its final report

Contd...

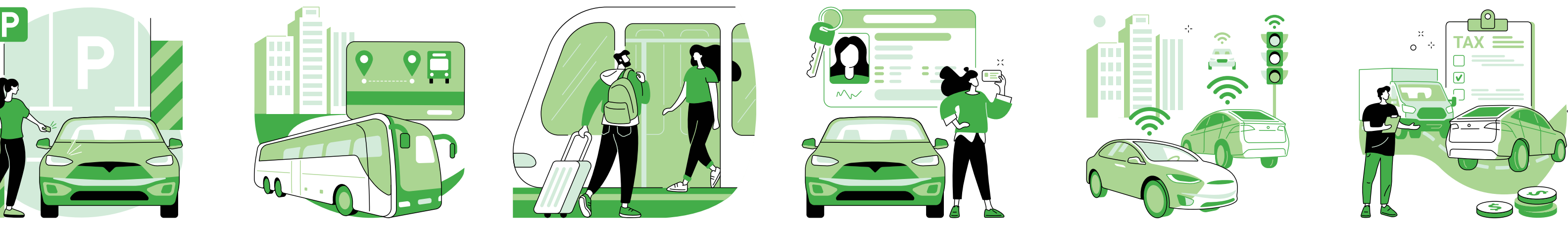
Table 27: *Contd...*

Date	Consultation	Outcome
10th May,2022	Capacity building workshop	The major outcomes were to identify the key challenges, knowledge sharing about best practises, CCS charging standard were promoted, market standardization, strategies to distribute batteries and building of charging infrastructure.



7.3 Development of learning programmes

The learning programmes were designed in such a way to give a comprehensive understanding of the charging infrastructure, mechanism of the grid integration, financial management, operational activities and asset utilization. All these components are essential to determine the manufacturing , demand and supply, market value and consumer's willingness to accept EVs as a mode of transport. Some of the learning programmes are given below in detail-



Electric vehicle charging infrastructure and its grid integration in India

The upgradation of the distribution network requires a significant amount of capital investment. DISCOMs can regain this investment through various means including securing financial support from the government, Imposing higher demand charges on customers who utilize electric vehicles (EVs) and commercial power outlets (CPOs) and Spreading the cost across the community.

The adoption of smart charging methods offers several advantages over system upgrades. It is a more cost-effective solution and does not require extensive infrastructure modifications. However, it does rely on the availability of communication and IT infrastructure. To implement time-based tariffs, tariff orders need to be in place. Additionally, investing in smart meters is necessary.

In the energy market, it is important to allow aggregated electric vehicles (EVs) to actively contribute as a load for ancillary services. This would necessitate regulatory interventions in the Indian Electricity Grid It is also beneficial for renewable energy sources to participate in sourcing EV charging. For example, the Green Open Access regulations now permit users with contracted demands of 100 kW or higher (previously it was 1 MW) to participate in the energy market.

Standardization is essential in some of the key areas within the electric vehicle ecosystem: chargers, communication, and e-roaming. In the context of chargers, it is important to establish consistent standards that ensure compatibility and seamless interaction between different charger models. Similarly, standardized communication protocols are crucial for enabling effective communication and data exchange between electric vehicles, chargers, and other components of the charging infrastructure. Lastly, interoperability in e-roaming is necessary to ensure that EV users can easily access charging networks across different locations, regardless of the service provider, through a standardized and interconnected system.

Asset utilization and operation

The requirement of an advanced platform can help in the appropriate utilization of vehicles as well as the charging infrastructure. An example of such system is the "AI-powered battery platform", (designed by 'Pointo' specifically for electric three-wheeler market). This innovative battery platform offers a comprehensive end-to-end ecosystem that includes standardization in charging infrastructure, tracking, data storage, security, and a buyback network. The working of the battery platform requires operational model which consists of various components, including a cluster-based approach, a hub and spoke design, microservices, and charging hubs. Additionally, it incorporates a cluster-type charging system and a setup for deploying batteries.

The introduction of the advanced battery platform has significant social and environmental impacts. On the social front, it brings several benefits, including:

» Income improvement: The platform reduces capital expenditure and eliminates range anxiety, resulting in increased income for drivers. Their earnings can improve from Rs. 700 to Rs. 1200.

» Medical credit shield: The platform provides all drivers with a credit shield in case of accidents, ensuring their financial protection when their lives are at risk.

» Hospicash policy: A hospicash policy is implemented, offering drivers up to Rs. 50,000 for family benefits, specifically for medical assistance. Up to four family members can benefit from this policy.

» Promoting entrepreneurship: With the high demand for battery-related services in the emerging EV segment, the hub-based model creates opportunities for revenue generation through EV services. State Bank of India (SBI) has also started providing loans through PMEGP to support the establishment of battery and EV service ventures.

» Income generation and asset creation for the long term: The platform enables income generation and asset creation in the long run through a low-maintenance vehicle and an unlimited pay-and-use battery subscription model. Within 12 months, the vehicle can become debt-free, and there are no lifetime battery advance costs.

» These social impacts contribute to the overall positive socio-economic development and well-being of drivers and their families, promoting sustainable entrepreneurship and financial security.

» The introduction of the advanced battery platform also has significant environmental impacts including:

» Reducing carbon footprint: The platform promotes the adoption of clean and green energy, thereby contributing to a reduction in carbon emissions and mitigating climate change.

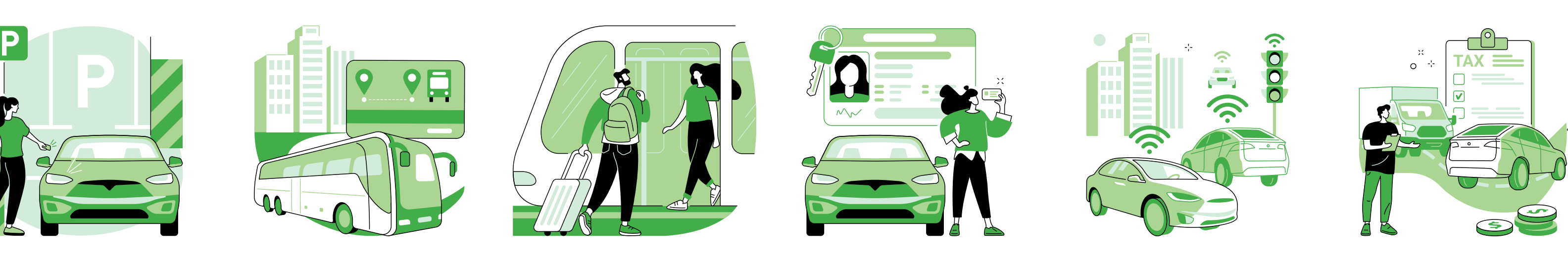
» Decreasing dependency on fossil fuels: By providing 11,000 EVs and expanding to four more states, Pointo's ESG impact aims to reduce reliance on fossil fuels for transportation, leading to a decrease in greenhouse gas emissions.

» Pollution reduction: The advanced battery platform helps in reducing both air and noise pollution. With electric vehicles replacing traditional combustion engine vehicles, harmful emissions are significantly reduced, improving air quality. Moreover, the quiet operation of electric vehicles contributes to a reduction in noise pollution.

» These environmental impacts align with sustainable practices and contribute to the overall well-being of the environment by promoting clean energy usage, reducing dependence on fossil fuels, and mitigating pollution. It is further targeting Sustainable development goal mainly the SDG 1-no poverty; SDG 7- Affordable and clean energy; SDG 8- Decent work and economic growth; SDG 9-Industry,innovation and infrastructure; SDG 11-Sustainable cities and communities.

Empowering the next level e-mobility

In India there are two categories of vehicle one is the low voltage vehicles which includes majority of 2/3 wheelers available in the Indian market, as well as previous generation fleet cars like the Mahindra eVerito and Tata Tigor. It also includes some current generation commercial vehicles such as the Tata Ace Electric. Early fleet vehicles utilized a variation of the GB/T protocol known as the "Bharat Standard." Presently, the current generation of two-wheelers and three-wheelers predominantly use proprietary protocols and connectors. While there are ongoing



efforts to standardize and harmonize these protocols, there is currently no universally accepted industry standard.

The second is the high voltage vehicles which comprises current generation passenger cars and heavy-duty commercial vehicles. All passenger cars introduced or planned for the Indian market come equipped with the CCS (Combined Charging System) protocol. Previously, buses were evenly divided between CCS and GB/T protocols. However, recent tenders from the Indian government indicate a shift towards the CCS standard, prompting some manufacturers to transition from GB/T to CCS.

Some of the recommendation for charging infra deployment are-

» Simple AC chargers can be installed to accommodate various models from different two-wheeler and three-wheeler manufacturers.

» If there is no specific recommendation for DC charging, it is advised to set up these chargers in later phase, once the manufacturers agree on a standard.

» It is advised to install EV chargers along major highways at intervals of approximately 50 kilometers. In later stages, chargers can be deployed at shorter intervals and on both sides of the road to facilitate long-distance travel.

» Additionally, it is recommended to allow the installation of AC or DC chargers in locations such as offices, malls, theaters, airports, and metro stations.

» Dedicated taxi chargers should be installed at high volume transit points such as metro stations, airports, and railway stations.

» To support this transition, BIS (Bureau of Indian Standards) approved chargers should be installed at bus depots, allowing open charging for operators. The cost of these chargers can be recovered through an increase in the per kilowatt-hour (KWh) charge.

» It is suggested to engage in discussions with State Transport Undertakings (STUs) and private operators to identify high viability routes with heavy traffic and adequate range. Particularly, intercity operations within the range of 100-200 km, such as Chennai-Pondicherry, Mumbai-Pune, etc., should be prioritized.

Financial planning for Electric bus Transition

The transition to electric buses necessitates a significant change in financial planning due to the shift in the business model and cost structure. The cost structure of bus operations has undergone a fundamental transformation, becoming capital-intensive and operationally light. Despite the availability of incentives from both the Central and State Governments, the lack of access to long-term funding and financing remains a significant barrier for bus agencies looking to transition to electric buses. As a result, international financial institutions (IFIs) have become more attractive sources of funding for electric bus projects. This presents a golden opportunity for State Transport Undertakings (STUs) to attract external capital investment for e-bus fleets and the development of charging infrastructure, in addition to their traditional budgetary allocations.

To evaluate the costs and benefits of electric vehicles (EVs), a financial model can be created. This model assesses the capital expenditure (CAPEX) and operating expenditure (OPEX) associated with EV implementation. The CAPEX cost factors include the cost of the bus itself, charging infrastructure expenses, licensing, registration, and insurance costs, depreciation, and salvage value. On the other hand, the OPEX cost factors encompass staff expenses, fuel costs, and maintenance costs. By analyzing these input parameters, the financial model provides insights into the overall cost and potential cost savings resulting from the implementation of EVs.

RE based charging infrastructure in bus depot

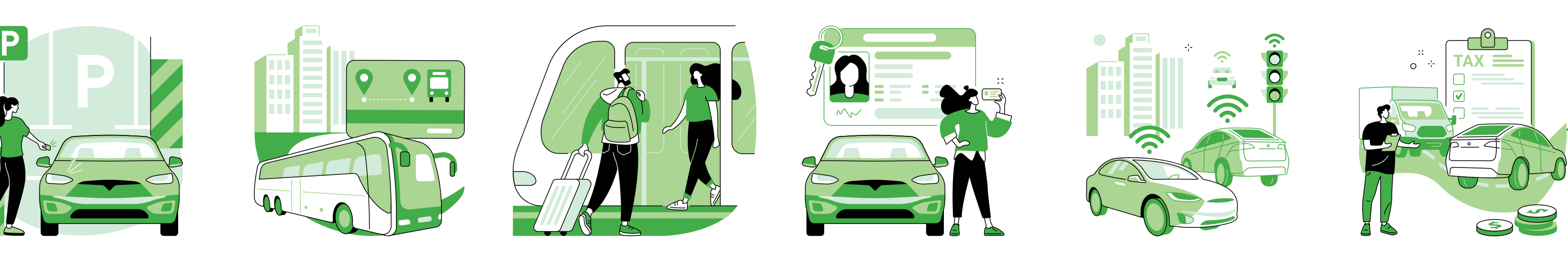
a) Decentralized Solar Systems in Bus Depots:

- Implementing solar power systems within bus depots in a decentralized manner.
- Installing solar panels on the depot premises to generate renewable energy locally.
- This allows bus depots to meet their energy needs using clean and sustainable solar power.

b) Solar Farms - Exporting Energy from Remote Locations:

- Establishing solar farms in distant locations to generate renewable energy.
- Harnessing solar power through large-scale solar installations.
- The energy produced at these solar farms can be transmitted and exported to other areas or the grid, contributing to the overall renewable energy supply.

Some of the other low hanging fruits for charging electric vehicles includes-Utilization of the Rooftop of the bus depot to have a larger coverage of solar panels. The number of buses for charging determines the capacity and scalability of the charging infrastructure. The charging time for buses can be in the morning or evening it influences the scheduling and utilization of the charging.



8. Conclusions

The study analyses the decarbonization of public transportation in the city of Kolkata and further studies the energy demand, power requirement, site suitability of public charging infrastructure for various vehicle segments. For e-Buses, the study for energy demand due to increase in buses is studied. Also, the renewable energy (specifically solar) potential for generation of electricity, along with the decarbonization roadmap for public transport is presented.

The summary of recommendations is given below;

For e-buses

Case-1 A (Uncontrolled Charging)	Case-1 B (Controlled Charging)	Case-2 (Optimized Charging)
» Charger utilization is between Case 1B and Case 2, i.e. . » The scheduling is difficult as charger utilization is dependent on random bus charging schedule. » Redundant chargers can be made available only if charger schedule is optimized.	» Charger utilization is minimum (34%) in this case. » Chargers are operated intermittently in the day and night. » By optimum scheduling, a charger can be islanded for maintenance.	» Charger utilization is maximum (58%) in this case. » Chargers are operated intermittently during the day however they run continuously at night. » There are no redundant chargers available hence the charger under maintenance may impact the overall charging schedule of the depot.

For e-2W, e-3W and e-4W

It is recommended that cumulatively 124 chargers may be installed in the city of Kolkata. This will lead to an energy demand of 32.64 MW.

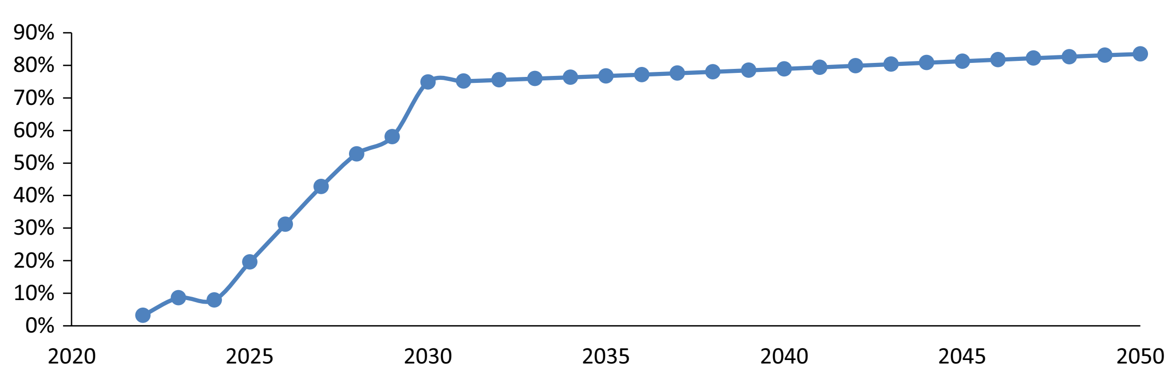
Type of vehicle	Proposed Charger Type	Proposed Charger rating	Number of Chargers	Power Demand (kW)	Hours of operation of charger	Energy Demand (kWh)
e-2W	Slow Charging only	10kW	34	340	12	4080
e-3W	BSS Only	30kW	22	660	12	7920
e-4W	Slow Charging	15kW (AC Type 2)	48	720	12	8640
	Fast Charging	50 kW (DC Type)	20	1000	12	12000
Total			**124**	**2720**		**32640**

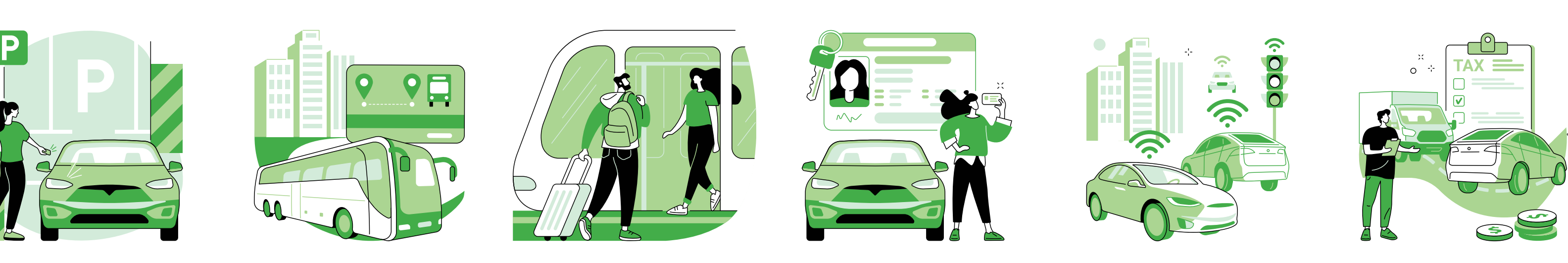
For renewable energy potential

The potential for solar generation was analyzed and it was found that at bus depots, the solar generation potential is 5.70 GWh per annum. For other charging stations' locations (for e-2W, e-3W and e-4W segment), the solar generation potential is based on the rooftops available close to the charging station site. It is calculated to be 603 GWh per annum.

Based on the decarbonization model developed for the public transportation for the modes such as Buses, Ferries, three wheelers the overall emission reductions over the period from 2022 to 2050 would be around 6 million tons of CO_2 with 800 tons of CO_2e per day. Model is developed considering 2022 as base year and decarbonization trend is analyzed up to 2050. Detailed model is developed with consideration related to the 100% conversion of public fleet to EV and the decarbonization pathway is given below. Under the category of buses decarbonization we have analyzed the impact specific to WBTC owned Buses only and private buses are not part of the scope of this study.

% Reduction of Emissions form Public Transportation over the years





In addition to the CO2e avoidance estimation, air quality impacts are also analyzed specific to Carbon Monoxide, Nitrogen Oxide, PM and Ammonia avoidance. Implementation of the decarbonization requires approximately 73,294 Million INR for both CAPEX and OPEX investment and the detailed costing for each mode is presented below. Costing calculations are made on the present scenario.

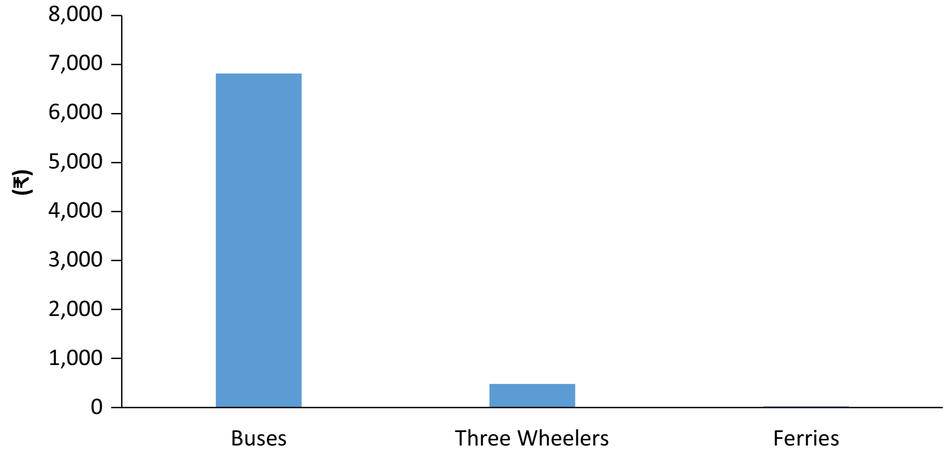
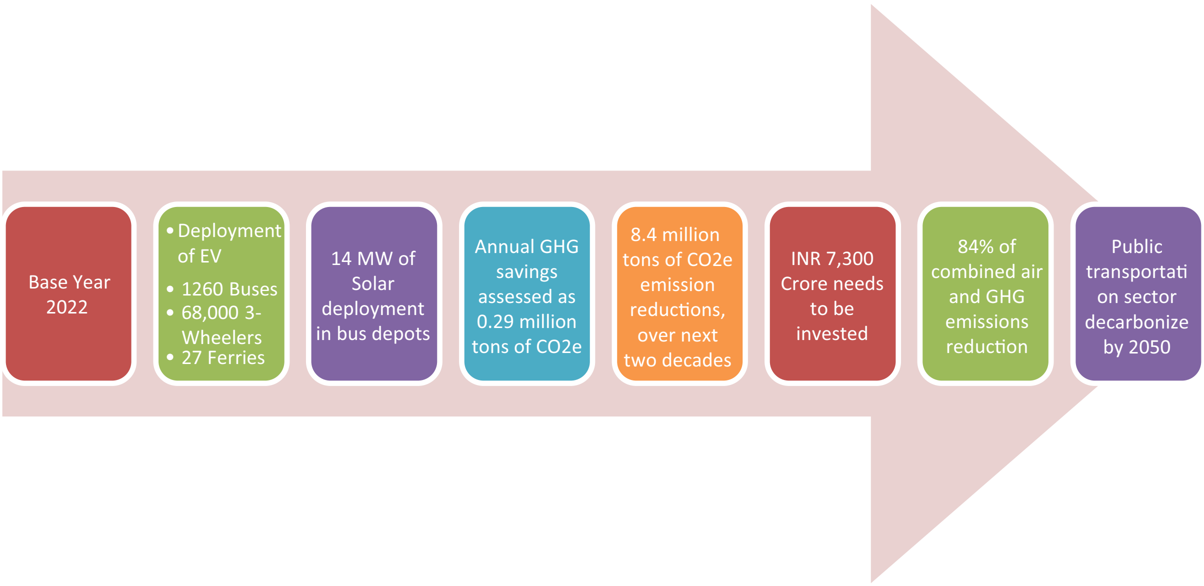


FIGURE 39: **Financial Requirements for Decarbonization**

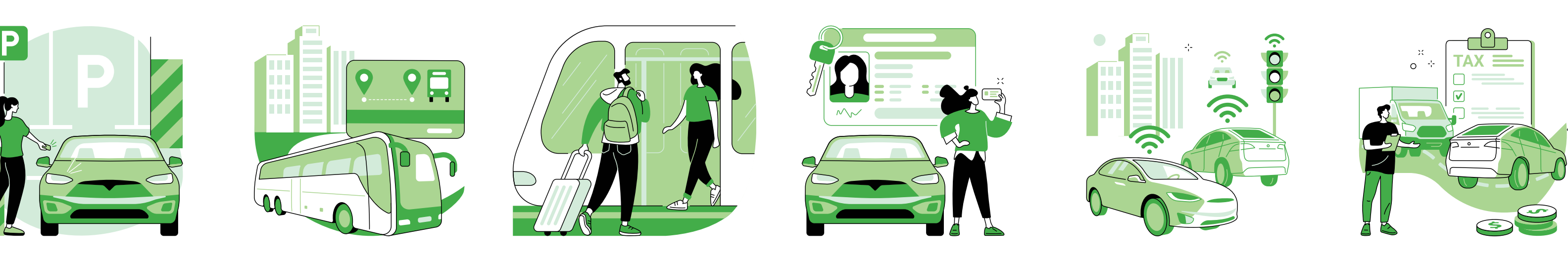
An important aspect related to the implementation of a decarbonization plan depends on various stakeholders' capacity development. As part of the study, we have conducted a series of workshops and focus group discussions with government officials, technology suppliers, and macro-level state-level public groups suggested to implement the decarbonization strategy.



Annexures

1. List of Diesel Buses under WBTC

Manufacturer Name	Type/ Details	Emission Standards	Number of Buses			Total	Mileage (km/L)		
			WBCSTC	WBCTC	WBSTC		WBCSTC	WBCTC	WBSTC
Volvo	Volvo AC	BS-IV	63			63	1.53		
	AC 9400	BS-IV		15		15		3.21	
	AC 8400	BS-III			38	38			1.7
	AC 9100	BS-III		14		14		3.15	
TATA	Non-AC 1623	BS-IV	120			120	1.8		
	Non-AC 1613	BS-IV	45	118	49	212	2.12	2.8	2.5
	Non-AC 1512	BS-III	33	171	50	254	2.22	3.04	2.84
	Non-AC 712	BS-III	4			4	3.5		
	AC 712 ES	BS-III	10			10	2.52		
	1618	BS-III		14		14		2.4	
	AC 1624	BS-III			24	24			1.54
	AC 1510 T	BS-II		8	8	16		3.2	2.27
EICHER	Non-AC 10.9	BS-IV	20	15	4	39			
	Non-AC 20.15	BS-III		35		35			
	Non-AC 10.75	BS-III		20		20			
Al Lynx	AC	BS-IV	38			38			
SML/ Mahindra	Cosmo	BS-IV	16	10		26			



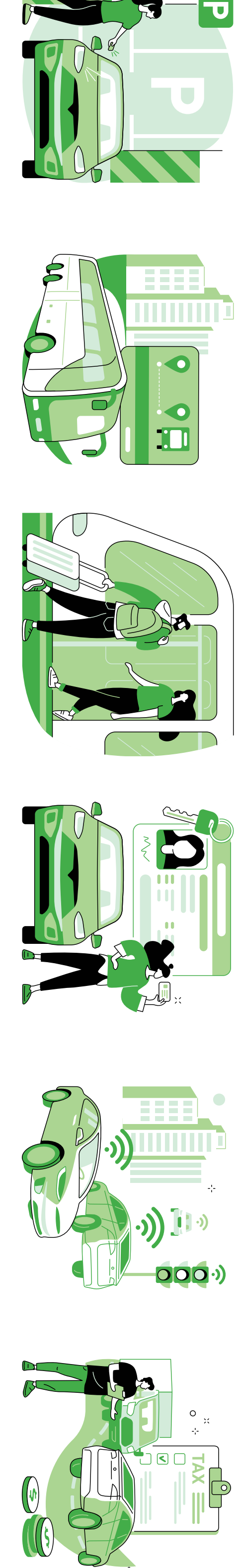
Manufacturer Name	Type/ Details	Emission Standards	Number of Buses			Total	Mileage (km/L)		
			WBCSTC	WBCTC	WBSTC		WBCSTC	WBCTC	WBSTC
Ashok Leyland	Jan bus AC ALFBV8/1	BS-IV	169			169			
	Jan bus AC ALFBV8/2	BS-IV	277			277			
	Non-AC ALFBV1/188	BS-III	11			11			
	Non-AC ALFBV2/51	BS-III	15			15			
	Non-AC 1/37	BS-III	15			15			
	Non-AC 2/48	BS-III		43	15	58			
	4-/85	BS-III		24	11	35			
	4-/86	BS-III			5	5			
	AC 4/88	BS-II			2	2			
	Non-AC 4/88	BS-II		16	4	20			
	TF1812	BS-IV			4	4			
Total Number of Buses			836	503	214	1553			
Total Number of Routes			94	87	34	215			

Source: WBTC, TERI analysis

2. List of E-buses under WBTC

Sl. No	Depot	9m E-Bus	12m E-Bus	Total E-buses
1	Belgharia	8	0	8
2	Kasba	0	8	8
3	Nonapukur	0	5	5
4	Thakurpukur	4	4	8
5	Howrah	5	5	10
6	Salt Lake	0	8	8
7	Lake	8	0	8
8	Gariahat	10	0	10
9	New Town	0	10	10
10	Digha*	5	0	5
	Total	40	40	80

Source: WBTC



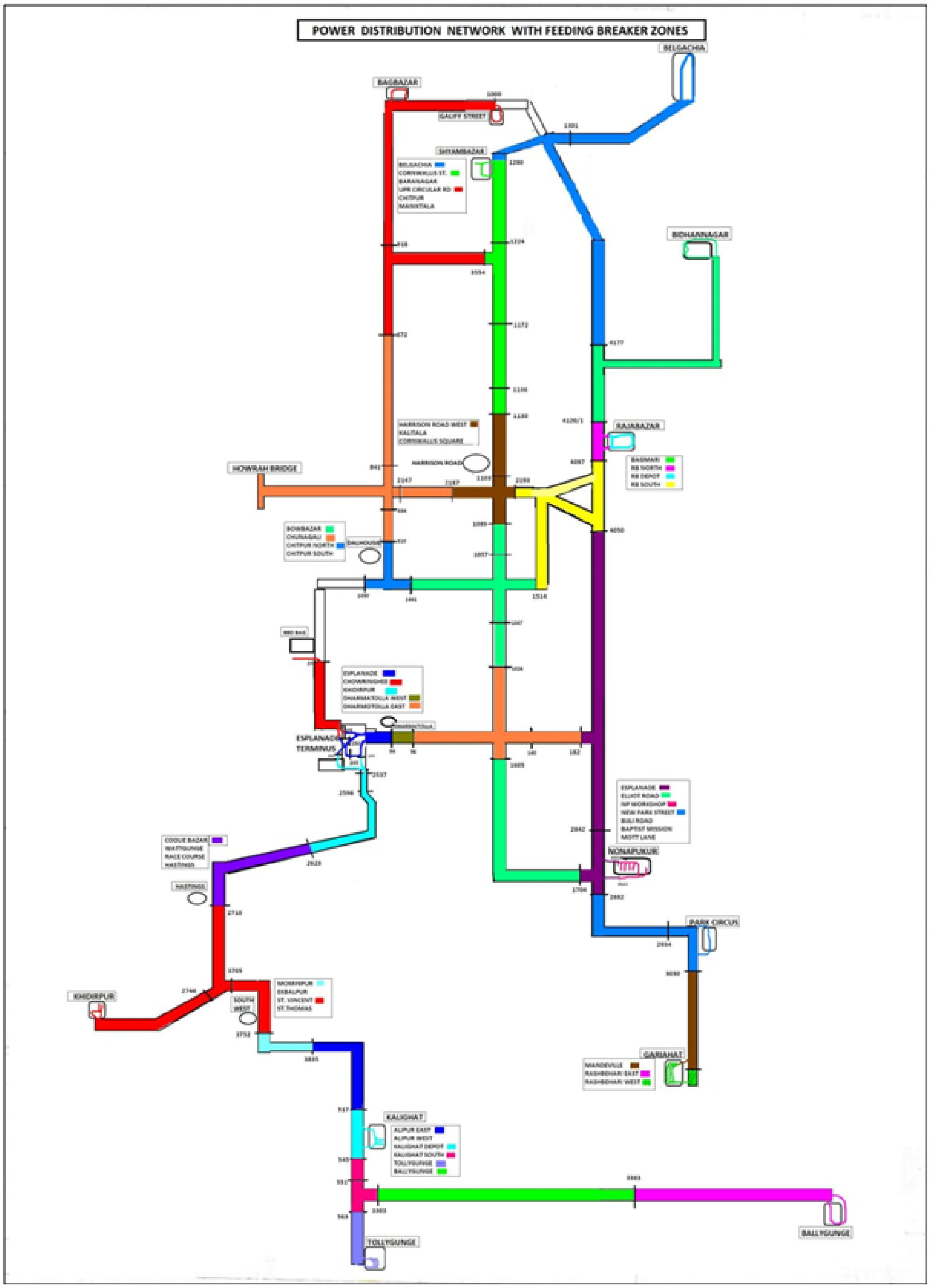
3. E-bus Routes under WBTC

Sl. No.	Route No.	No. of Trip	Route length	Originating Point	Terminating Point	Alignment	Average Bus	**Operation Hours
1	AC-4B	2	33	Joka	New Town	Thakurpukur-Cancer Hospital-Kabardanga-Haridevpur-Karunamoyee-Tollygunge Metro-Rashbehari Xing.-Gariahat-Ruby-Chingrihata-SDF-College More-Technopolis.	4	Both shift
2	AC-12	3	25	New Town (Sapoorji)	Howrah	Narkel Bagan-Newtown-SDF-Chingrihata-SC City-Topsia-Exide- Esplanade-BBD Bag	10	12
3	AC-12D	4	21	Joka	Howrah	THAKURPUKUR-BEHALA-MOMINPUR-ZOO-PTS-RABINDRA SADAN-ESPLANADE-MISSION ROW XING-BBD BAG.	4	12
4	EB-14	2	31	Santragachi	Eco Space	Via-Betore More - Mandirtala-Toll Plaza - P.T.S.-Rabindra Sadan-Beckbagan - Topsia Road Xing - Sc. City – Chingrihata - Nicco Park - Swastha Bhawan -College More-Technopolish-New Town-Narkelbagan-Unitech.	6	Both shift
5	AC-23A	3	35	Salt Lake Depot Gate	Rajchandrapur	Via : College More-New Town-Unitech-Eco Space-Aliah University-Daber More-ECO Park-City Centre II- Haldiram-Airport Gate No. 1- Belghoria Exp. Way-Dakshineswar-Ballyhalt.	7	12

Contd...

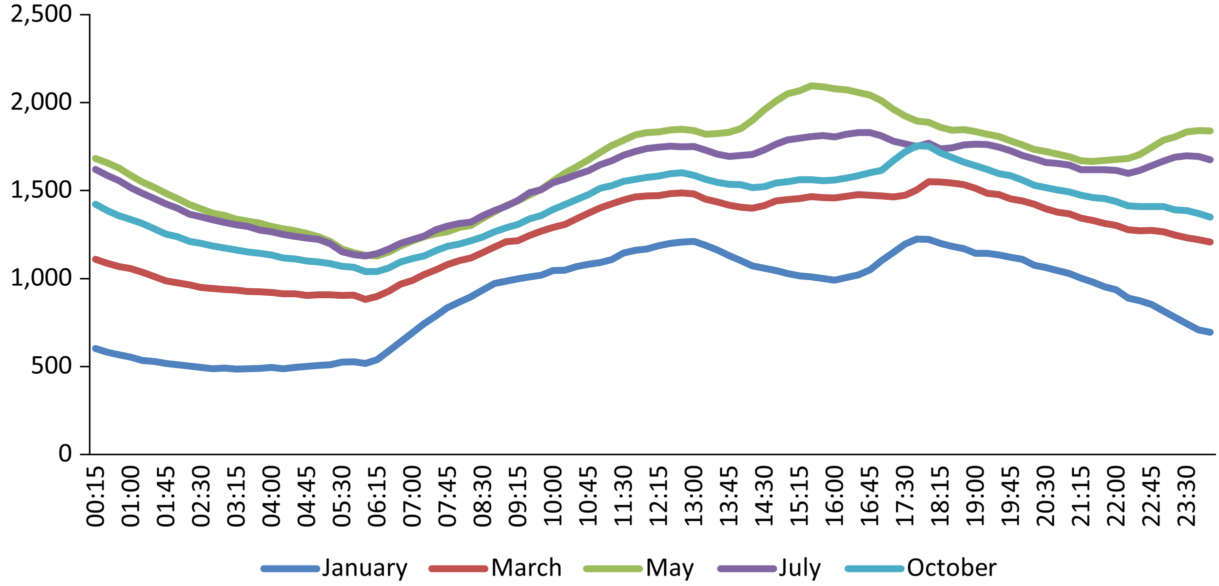
Sl. No.	Route No.	No. of Trip	Route length	Originating Point	Terminating Point	Alignment	Average Bus	**Operation Hours
6	AC-24	4	21	Patuli	Howrah	RUBY-GARIAHAT-HAZRA-EXIDE-PARK STREET- ESPL.	6	Both shift
7	AC-24A	3	24.5	Kamalgazi	Howrah Station	Dhalai Bridge-Patuli-Peerless Hospital-Ajay Nagar-Kalikapur-Ruby Hospital-Gariahat-Rashbehari Xing-Hazra Park-Rabindrasadan-Park Street-Esplanade-BBD Bag-Howrah Bridge East.	5	12
8	AC-54	3	13	Rathtala	Howrah Station	Dunlop,Sinthee More, Shyambazar,C.R. Avenue,Girish Park,Chitpur,Barrabazar.	7	Both shift
9	V-1	2	27	Tollygunge	Airport Terminal	Tollygunge Phari-Rashbehari Xing-Gariahat-Ruby-VIP Bazar-Science City-Chingrihata-Appolo Hospital-Bengal Chemical-HUDCO-Bangur-Raghunathpur-Kaikhali	6	Both shift
10	EB-1			Rathtolla - Nabanna - Santragachi		Dunlop - Shyambazar - Maniktolla - Sealdah - - Beckbagan - Minto Park - Exide - Rabindra Sadan - PTS - Nabanna - Balepole		
11	EB 2A			TG Metro- Karunamoyee		Gariahat- Ruby- Sc. City - Chingrighata- Vivekananda Yubha Bharati Stadium		
12	EB-3			TG Metro-Deshyapriya Park - Ecospace		Gariahat - Rubby - Science City - Nicco Park - SDF - New Town - Rabindra Tirtha		

4. Electrical Line Diagram of Tram Network In Kolkata:



Source: WBTC

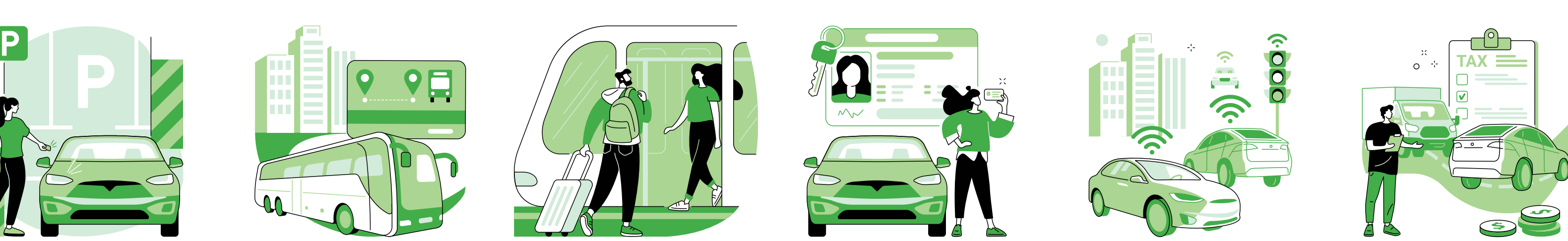
5. Seasonal Load Pattern of CESC



Source: CESC

6. Area identified for 60 shortlisted locations from the preliminary survey

 Location: L-1 CPC Ground, Hastings	 Location: L-2 Park Street Metro Station
 Location: L-3 Maidan	 Location: L-4 Millenium Park
 Location: L-5 Writers' Building	 Location: L-6 Sealdah Station



Location: L-7 Sapoorji

Location: L-8 HIDCO Bhawan

Location: L-9 Ecopark

Location: L-10 City Centre 2 Metro

Location: L-11 New Town Bus Stand

Location: L-12 Central Park Metro

Location: L-13 Dumdum Metro

Location: L-14 Airport

Location: L-15 Baguiati

Location: L-16 Bangaon-Kulpi Highway

Location: L-17 Star Mall, Barasat

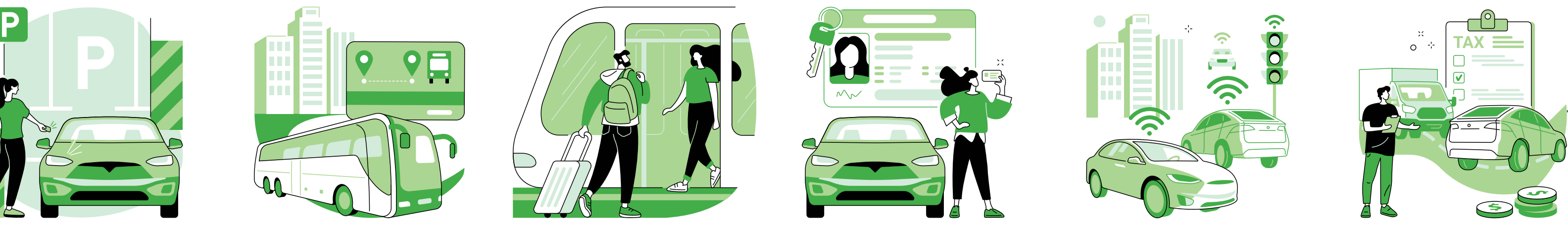
Location: L-18 City Centre 1

Location: L-19 Salt Lake Sector V Metro

Location: L-20 Dakshineshwar Temple

Location: L-21 Kharda Industrial Area

Location: L-22 Noapara Metro




Location: L-23 Mani Square


Location: L-24 Salt Lake Stadium


Location: L-25 Shyambazar


Location: L-26 Girish Park

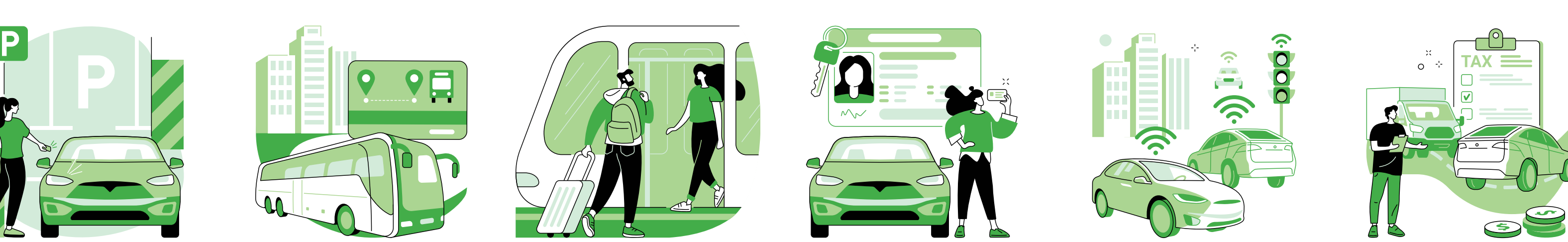

Location: L-27 Science City


Location: L-28 Fortis Hospital


Location: L-29 Ruby General


Location: L-30 Spencer’s Ruby

 Location: L-31 Metropolis Mall, Garia	 Location: L-32 New Garia Metro
 Location: L-33 Kavi Nazrul Metro	 Location: L-34 Dhakuria
 Location: L-35 South City Mall	 Location: L-36 Tollygunge



 Location: L-37 Netaji Metro	 Location: L-38 Behala Chowrasta
 Location: L-39 Joka	 Location: L-40 Majerhat
 Location: L-41 Taratala	 Location: L-42 Garden Reach

Location: L-43 Khiderpore

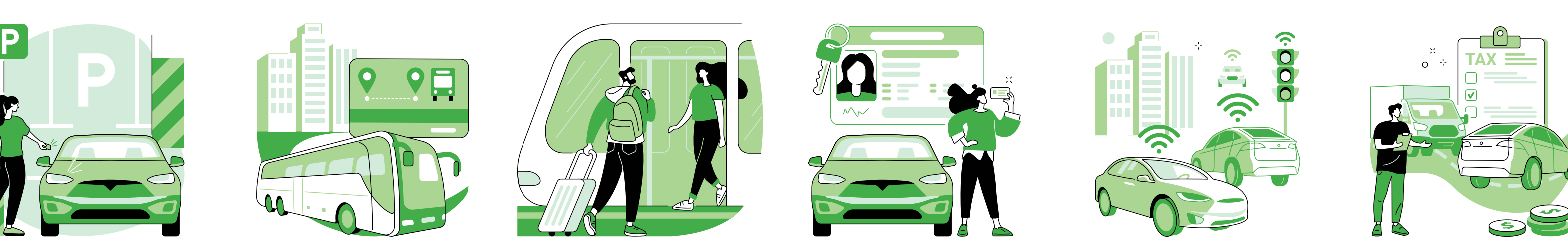
Location: L-44 Ballygunge

Location: L-45 Lake Mall

Location: L-46 Ladies Park, Mullick Bazar

Location: L-47 Quest Mall

Location: L-48 Alipore



Location: L-49 Golpark Gariahat

Location: L-50 Beltala

Location: L-51 Barasat

Location: L-52 Kalyani Highway

Location: L-53 Howrah Maidan

Location: L-54 Avani Riverside Mall

Location: L-55 Shalimar Station

Location: L-56 Howrah Station

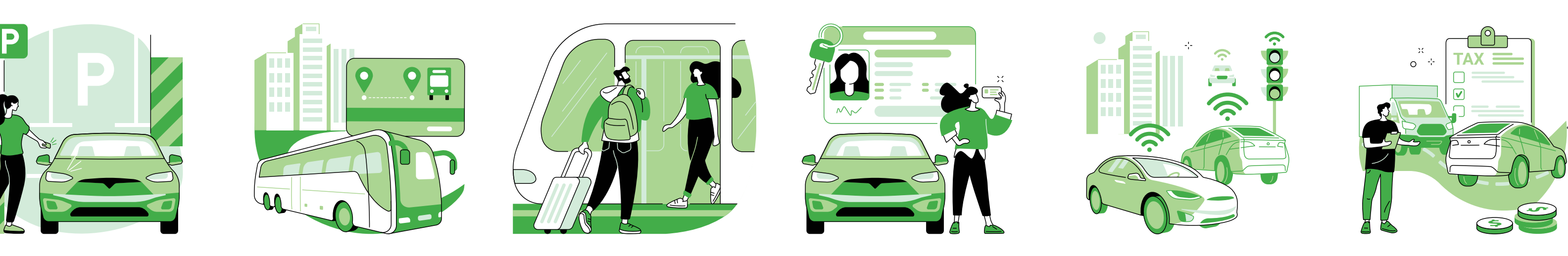
Location: L-57 Jadavpur University (Lake Campus)

Location: L-58 KPC Medical College

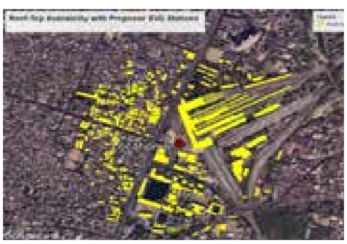
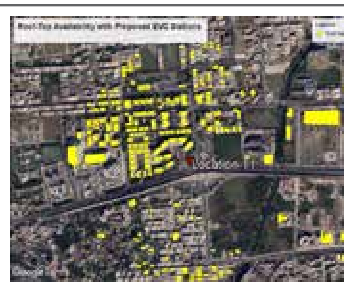
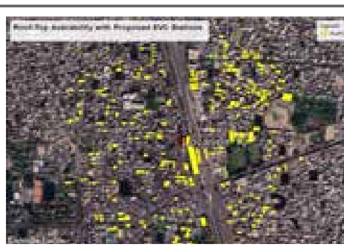
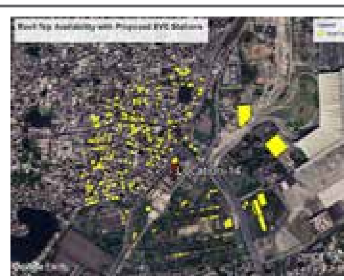
Location: L-59 Bansdroni

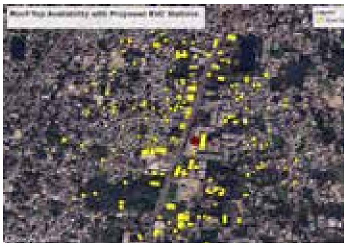
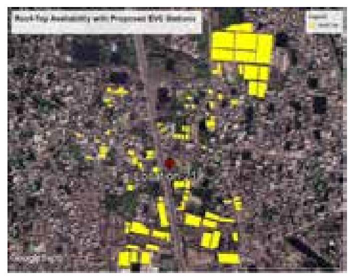
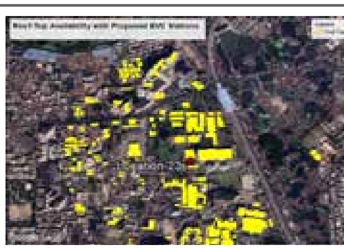
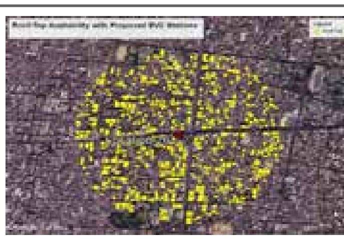
Location: L-60 Thakurpukur

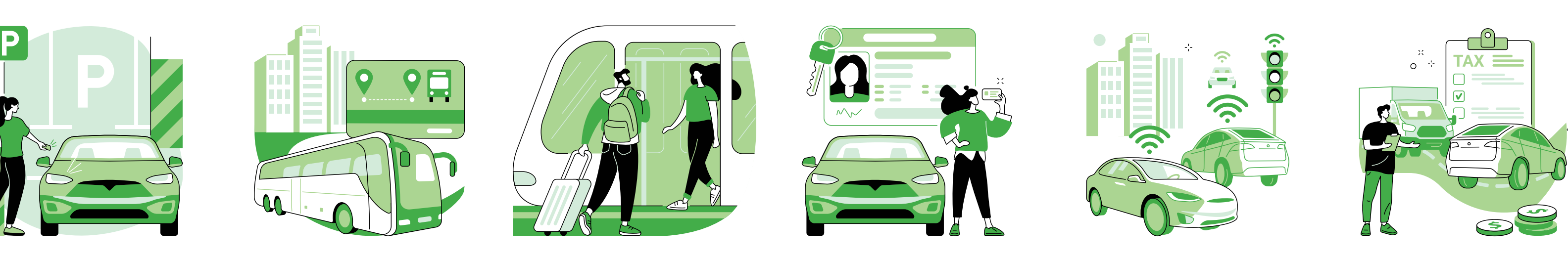
Source: TERI analysis



7. Rooftop Digitization of 60 Shortlisted locations (in order)

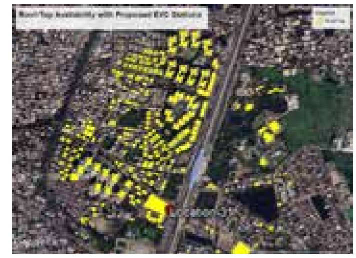
 Location: L-1 CPC Ground Hastings	 L Location: L-2 Park Street Metro Station	 Location: L-3,4,5 Maidan, Millenuim Park, aand Writer's Building
 Location: L-6 Sealdah Station	 Location: L-7 Sapoorji	 Location: L-8,9 HIDCO Bhawan and Ecopark
 Location: L-10 City Centre 2	 Location: L-11 New Town Bus Stand	 Location: L-12 Central Park Metro
 Location: L-13 Dumdum Metro	 Location: L-14 Airport	 Location: L-15 Baguiati

 Location: L-17 Star Mall, Barasat	 Location: L-18 City Centre 1	 Location: L-19 Salt Lake Sector 5 Metro
 Location: L-20 Dakshineshwar Temple	 Location: L-21 Kharda Industrial Area	 Location: L-22 Noapara Metro
 Location: L-23 Mani Square	 Location: L-24 Salt Lake Stadium	 Location: L-25 Shyambazar
 Location: L-26 Girish Park	 Location: L-27 Science City	 Location: L-28 Fortis Hospital

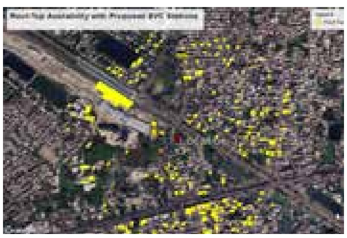


Location: L-29 Ruby General

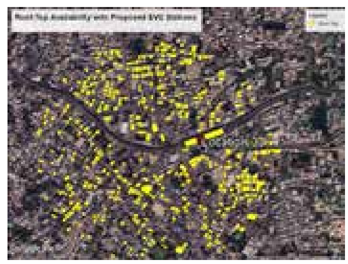
Location: L-30 Spencer's Ruby



Location: L-31 Metropolis Mall Garia



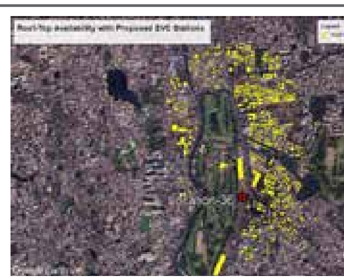
Location: L-32 New Garia Metro



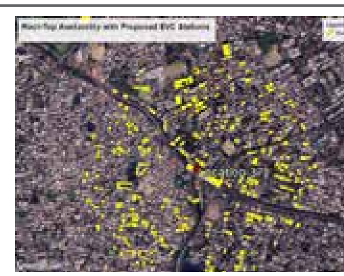
Location: L-33 Kavi Nazrul Metro

Location: L-34 Dhakuria

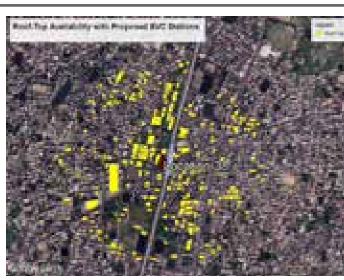
Location: L-35 South City Mall



Location: L-36 Tollygunge



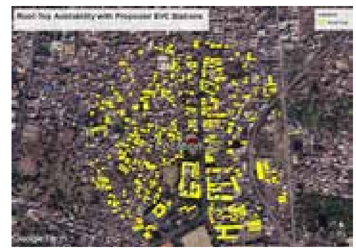
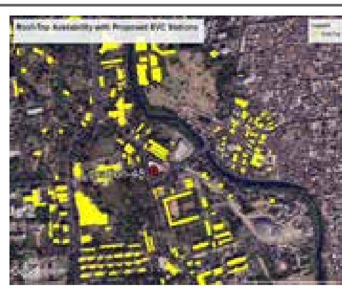
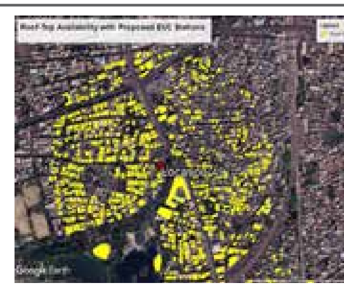
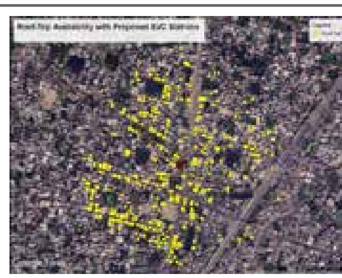
Location: L-37 Netaji Metro

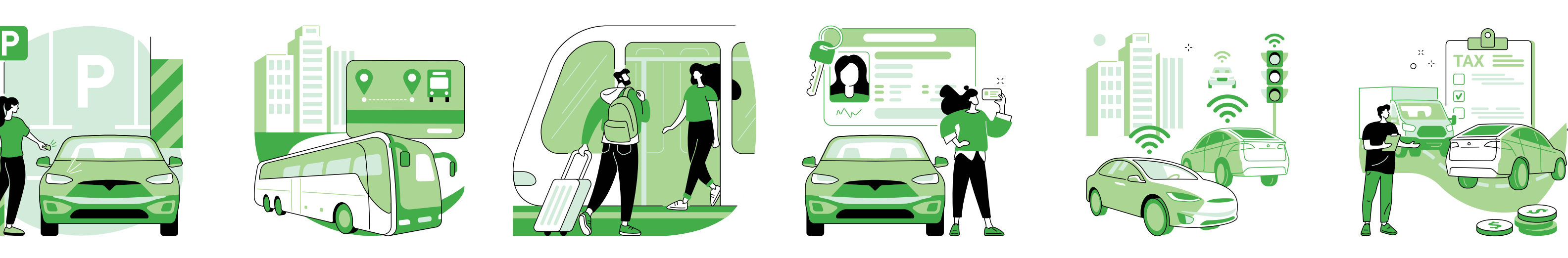


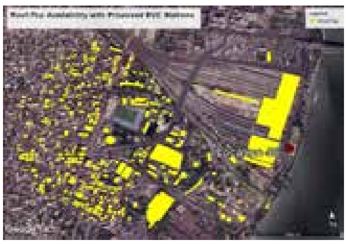
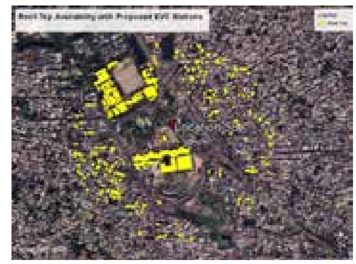
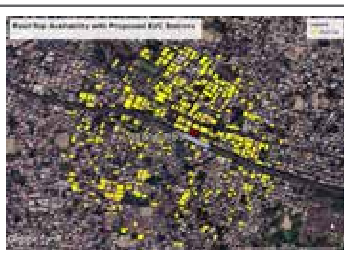
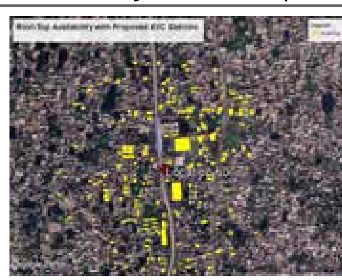
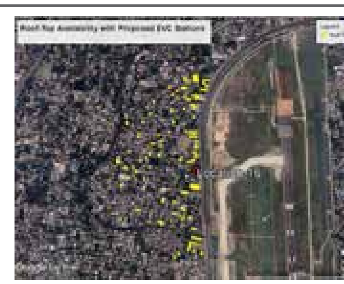
Location: L-38 Behala Chowrasta

Location: L-39 Joka

Location: L-40 Majerhat

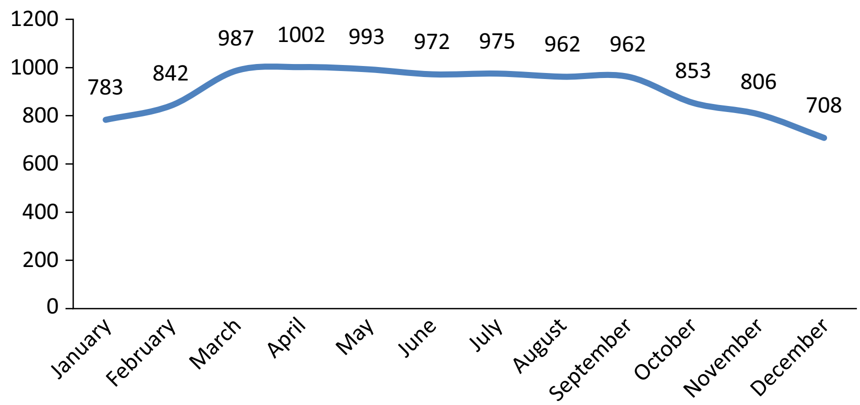
 Location: L-41 Taratala	 Location: L-42 Garden Reach	 Location: L-43 Khiderpore
 Location: L-44 Ballygunge	 Location: L-45 Lake Mall	 Location: L-46 Ladies Park, Mullick Bazar
 Location: L-47 Quest Mall	 Location: L-48 Alipore	 Location: L-49 Golpark Gariahat
 Location: L-50 Beltala	 Location: L-51 Barasat	 Location: L-52 Kalyani Highway



 Location: L-53 Howrah Maidan	 Location: L-54 Avani Riverside Mall	 Location: L-55 Shalimar Station
 Location: L-56 Howrah Station	 Location: L-57 Jadavpur University (Lake Campus)	 Location: L-58 KPC Medical College
 Location: L-59 Bansdroni	 Location: L-60 Thakurpukur	 Location: L-16 Bangaon Kulpi Highway

Source: TERI analysis

9. GHI of Kolkata city (Source: NREL Database 2020)

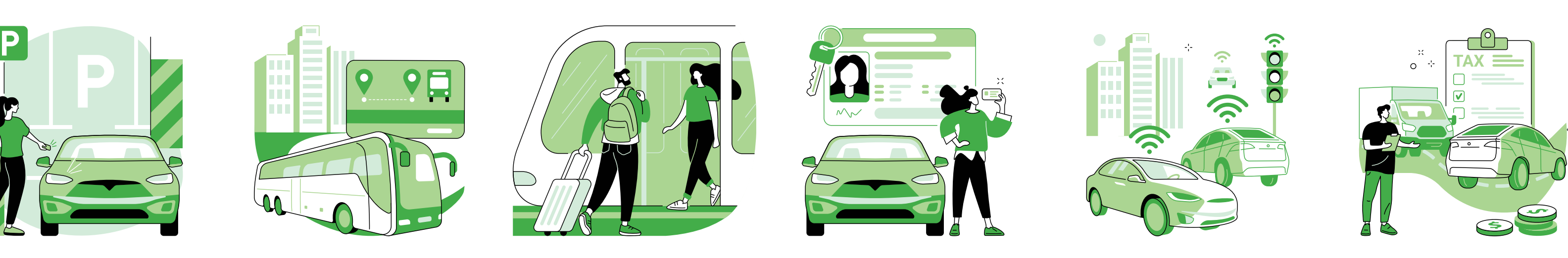


Source: NREL Database

10. Summary of Stakeholder Interactions (Gist of Discussions):

» Inception Workshop (6th May 2022)

Discussion Point	Action to be taken
General guidelines	TERI is requested to follow the terms and conditions of using the logos of the sponsor.
Constitution of 'State-level public e-mobility stakeholder consultation group' and/ or 'Project advisory committee'	TERI team informed that the requirement and feasibility of having a stakeholder consultation group, and a project advisory committee would be discussed with West Bengal Transport Corporation (WBTC). The recommendation of WBTC would be followed on whether to constitute both or either one of them. TERI to provide a short note on the final recommendation of WBTC on the same, along with the envisaged role of the selected in the project.
Maintain a shared folder for putting all project-related documents by TERI	It is agreed to create a sub-folder for each work package and save the project documents accordingly.
Intent letter from WBTC	TERI to follow up with WBTC for the approval/ intent letter for the study. Post-approval, the TERI team will visit Kolkata for an inception meeting.
Monthly project review meeting	TERI has agreed to the same and requested flexibility with the review meeting dates.



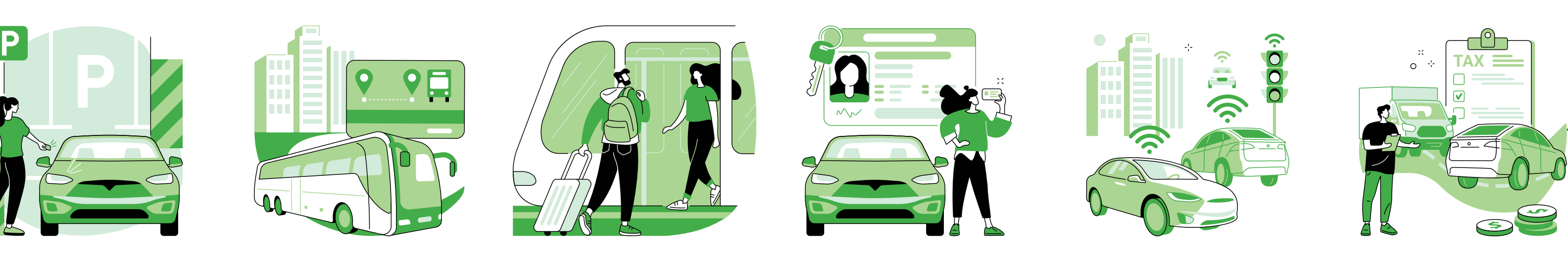
» Stakeholder interaction regarding tramways (14th June 2022)

Questions	Answers- Summary Points
Which are the high-density routes now?	» High density routes were: » Khidirpur – Esplanade via Maidan » Shyambazar – Esplanade » Ballygunge – Tollygunge (The Ballygunge – Tollygunge route that has been stopped for 4 years, was the high-density route)
What all challenges are faced in operating the trams?	» For Trams, there was used to be reserved track systems (. In 2003–2004, dedicated lines were discontinued) However, they now share the road with vehicles » Trams face limitations in their speed and braking capabilities » The absence of dedicated track systems (prevents them from moving at faster rates) » Traffic lights regulate both automobiles and trams on the road, trams cannot bypass these signals, contributing to their constrained speed and longer braking distances
What is the latest time schedule followed by the operating trams?	» The existing tram routes do not adhere to a strict time schedule. The timing of tram services is heavily influenced by peak hours and periods of high congestion
Details of distance, speed, stoppage and fares	» The minimum fare for tram rides on Route no. 25 is either ₹6 or ₹7. This fare allows passengers to travel up to a maximum of 22 stops along the route. The average speed of trams on this route is approximately 10-15 km/hr. Each route spans a distance of approximately 8 kilometres.
Which category of people are the usual passengers?	» The major commuters of the trams consists of elderly individuals, women, and children. Additionally, school and college students choose to travel by trams due to safety reasons. However, during holidays, the revenue generated by the trams experiences a decline of approximately 10-15%.
What are the currently operational tramway routes?	» The Ballygunge to Tollygunge route (Route no. 24/29) covers a distance of 5.5 kilometers and includes 18 stops. » Gariahat to Esplanade route (Route no. 25) spans a distance of approximately 7-8 kilometers and encompasses 22 stops.

Questions		Answers- Summary Points
How many tramcars are running in each route?	»	A total of 25 tramcars, comprising both single and double bogies, are in operation across the two routes
Can we get stoppage-wise revenue in each route?	»	Data regarding the time taken from one stop to another, as recorded by the Electronic Ticketing Machine(ETM) Not Available
Does tram route overlap with other mode of transport?	»	There is a significant overlap of 3-5 routes, particularly in the Esplanade area, where the tram route coincides with the metro route

» Stakeholder Interaction regarding ferries (2nd September 2022)

Summary Points
» There are 33 operational ferries in all (4 cruises and 29 cross-ferry vessels)
» Ferry bifurcation in terms of person carrying capacity: Cross Ferry Vessels have a person capacity of 100, 150, 200, 250, 300, 384, and 400, the cruise ship has a capacity of 30, 150, and 2 x 200
» Cruise ships typically sails two to three times per month. The duration of their operation is determined by the number of reservations made by third-party entities
» The refuelling station for boats is located at Babughat. To take advantage of the downtime when the train lines are not in use, the ferries are typically filled with fuel during night time hours. Average daily diesel consumption is 1300 litres
» In normal day- all the ferries operate around 130 hours
» The West Bengal Government has proposed the establishment of E-vessel routes connecting Salkia - Fairlie - Shipping (fares not fixed yet)
» Shipping, Howrah, and Belur are the proposed locations for e-vessel charging
» A circular railway track is located close to the ferry Ghats
» Areas suitable for electronic charging of vessels: Shipping, Fairlie, Belur, and Kashipur. The railway tracks go through Dumdum, Bagbazar, Ballygunge, Park Circus, Bidhannagar, Ultadanga and Dumdum (in that order)
» The land for Millennium Park is owned by Kolkata Port Trust, and AMD built it.
» Rooftop areas (potential RTS areas) include the boat terrace area (150-200 sq. m.), jetty (30-40 m in length) and building office area (3500 sq. ft.)."

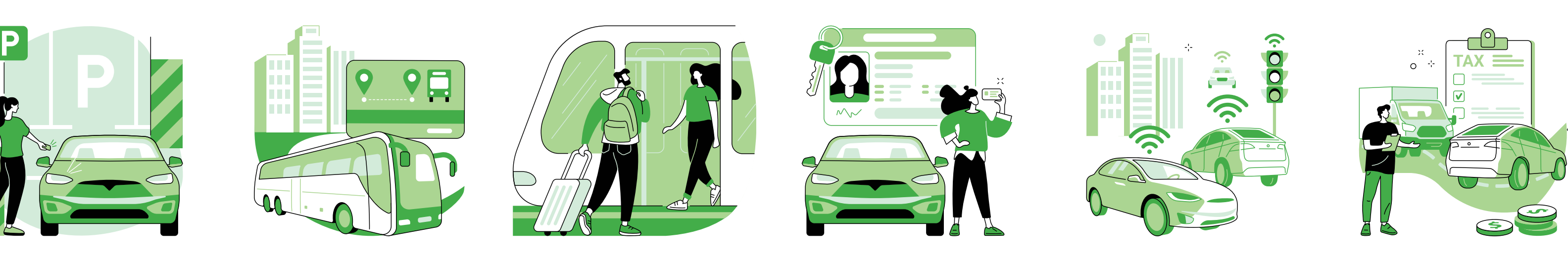


» Stakeholder Interaction with WBTC, CESC, Map My India, and TVS Motors (13th March 2023)

Highlighted points	Comments	Action to taken
The effect of bus charging for current and future e-buses, as well as 3Wheelers, Ferries, and Trams, on system demand (kW) during peak hours and concurrent peak	Mr. Rajiv Das from CESC asked about the impact on system demand during peak hours and the coincident peak for bus charging.	» During the interaction, the TERI team agreed to make changes to the system demand and sudden peak for bus charges. » The TERI team also agreed to apply the same rules to trams, ferries, and three-wheelers.
Other than the bus depot and safety considerations, bus charging on the side of the road.	Bus charging at the roadside has been a source of safety issues, according to Mr. Rajiv Das from CESC.	» TERI team will incorporate the safety aspects of bus charging on the roadside in its final report.
For locating charging stations for various car kinds, a map or app will be created.	Dr. Brijmohan and Mr. Rajiv from Map My India recommended examining traffic volume and waiting times in specific areas to identify the vehicles that are frequently seen there and concentrating on installing recharge stations for such vehicles.	» In order to further identify which vehicles are frequently seen in that area and to focus on installing charge stations for those vehicles, the TERI team will identify traffic frequency and waiting times at specific places. » In the final report, the TERI team will include a map that shows the locations of charging stations for various kinds of vehicles.
Financial assistance and a plan for the widespread installation of charging infrastructure	The models and financial assistance necessary for the widespread deployment of charging infrastructure were discussed by Mr. Anurag Yadav from TVS Motors.	» The financial model and financial assistance for the widespread deployment of charging infrastructure are included in the scope of this study as pointed by TERI.

Contd...

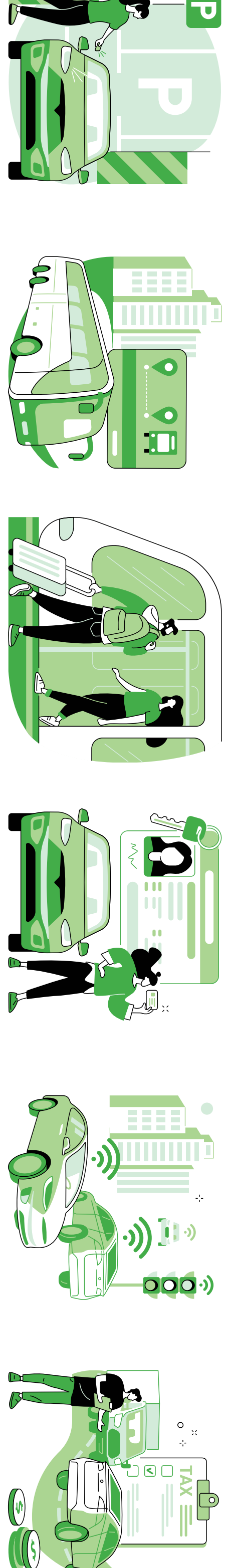
Highlighted points	Comments	Action to taken
GHG emission and air pollution mapping	To help with the transition to net-zero emissions, Dr. Brijmohan and Rajiv from Map my India advised mapping air pollution and GHG emissions levels route-wise.	» TERI team will provide a baseline emission scenario and the project emission scenario for the Kolkata city for a whole year.
Various charging techniques and control methods	Mr. Anurag Yadav suggested to use different charging mechanisms and control strategies	» In the final report, the TERI team will outline some of the best alternatives to the suggested charge mechanisms and control measures (that can be used in Kolkata).
Reduction in peak demand, and the use of renewable energy.	Mr. Anurag Yadav added regarding the distribution of load during peak demand, use of renewable energy for charging of electric vehicles	» TERI team explained that all the mentioned points are coming under the scope of the study and will be incorporated in the final report
Engagement with government stakeholders	According to Mr. Rajiv Das, government officials will continue to interact with stakeholders to make sure that all concerns and recommendations are taken into account during the planning and execution of the net-zero transition.	» TERI team will incorporate all the suggestions from the stakeholders in the final report



11. Site suitability analysis for 60 locations

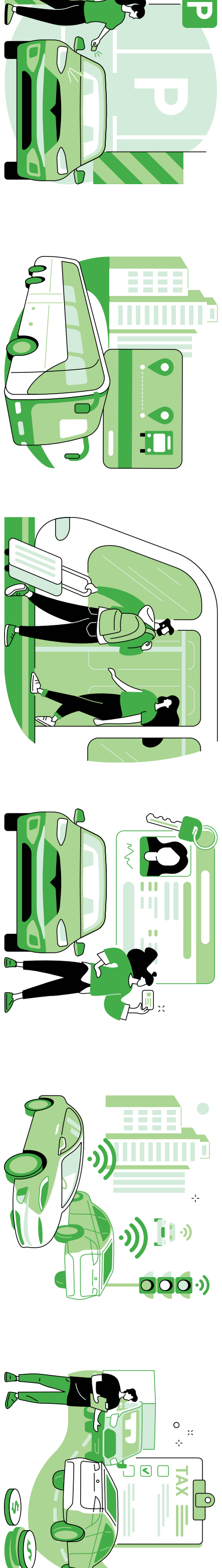
Name	Traffic Survey Site	Area (Sq. M.)	Parked vehicles Near to Proposed Site (site survey) 30%				Vehicle Density near to Proposed Site (traffic survey) 70%			Avg. Vehicle Density near to Proposed Site			No of Chargers required for 3 W (30KW Bulk Battery Swapping Charger)	No of Chargers required for 2 W (Bharat AC-001 (3.3*3 = 10KW) Slow Charger)	No of Chargers required for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	No of Chargers required for 4 W (CCS (50 KW) Fast Charger)	No of Battery Swapping Chargers can be installed based on Area Availability	No of Slow Chargers can be installed based on Area Availability	No of Fast Chargers can be installed based on Area Availability	Minimum No of Chargers proposed for 3 W (30KW Bulk Battery Swapping Charger)	Minimum No of Chargers proposed for 2 W (Bharat AC-001 (3.3*3= 10KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (CCS (50 KW) Fast Charger)
			2 Wheelers	3 Wheelers	4 Wheelers	Avg. wait time	2 Wheelers	3 Wheelers	4 Wheelers	2 Wheelers	3 Wheelers	4 Wheelers											
L-1	TSS 26	7095	300	0	200	60 MINUTES	21210	294	9930	2391	30	1173	1	2	2	1	469	67	67	1		1	
L-2	TSS 20	310	400	0	200	30 MINUTES	15690	3490	19934	1929	349	2174	1	2	3	2	21	2	2		1		
L-2A	TSS 20	1095	400	0	200	30 MINUTES	15690	3490	19934	1929	349	2174	1	2	3	2	72	10	10				1
L-2B	TSS 20	166	400	0	200	30 MINUTES	15690	3490	19934	1929	349	2174	1	2	3	2	11	1	1			1	
L-3	TSS 19	1128	50	0	100	60 MINUTES	4806	0	8440	526	0	934	0	1	2	1	75	10	10				1
L-3B	TSS 19	706	0	0	100	60 MINUTES	4806	0	8440	481	0	934	0	1	2	1	47	6	6		1		
L-4	TSS 18	1265	0	0	50	60 MINUTES	13552	0	15420	1356	0	1587	0	2	2	1	84	12	12		1		
L-4A	TSS 18	895	100	0	50	60 MINUTES	13552	0	15420	1446	0	1587	0	2	2	1	59	8	8			1	
L-5	TSS 18	494	200	0	0	60 MINUTES	13552	0	15420	1536	0	1542	0	2	2	1	33	4	4		1		
L-5	TSS 18	840	200	0	0	60 MINUTES	13552	0	15420	1536	0	1542	0	2	2	1	56	8	8		1		
L-6	TSS 34	1799	1000	500	1000	60 MINUTES	16006	3778	21794	2501	828	3080	1	3	4	2	119	17	17				1
L-6A	TSS 34	385	1000	500	1000	60 MINUTES	16006	3778	21794	2501	828	3080	1	3	4	2	25	3	3			1	
L-7	TSS 8	5991	200	100	200	120 MINUTES	6516	4224	2880	832	513	468	1	1	1	1	396	57	57			1	
L-8	TSS 7	7471	100	50	50	120 MINUTES	9930	1080	15306	1083	153	1576	1	1	2	1	494	71	71			1	
L-8A	TSS 7	1817	100	50	50	120 MINUTES	9930	1080	15306	1083	153	1576	1	1	2	1	120	17	17				1
L-8B	TSS 7	1388	100	50	50	120 MINUTES	9930	1080	15306	1083	153	1576	1	1	2	1	92	13	13				1
L-8C	TSS 7	1349	100	50	50	120 MINUTES	9930	1080	15306	1083	153	1576	1	1	2	1	89	12	12			1	
L-8D	TSS 7	1540	100	50	50	120 MINUTES	9930	1080	15306	1083	153	1576	1	1	2	1	102	14	14			1	
L-8E	TSS 7	3666	0	0	100	120 MINUTES	9930	1080	15306	993	108	1621	1	1	3	2	242	34	34			1	
L-9A	TSS 9	249	200	100	0	60 MINUTES	10534	1136	15308	1234	204	1531	1	2	2	1	16	2	2	1			
L-9C	TSS 9	2500	200	0	0	60 MINUTES	10534	1136	15308	1234	114	1531	1	2	2	1	165	23	23		1		

Name	Traffic Survey Site	Area (Sq. M.)	Parked vehicles Near to Proposed Site (site survey) 30%				Vehicle Density near to Proposed Site (traffic survey) 70%			Avg. Vehicle Density near to Proposed Site			No of Chargers required for 3 W (30KW Bulk Battery Swapping Charger)	No of Chargers required for 2 W (Bharat AC-001 (3.3*3 = 10KW) Slow Charger)	No of Chargers required for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	No of Chargers required for 4 W (CCS (50 KW) Fast Charger)	No of Battery Swapping Chargers can be installed based on Area Availability	No of Slow Chargers can be installed based on Area Availability	No of Fast Chargers can be installed based on Area Availability	Minimum No of Chargers proposed for 3 W (30KW Bulk Battery Swapping Charger)	Minimum No of Chargers proposed for 2 W (Bharat AC-001 (3.3*3= 10KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (CCS (50 KW) Fast Charger)
			2 Wheelers	3 Wheelers	4 Wheelers	Avg. wait time	2 Wheelers	3 Wheelers	4 Wheelers	2 Wheelers	3 Wheelers	4 Wheelers											
L-9D	TSS 9	5774	0	0	100	60 MINUTES	10534	1136	15308	1054	114	1621	1	1	3	2	382	54	54				1
L-9E	TSS 9	1689	200	0	0	60 MINUTES	10534	1136	15308	1234	114	1531	1	2	2	1	112	16	16			1	
L-10	TSS 9	1812	50	0	0	60 MINUTES	10534	1136	15308	1099	114	1531	1	1	2	1	120	17	17			1	
L-10A	TSS 9	2152	50	0	0	60 MINUTES	10534	1136	15308	1099	114	1531	1	1	2	1	142	20	20		1		
L-11	TSS 7	498	500	50	100	30 MINUTES	9930	1080	15306	1443	153	1621	1	2	3	2	33	4	4		1		
L-11	TSS 7	357	500	50	100	30 MINUTES	9930	1080	15306	1443	153	1621	1	2	3	2	24	3	3		1		
L-11A	TSS 7	2027	500	50	100	30 MINUTES	9930	1080	15306	1443	153	1621	1	2	3	2	134	19	19			1	
L-12	TSS 6	767	250	100	100	120 MINUTES	10154	1180	15982	1241	208	1689	1	2	3	2	51	7	7		1		
L-12	TSS 6	562	250	100	100	120 MINUTES	10154	1180	15982	1241	208	1689	1	2	3	2	37	5	5		1		
L-12	TSS 6	959	250	100	100	120 MINUTES	10154	1180	15982	1241	208	1689	1	2	3	2	63	9	9		1		
L-12	TSS 6	855	250	100	100	120 MINUTES	10154	1180	15982	1241	208	1689	1	2	3	2	57	8	8		1		
L-12	TSS 6	568	250	100	100	120 MINUTES	10154	1180	15982	1241	208	1689	1	2	3	2	38	5	5		1		
L-12	TSS 6	951	250	100	100	120 MINUTES	10154	1180	15982	1241	208	1689	1	2	3	2	63	9	9		1		
L-13	TSS 14	95	0	100	0	60 MINUTES.	10922	2490	15080	1093	339	1508	1	1	2	1	6	0	0	1			
L-14	TSS 12	4811	50	100	100	60 MINUTES	10042	1962	10522	1050	287	1143	1	1	2	1	318	45	45				1
L-15	TSS 39	524	0	400	0	30 MINUTES	11006	1396	15602	1101	500	1561	1	1	2	1	35	4	4	1			
L-15A	TSS 39	1028	0	0	100	30 MINUTES	11006	1396	15602	1101	140	1651	1	1	3	2	68	9	9			1	
L-15B	TSS 39	886	0	0	100	30 MINUTES	11006	1396	15602	1101	140	1651	1	1	3	2	59	8	8			1	
L-16	TSS 11	615	100	0	100	60 MINUTES	9974	1752	10068	1088	176	1097	1	1	2	1	41	5	5				1
L-16A	TSS 11	705	100	0	100	60 MINUTES	9974	1752	10068	1088	176	1097	1	1	2	1	47	6	6				
L-17	TSS 10	998	300	0	200	60 MINUTES	7584	1512	9458	1029	152	1126	1	1	2	1	66	9	9		1		
L-17A	TSS 10	1106	300	100	200	60 MINUTES	7584	1512	9458	1029	242	1126	1	1	2	1	73	10	10			1	
L-18	TSS 5	187	0	0	1000	120 MINUTES	8160	462	7998	816	47	1700	1	1	3	2	12	1	1				1

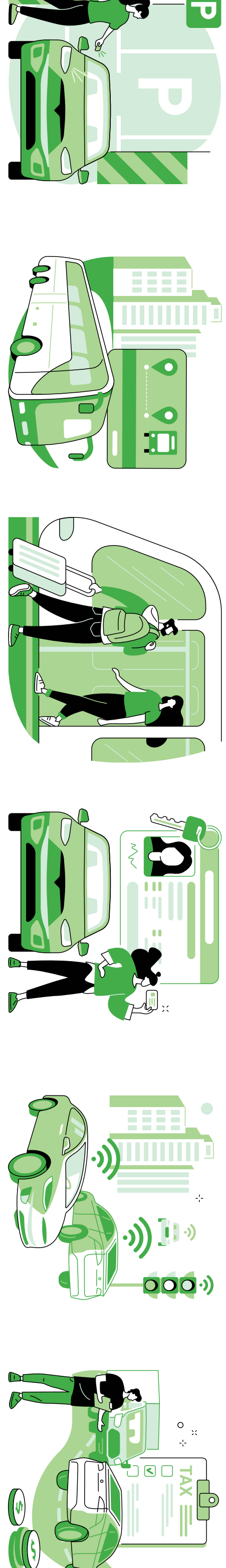


Name	Traffic Survey Site	Area (Sq. M.)	Parked vehicles Near to Proposed Site (site survey) 30%				Vehicle Density near to Proposed Site (traffic survey) 70%			Avg. Vehicle Density near to Proposed Site			No of Chargers required for 3 W (30KW Bulk Battery Swapping Charger)	No of Chargers required for 2 W (Bharat AC-001 (3.3*3 = 10KW) Slow Charger)	No of Chargers required for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	No of Chargers required for 4 W (CCS (50 KW) Fast Charger)	No of Battery Swapping Chargers can be installed based on Area Availability	No of Slow Chargers can be installed based on Area Availability	No of Fast Chargers can be installed based on Area Availability	Minimum No of Chargers proposed for 3 W (30KW Bulk Battery Swapping Charger)	Minimum No of Chargers proposed for 2 W (Bharat AC-001 (3.3*3= 10KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (CCS (50 KW) Fast Charger)
			2 Wheelers	3 Wheelers	4 Wheelers	Avg. wait time	2 Wheelers	3 Wheelers	4 Wheelers	2 Wheelers	3 Wheelers	4 Wheelers											
L-18	TSS 5	321	0	0	1000	120 MINUTES	8160	462	7998	816	47	1700	1	1	3	2	21	3	3			1	
L-18A	TSS 5	732	1500	0	0	120 MINUTES	8160	462	7998	2166	47	800	1	2	1	1	48	6	6		1		
L-19	TSS 6	2053	200	0	0	120 MINUTES	10154	1180	15982	1196	118	1599	1	1	2	1	136	19	19		1		
L-19A	TSS 6	256	0	0	100	120 MINUTES	10154	1180	15982	1016	118	1689	1	1	3	2	17	2	2			1	
L-19B	TSS 6	804	0	0	100	120 MINUTES	10154	1180	15982	1016	118	1689	1	1	3	2	53	7	7			1	
L-20	TSS 37	3228	0	400	200	120 MINUTES	6766	1422	9158	677	503	1096	1	1	2	1	213	30	30				1
L-20A	TSS 37	1168	0	400	200	120 MINUTES	6766	1422	9158	677	503	1096	1	1	2	1	77	11	11				1
L-20A	TSS 37	1508	0	400	200	120 MINUTES	6766	1422	9158	677	503	1096	1	1	2	1	100	14	14				1
L-21A	TSS 38	6068	0	20	0	20 MINUTES	6378	1512	8734	638	170	874	1	1	2	1	401	57	57	1			
L-22	TSS 37	260	20	50	0	30 MINUTES	6766	1422	9158	695	188	916	1	1	2	1	17	2	2	1			
L-23	TSS 4	605	1000	0	0	120 MINUTES	11394	0	12380	2040	0	1238	0	2	2	1	40	5	5		1		
L-23	TSS 4	659	1000	0	0	120 MINUTES	11394	0	12380	2040	0	1238	0	2	2	1	44	6	6		1		
L-23	TSS 4	235	1000	0	0	120 MINUTES	11394	0	12380	2040	0	1238	0	2	2	1	16	2	2		1		
L-24	TSS 4	801	0	0	300	120 MINUTES.	11394	0	12380	1140	0	1508	0	1	2	1	53	7	7		1		
L-25	TSS 15	43	50	0	0	30 MINUTES.	11196	2402	14870	1165	241	1487	1	1	2	1	3	0	0	1			
L-25 A	TSS 15	94	50	0	0	30 MINUTES.	11196	2402	14870	1165	241	1487	1	1	2	1	6	0	0	1			
L-26	TSS 16	116	0	100	0	30 MINUTES	11282	2416	14024	1129	332	1403	1	1	2	1	8	1	1	1			
L-27	TSS 3	4940	500	0	300	120 MINUTES	11226	7464	18806	1573	747	2151	1	2	3	2	327	47	47				1
L-28	TSS 2	1562	0	0	400	120 MINUTES	8880	960	22752	888	96	2636	1	1	4	2	103	14	14			1	
L-28A	TSS 2	1266	0	0	400	120 MINUTES	8880	960	22752	888	96	2636	1	1	4	2	84	12	12			1	
L-28B	TSS 2	10787	200	100	400	120 MINUTES	8880	960	22752	1068	186	2636	1	1	4	2	713	102	102			1	
L-29	TSS 2	6366	400	100	500	120 MINUTES	8880	960	22752	1248	186	2726	1	2	4	2	421	60	60			1	
L-29A	TSS 2	1938	400	100	0	120 MINUTES	8880	960	22752	1248	186	2276	1	2	3	2	128	18	18	1			

Name	Traffic Survey Site	Area (Sq. M.)	Parked vehicles Near to Proposed Site (site survey) 30%				Vehicle Density near to Proposed Site (traffic survey) 70%			Avg. Vehicle Density near to Proposed Site			No of Chargers required for 3 W (30KW Bulk Battery Swapping Charger)	No of Chargers required for 2 W (Bharat AC-001 (3.3*3 = 10KW) Slow Charger)	No of Chargers required for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	No of Chargers required for 4 W (CCS (50 KW) Fast Charger)	No of Battery Swapping Chargers can be installed based on Area Availability	No of Slow Chargers can be installed based on Area Availability	No of Fast Chargers can be installed based on Area Availability	Minimum No of Chargers proposed for 3 W (30KW Bulk Battery Swapping Charger)	Minimum No of Chargers proposed for 2 W (Bharat AC-001 (3.3*3= 10KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (CCS (50 KW) Fast Charger)
			2 Wheelers	3 Wheelers	4 Wheelers	Avg. wait time	2 Wheelers	3 Wheelers	4 Wheelers	2 Wheelers	3 Wheelers	4 Wheelers											
L-29B	TSS 2	1594	400	100	500	120 MINUTES	8880	960	22752	1248	186	2726	1	2	4	2	105	15	15			1	
L-30	TSS 2	403	200	0	200	45 MINUTES	8880	960	22752	1068	96	2456	1	1	4	2	27	3	3				1
L-31	TSS 1	402	200	0	100	60 MINUTES	6160	0	21120	796	0	2202	0	1	3	2	27	3	3				1
L-31A	TSS 1	264	200	0	0	60 MINUTES	6160	0	21120	796	0	2112	0	1	3	2	17	2	2		1		
L-31C	TSS 1	128	0	0	100	60 MINUTES	6160	0	21120	616	0	2202	0	1	3	2	8	1	1			1	
L-32	TSS 1	4680	5	15	0	30 MINUTES	6160	0	21120	621	14	2112	1	1	3	2	309	44	44		1		
L-33	TSS 24	2174	300	0	0	120 MINUTES	432	4800	864	314	480	87	1	1	1	1	144	20	20		1		
L-34	TSS 21	316	0	0	50	60 MINUTES.	16006	3824	21942	1601	383	2240	1	2	3	2	21	3	3				1
L-35	TSS 22	1962	500	0	500	120 MINUTES	4896	2448	14880	940	245	1938	1	1	3	2	130	18	18			1	
L-35A	TSS 22	3205	0	0	500	120 MINUTES	4896	2448	14880	490	245	1938	1	1	3	2	212	30	30			1	
L-35B	TSS 22	4860	500	0	500	120 MINUTES	4896	2448	14880	940	245	1938	1	1	3	2	321	46	46			1	
L-36	TSS 25	486	0	700		30 MINUTES for 3 wheelers and 120 MINUTES for 2 wheelers	25132	3776	14264	2514	1008	1427	1	3	2	1	32	4	4	1			
L-36A	TSS 25	294	0	0	50	30 MINUTES for 3 wheelers and 120 MINUTES for 2 wheelers	25132	3776	14264	2514	378	1472	1	3	2	1	19	2	2			1	
L-36B	TSS 25	199	300	0	0	30 MINUTES for 3 wheelers and 120 MINUTES for 2 wheelers	25132	3776	14264	2784	378	1427	1	3	2	1	13	1	1		1		



Name	Traffic Survey Site	Area (Sq. M.)	Parked vehicles Near to Proposed Site (site survey) 30%				Vehicle Density near to Proposed Site (traffic survey) 70%			Avg. Vehicle Density near to Proposed Site			No of Chargers required for 3 W (30KW Bulk Battery Swapping Charger)	No of Chargers required for 2 W (Bharat AC-001 (3.3*3 = 10KW) Slow Charger)	No of Chargers required for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	No of Chargers required for 4 W (CCS (50 KW) Fast Charger)	No of Battery Swapping Chargers can be installed based on Area Availability	No of Slow Chargers can be installed based on Area Availability	No of Fast Chargers can be installed based on Area Availability	Minimum No of Chargers proposed for 3 W (30KW Bulk Battery Swapping Charger)	Minimum No of Chargers proposed for 2 W (Bharat AC-001 (3.3*3= 10KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (CCS (50 KW) Fast Charger)
			2 Wheelers	3 Wheelers	4 Wheelers	Avg. wait time	2 Wheelers	3 Wheelers	4 Wheelers	2 Wheelers	3 Wheelers	4 Wheelers											
L-36C	TSS 25	299	0	0	50	30 MINUTES for 3 wheelers and 120 MINUTES for 2 wheelers	25132	3776	14264	2514	378	1472	1	3	2	1	20	2	2			1	
L-37	TSS 35	1155	0	200	50	120 MINUTES	2238	1536	3574	224	334	403	1	1	1	1	76	10	10	1			
L-37A	TSS 35	2143	200	0	0	120 MINUTES	2238	1536	3574	404	154	358	1	1	1	1	142	20	20		1		
L-38A	TSS 30	80	50	0	0	120 MINUTES	3840	3168	7296	429	317	730	1	1	1	1	5	0	0	1			
L-38B	TSS 30	954	50	100	50	120 MINUTES	3840	3168	7296	429	407	775	1	1	1	1	63	9	9		1		
L-39A	TSS 29	343	50	20	50	120 MINUTES	3780	3204	7134	423	339	759	1	1	1	1	23	3	3			1	
L-40	TSS 31	855	0	0	100	120 MINUTES	3810	3248	7416	381	325	832	1	1	2	1	57	8	8		1		1
L-41	TSS 31	244	50	50	0	30 MINUTES	3810	3248	7416	426	370	742	1	1	1	1	16	2	2				
L-41A	TSS 31	101	50	0	0	30 MINUTES	3810	3248	7416	426	325	742	1	1	1	1	7	0	0	1			
L-41B	TSS 31	56	50	50	0	30 MINUTES	3810	3248	7416	426	370	742	1	1	1	1	4	0	0	1			
L-41C	TSS 31	50	50	50	0	30 MINUTES	3810	3248	7416	426	370	742	1	1	1	1	3	0	0	1			
L-42A	TSS 32	208	50	0	100	60 MINUTES	3598	3194	7378	405	320	828	1	1	2	1	14	1	1			1	
L-42A	TSS 32	2999	50	0	100	60 MINUTES	3598	3194	7378	405	320	828	1	1	2	1	198	28	28			1	
L-43	TSS 26	2673	0	0	200	120 MINUTES	21210	294	9930	2121	30	1173	1	2	2	1	177	25	25			1	
L-44	TSS 21	548	0	0	50	30 MINUTES	16006	3824	21942	1601	383	2240	1	2	3	2	36	5	5			1	
L-45	TSS 28	114	200	0	0	30 MINUTES.	8234	7056	9722	1004	706	973	1	1	2	1	8	1	1		1		
L-47	TSS 20	19487	500	0	1000	120 MINUTES	15690	3490	19934	2019	349	2894	1	2	4	2	1288	185	185			1	
L-47A	TSS 20	214	0	0	1000	120 MINUTES	15690	3490	19934	1569	349	2894	1	2	4	2	14	2	2			1	
L-47B	TSS 20	231	0	0	1000	120 MINUTES	15690	3490	19934	1569	349	2894	1	2	4	2	15	2	2			1	
L-47B	TSS 20	279	0	0	1000	120 MINUTES	15690	3490	19934	1569	349	2894	1	2	4	2	18	2	2			1	
L-48	TSS 27	12192	0	0	1000	120 MINUTES	20430	524	52500	2043	53	6150	1	2	8	4	806	116	116			1	



Name	Traffic Survey Site	Area (Sq. M.)	Parked vehicles Near to Proposed Site (site survey) 30%				Vehicle Density near to Proposed Site (traffic survey) 70%			Avg. Vehicle Density near to Proposed Site			No of Chargers required for 3 W (30KW Bulk Battery Swapping Charger)	No of Chargers required for 2 W (Bharat AC-001 (3.3*3 = 10KW) Slow Charger)	No of Chargers required for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	No of Chargers required for 4 W (CCS (50 KW) Fast Charger)	No of Battery Swapping Chargers can be installed based on Area Availability	No of Slow Chargers can be installed based on Area Availability	No of Fast Chargers can be installed based on Area Availability	Minimum No of Chargers proposed for 3 W (30KW Bulk Battery Swapping Charger)	Minimum No of Chargers proposed for 2 W (Bharat AC-001 (3.3*3= 10KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (Bharat AC-001 (7.4*2= 15KW) Slow Charger)	Minimum No of Chargers proposed for 4 W (CCS (50 KW) Fast Charger)
			2 Wheelers	3 Wheelers	4 Wheelers	Avg. wait time	2 Wheelers	3 Wheelers	4 Wheelers	2 Wheelers	3 Wheelers	4 Wheelers											
L-49	TSS 21	41	0	0	0	30 MINUTES.	16006	3824	21942	1601	383	2195	1	2	3	2	3	0	0	1			
L-50	TSS 40	501	0	0	0	120 MINUTES.	5818	494	7622	582	50	763	1	1	1	1	33	4	4		1		
L-51	TSS 10	1182	100	100	0	30 MINUTES	7584	1512	9458	849	242	946	1	1	2	1	78	11	11			1	
L-51A	TSS 10	201	100	100	0	30 MINUTES	7584	1512	9458	849	242	946	1	1	2	1	13	1	1	1			
L-51B	TSS 10	441	100	100	0	30 MINUTES	7584	1512	9458	849	242	946	1	1	2	1	29	4	4	1			
L-52	TSS 13	183	50	100	50	60 MINUTES	9730	1890	10356	1018	279	1081	1	1	2	1	12	1	1			1	
L-52A	TSS 13	1197	50	100	50	60 MINUTES	9730	1890	10356	1018	279	1081	1	1	2	1	79	11	11				1
L-53	TSS 17	224	100	0	100	60 MINUTES	14904	9540	15314	1581	954	1622	1	2	3	2	15	2	2	1			
L-53A	TSS 17	2186	100	0	100	60 MINUTES	14904	9540	15314	1581	954	1622	1	2	3	2	145	20	20			1	
L-54	TSS 33	2397	2000	500	500	60 MINUTES	2924	732	3428	2093	524	793	1	2	1	1	159	22	22		1		
L-54A	TSS 33	272	0	0	0	0 MINUTES	2924	732	3428	293	74	343	1	1	1	1	18	2	2			1	
L-54B	TSS 33	2458	0	0	100	60 MINUTES	2924	732	3428	293	74	433	1	1	1	1	162	23	23	1			
L-55	TSS 33	674	100	100	500	30 MINUTES	2924	732	3428	383	164	793	1	1	1	1	45	6	6				1
L-55A	TSS 33	408	100	100	500	30 MINUTES	2924	732	3428	383	164	793	1	1	1	1	27	3	3			1	
L-55B	TSS 33	216	100	100	500	30 MINUTES	2924	732	3428	383	164	793	1	1	1	1	14	2	2		1		
L-56	TSS 17	2902	0	0	2000	120 MINUTES	14904	9540	15314	1491	954	3332	1	2	5	3	192	27	27				1
L-56A	TSS 17	691	0	0	2000	120 MINUTES	14904	9540	15314	1491	954	3332	1	2	5	3	46	6	6			1	
L-56B	TSS 17	1972	0	0	2000	120 MINUTES	14904	9540	15314	1491	954	3332	1	2	5	3	130	18	18			1	
L-57	TSS 3	720	200	0	100	60 MINUTES	11226	7464	18806	1303	747	1971	1	2	3	2	48	6	6			1	
L-58	TSS 23	519	400	50	300	120 MINUTES	7232	4128	10016	1084	458	1272	1	1	2	1	34	4	4			1	
L-60	TSS 30	299	20	0	50	60 MINUTES	3840	3168	7296	402	317	775	1	1	1	1	20	2	2	1			
L-60A	TSS 30	2587	20	0	0	60 MINUTES	3840	3168	7296	402	317	730	1	1	1	1	171	24	24		1		
		206344	23115	7205	27750		1223598	269482	1703098	143207	33470	195334	111	180	301	180	13645	1901	1901	22	34	48	20

Source: TERI analysis