100 E-Bus Trial Jakarta
Technical Feasibility Study

September 18, 2020

C40 CITIES FINANCE FACILITY

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ABOUT THE C40 CITIES FINANCE FACILITY

The C40 Cities Finance Facility (CFF) is a collaboration of the C40 Cities Climate Leadership Group and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The CFF supports cities in developing and emerging economies to develop finance-ready projects to reduce emissions to limit global temperature rise to 1.5°C and strengthen resilience against the impacts of a warming climate. The CFF is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), the Children's Investment Fund Foundation (CIFF), the Government of the United Kingdom and the United States Agency for International Development (USAID).

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LIST OF ABBREVIATIONS

AC	Air Conditioning
ADB	Asian Development Bank
BAU	Business as Usual
BC	Black Carbon
BEB	Battery Electric Bus
BNEF	Bloomberg New Energy Finance
BRT	Bus Rapid Transit
BYD	Build Your Dreams (a Chinese EV manufacturer)
CapEx	Capital Expenditure
C40	C40 Cities Climate Leadership Group
CFF	C40 Cities Finance Facility
C40 KAPM	C40 Knowledge and Partnership Manager
CNG	Compressed Natural Gas
CO2	Carbon dioxide
DC	Direct Current
DKI Jakarta	Daerah Khusus Ibukota or Special Capital Region of Jakarta
E-bus	Electric bus
E-mobility	Electric mobility
EV	Electric Vehicles
FAME	Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles
FUSE	Discussion Forum for Electric Vehicles and Buses, Indonesia
GCF	Green Climate Fund
GEFF	Green Economy Financing Facility
GGGI	Global Green Growth Institute
GGF	Green for Growth Fund
GHG	Greenhouse Gas
GIZ	German Development Agency
HEAT	Habitat, Energy Application and Technology (HEAT GmbH)
ICE	Internal Combustion Engine
IDR	Indonesian Rupiah
IEA	International Energy Agency
IPCC	Inter-Governmental Panel on Climate Change
KPBB	Committee for the Phasing Out of Leaded Fuel (Indonesian NGO)
MAB	Mobil Anak Bangsa (Indonesian e-bus manufacturer)
MEMR	Ministry of Energy and Mineral Resources, Indonesia
MYS	PT Mayasari Bakti bus company
NAMA	Nationally Appropriate Mitigation Action
NCV	Net Calorific Value
NDC	Nationally Determined Contribution
NDE	National Designated Entity
NOx	Nitrous Oxide pollutants
ODS	Ozone Depleting Substances
OEM	Original Equipment Manufacture

OpEx	Operational Expenditure
PIU	Project Implementation Unit
PLN	Perusahaan Listrik Negara (Indonesia's state-owned electricity company)
PM	Particulate Matter
PM2.5	Particulate Matter less than 2.5 micrometres in width
PPF	Project Preparation Facility
PPP	Public-Private Partnership
Presidential decree	The Presidential Decree on Acceleration of Battery-Based Electric Vehicles
SOC	State of Charge
SP	Service Provider
SPA	Senior Project Advisor
SUTP	Sustainable Urban Transport Project
TCO	Total Cost of Operations
TJ	TransJakarta
TL	Team Leader
ToR	Terms of Reference
TTW	Tank-to-Wheel
UITP	International Association of Public Transport
UNFCCC	United Nations Framework on Climate Change Convention
WP	Work Package
WTT	Well-to-Tank
WTW	Well-to-Wheel

EXECUTIVE SUMMARY

Background

The Government of Indonesia through the DKI Jakarta has prepared a project entitled "Zero Emission Buses in Jakarta". The project is being implemented with TransJakarta (TJ) over an 11-month period beginning February 2020, with the support of the C40 Cities Finance Facility (CFF).

The impact per vehicle unit in terms of avoided emissions is much larger for buses than for privately used vehicles. More than 110 e-motorcycles or 40 e-cars are required to achieve the same GHG mitigation impact as 1 Electric bus (E-bus). Therefore, Jakarta would like to electrify their buses first as the city embarks on the adoption of electric vehicles (EV).

Goals of the 100 E-bus Trial Phase

This project concerns the implementation of a fleet of 100 E-buses and associated e-charging infrastructure over TJ's network. For Jakarta, the trial project and its preparation are seen as an opportunity to learn about the technology, operation and business model of E-bus fleets.

The goal also includes developing a methodology for the selection of the routes and charging options and the pace of adoption of E-buses.

The E-bus is DIFFERENT from the internal combustion bus. It is NOT about CHOOSING THE "PERFECT VEHICLE", it is about "DESIGNING the system according to the needs of the service and the TECHNOLOGICAL FEATURES".

The bus technology system has the following three elements: Battery Technology (powertrain), Charging Stations and the Infrastructure and Power supply.

Findings

It is recommended to deploy big battery E-buses on the BRT routes. For the Non-BRT corridors with single bus or low-entry bus it is recommended to deploy medium battery E-buses with fast charging. Furthermore, some of the findings include:

- Route Characteristics play an important role in rolling stock selection;
- Total Cost of Ownership needs to be calculated at the route level;
- Government fiscal incentives are needed in the early push for E-bus deployment. China deployed a National Policy for deploying E-buses with subsidies;

- The infrastructure requirement cannot be an afterthought but needs to be planned at the very beginning;
- There is a need to plan for maintenance for E-buses;
- There is a need to understand vehicle availability in the market to avoid customization;
- New Actors should be considered – at Transantiago in Santiago, Chile, the implementation of E-buses meant that the energy companies (ENEL & ENGIE) carried out the acquisition of the fleet and sublet it to the operators.

TCO Analysis for E-buses with big battery size (324 kWh) was carried out for each of the 13 BRT routes and was then compared to the TCO for diesel buses. The TCO for E-buses is higher than for diesel buses by about 29 % (on average). The average TCO/km for E-buses is $ 1.32[1] whilst for diesel buses the average TCO/km is $ 1.02.

TCO Analysis for E-buses with medium battery size (180 kWh) was carried out for each of the 13 BRT routes and was then compared to the TCO for diesel buses. The TCO for E-buses is higher than for diesel buses by about 11 % (on average). The average TCO/km for E-buses is $ 1.13 while for the diesel buses the average TCO/km is $ 1.02.

TCO analysis was further calculated for the non-BRT routes (currently operating low entry or single buses) with Big-Battery and Medium-Battery sizes. The average TCO/km for E-buses with a big battery size is $ 1.49, for E-buses with medium battery size it is $ 1.26 and the TCO/km for diesel buses is $ 1.10. The average TCO for E-buses with bigger battery size is 36% higher when compared to the average TCO for diesel buses whilst the average TCO of E-buses with medium battery size is 13% higher when compared to average TCO of diesel buses.

TCO analysis was then calculated for Non-BRT routes (currently operating medium buses) with small battery size (135 kWh). The average TCO/km of E-buses is $ 0.94, and the average TCO/km for diesel buses is $ 0.61. The average TCO of E-buses is 53% higher when compared to the average TCO of diesel buses.

Using energy consumption of 1.3-1.5 kWh/km for the 100 E-buses, with an average running kms of 240 kms, it is estimated that the energy required on a daily basis will be in the range of 31 Mwh to 36 Mwh. Most of this charging will be overnight charging, with opportunity charging as required. Assuming that about 15% of the buses may be needed to be charged during peak load, the peak-loading power requirement will be about 2.25 MW.

A Phased Road Map for Electrification

A detailed road map for electrification needs to be put in place, ideally at the city level. This road map should take into account measures that will help overcome the challenges related to adoption of E-buses. Based on learning from across the globe, four major

[1] Conversion Factor 1 USD= 14,600 IDR.

factors are listed below that will help in moving towards complete electrification of the buses in the TJ network:

- National and local subsidies;
- Leases to reduce upfront (capital) investment;
- Optimized charging and operations; and
- Lifetime warranty of batteries.

Accordingly, a 5-phase road map for EV rollout in Jakarta has been suggested, as highlighted below:

- **Phase 1- Continuation of trials phase (About 5-10 E-buses)** – where an initial set of buses are deployed to create a quick demonstration value; this phase has to be short;
- **Phase 2-Scale up phase (About 100 E-buses)** – where subsidy incentives and persuasion help reach a tipping point;
- **Phase 3- Self-propelled phase (1000+ E-buses)** - where the technology has established itself and business models are in place towards large scale electrification;
- **Phase 4- Progressive Development Charging Systems phase (1000-2500 E-buses)** - where the technology has established itself and where the ability to try new technologies and business models as a stepping stone towards large scale electrification exists; and
- **Phase 5- Progressive Development Charging Systems and DKI e-fleet expansion** including other vehicles such as Motorcycles, Trucks and all buses.

The support of CFF to TJ considers only Phase 2 above: the scaling up from the pre-trial phase in 2020 to the provision of the 100 E-buses and associated charging infrastructure trial, in 2021.

Recommendations

Routes:

The following BRT and Non-BRT routes have been shortlisted for the deployment of E-buses:

- **BRT:** Route 1, 3, 4, 6, 8 and 10.
- **Non-BRT:** Route 1A, 7A, 7D, GR1, 6D, 1B, 6H, 9D, 5F and GR2.

Charging Strategy:

The charging strategy for BRT and Non-BRT routes should be selected based on the battery size. In case a big battery size is selected (>300 kWh), it can serve a distance of 230 kms in single charge and depot charging alone is recommended. One (1) charger for two buses with a power rating of 50-100 kW is recommended.

In case a medium or small battery is selected to serve a distance of 230 kms, depot charging and opportunity charging (Fast Charging) at terminals is required. One (1) charger for two buses with a power rating of 50-100 KW and one (1) fast charger for five buses with a power rating of about 150 KW is recommended.

Early Technical Decisions by DKI Jakarta and TJ

It will be important for the DKI PIU to agree on the key technical conclusions of the Technical Study, particularly in respect of selected routes and depots. A list of Key Decisions would be as follows:

- Finalize routes selected for deploying E-buses;
- Agree on the charging strategies and charger specifications;
- General agreement around fleet size and specifications (bus length, battery size and capacity); and
- Finalize outline selection of operators.

1. INTRODUCTION

1.1 Background

The Government of Indonesia through the DKI Jakarta has prepared a project entitled "Zero Emission Buses in Jakarta". The project is being implemented with TransJakarta (TJ) over an 11-month period beginning February 2020, with the support of the C40 Cities Finance Facility (CFF).

The impact per vehicle unit in terms of avoided emissions is much larger for buses than for privately used vehicles. More than 110 e-motorcycles or 40 e-cars are required to achieve the same GHG mitigation impact as 1 E-bus. Therefore, Jakarta would like to electrify their buses first as the city embarks on the adoption of electric vehicles.

1.2 Project Scope

The City Government intends to completely 'electrify' commercial vehicles used for public transport in Jakarta. This project is the implementation of a fleet of 100 E-buses and associated e-charging infrastructure over TJ's network. For Jakarta, the trial project and its preparation are seen as an opportunity to learn about the technology, operation and business model of E-bus fleets. A recent study[2] concluded positive about the cost competitiveness of E-bus operations for TJ and recommended conducting a detailed technical and financial analysis for the roll out.

1.3 Terms of Reference

Details of the ToR are provided in Annex 1.

In Activity 2.1.1 the assessment is conducted at a detailed level and a set of recommendations are made. Subject to approval of the Study findings on routes for the 100 E-bus Trial, the technical evaluation will be further developed during Activity 2.2 Business Case, in September 2020.

1.4 Data Collection

The data collection focuses on the following aspects:

- Bus Operations Data obtained from TJ;
- Review of existing studies carried out for implementation of E-buses in Jakarta;
- Available literature on urban E-bus systems – Battery Chemistry;

[2] Grutter Consulting, 2019. E-Buses for BRT Corridors 1 and 6 of TransJakarta.

- Preliminary market research around E-bus manufacturers and charging stations; and
- Learning from around the World about the implementation of E-buses.

1.5 Purpose of this Report

The purpose of the Report for WP 2.1.1 is as follows:

i. Gather relevant information from all available sources; and
ii. On the basis of the Study findings, prepare the technical aspects of the project to a degree that allows the city to make correct decisions and potential bidders to prepare a robust proposal.

1.6 Main Implementation Steps for the Technical Study

The process to compile information for the Technical Study is shown in Figure 1. As noted, several important components of this Report will be elaborated further in the WP 2.2 Business Case and thereafter in the WP2.3 Procurement Phase.

Figure 1: WP 2.1.1 Main Sequential Steps for 100 E-Bus Trial Technical Studies

WP 2.1.1: Mobilisation, Data Collection from DKI and TJ

↓

WP2.1.1: Examination of E-bus Pre-Trial results (This Report)

↓

WP2.1.1: Recommendations for Design of E-bus Power Supply Options for 100 E-bus Trial (This Report)

↓

WP2.2.1: TJ BRT and Non-BRT Route Analyses and elaboration of TCO/Km per route (This Report)

↓

WP2.1.1 Recommendations for E-bus Fleet and Vehicle Standards for 100 E-bus Trial (This Report)

↓

WP2.1.1 Rapid Approval by DKI PIU of Choice of Technology, Routes and Selected Operators for a 100 E-bus Trial commencing in 2021 (Next Step: by end August 2020)

↓

WP 2.2 Refined Development of Technical Approach through further appraisal (*Business Case phase)* and elaboration of specifications *in* WP2.3 Project Procurement (Final Step:- October/ November 2020)

Source: Consultant Team

1.7 Structure of the Report

This report introduces the Technical Study in Chapter 1. This is followed by a brief examination of the results of the pre-trial phase in Chapter 2. Chapter 3 provides an examination of current bus operation on selected TJ routes. This is followed by a review of reference documents and existing E-bus studies in Chapter 4.

Prior to the launch of market (Operator) surveys in Jakarta[3], Chapter 5 provides some details international market analysis of E-buses, and charging infrastructure in Annex 4 and Chapter 6 provides some details of E-bus Manufacturers. An overview of the phased approach to E-bus Development in Jakarta and a tentative road map is provided with the focus on Phase 1 E-bus Pre-Trial and Phase 2: the 100 E-bus Trial is provided in Chapter 7.

An analysis and detailed recommendations for E-bus routes (BRT and Non-BRT) is included in Chapter 8 as well as a comparative TCO/km per route is provided for E-buses and diesel-powered buses. Initial identification of operators for BRT and Non-BRT routes is indicated. Chapter 9 provides recommendations for design of E-bus power supply options and Chapter 10 provides commendations for fleet and vehicle standards. Finally, Chapter 11 outlines the next steps including key decisions that should be made by DKI Jakarta and TJ to advance to the next Business Case preparatory phase of the 100 E-bus Trial.

The following Annexes supplement the main report:

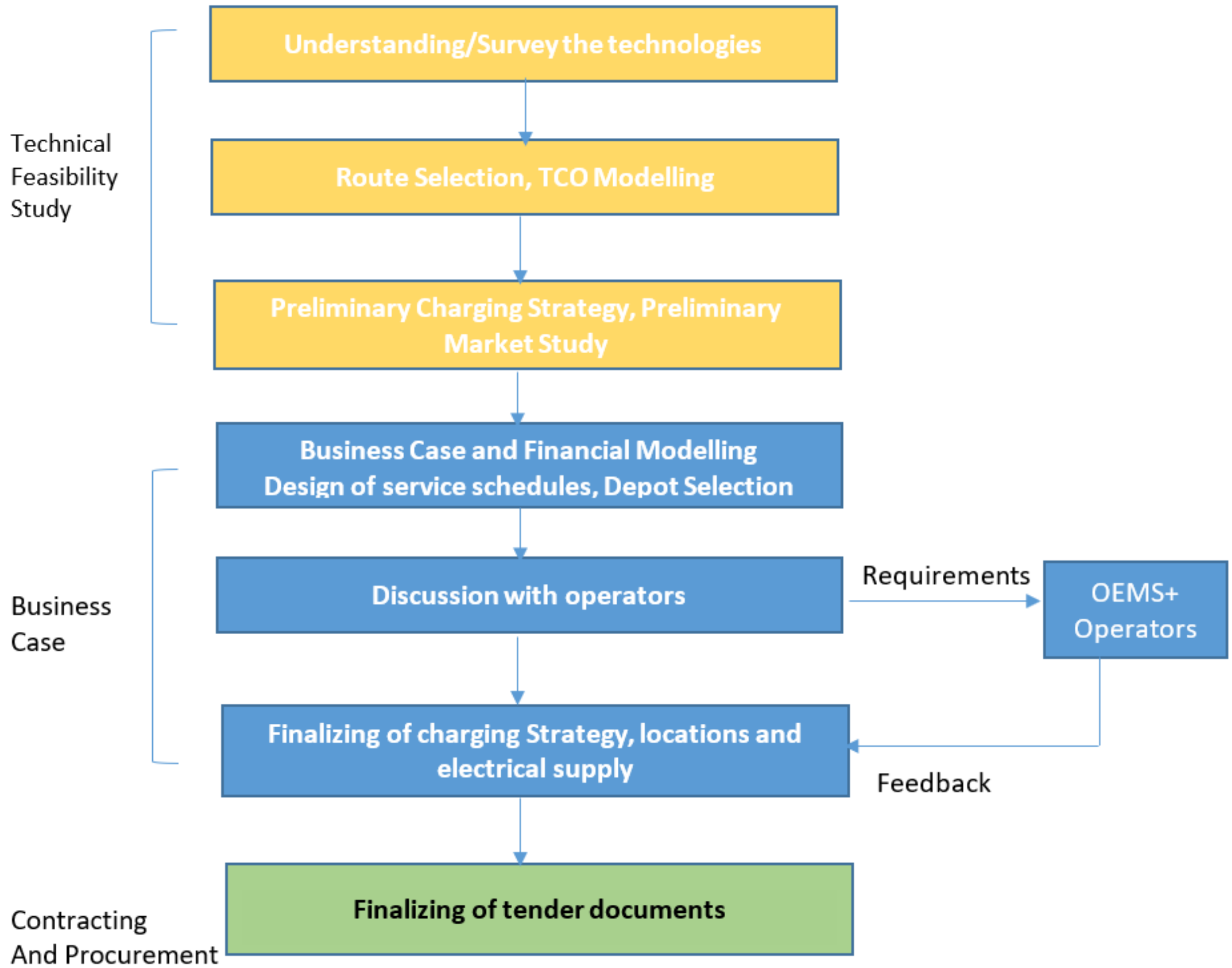
Annex 1 Technical Feasibility ToR;
Annex 2 E-bus charging devices;
Annex 3 Market Research Questions for E-bus Suppliers and/or Operators; and
Annex 4 Bibliography.

1.8 Methodological approach

E-buses are a fast-evolving technology as compared to Diesel/CNG buses, which directly impacts operational aspects. Both authorities and operators are still in a learning phase and the use of battery buses is a paradigm shift in city bus operations. Any project and phasing structure must take into consideration the technical and operational challenges that come with the introduction of E-buses. The technical feasibility should focus on understanding the technologies and route selection. Business case phase will develop different scenarios and finalize the charging strategies in conversation with operators and OEMs followed by contracting and procurement.

[3] Completed July 2020.

Figure 2: Approach for E-bus adoption and deployment



Source: Consultant Team

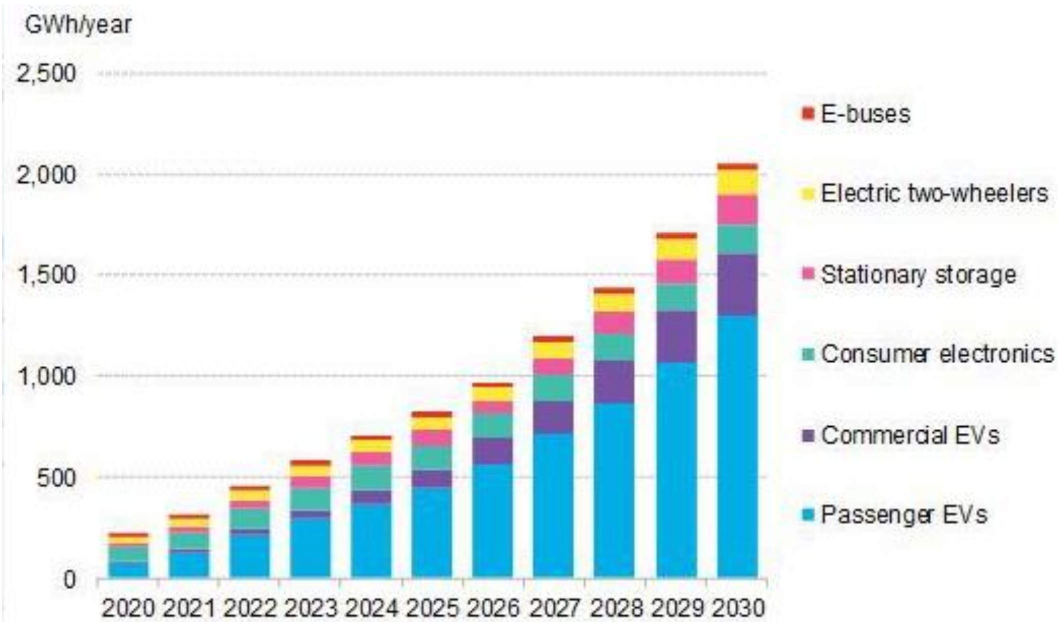
1.8.1 Technology Mix

The Li-ion battery is likely to dominate the EV market for the next 10 years. This could be attributed to the fact that this technology is well established, it's been commercially deployed across multiple geographies and it being scaled up in manufacturing also. There is a good understanding on the performance and its long-term durability. The supply chain has been well established, and this would be a hindrance for new technologies. The viability in urban bus space for the alternatives technologies is to be clearly understood and their applications for buses is still in very nascent stage.

More advanced chemistry that is likely to enter the market is the lithium-metal solid state battery. This technology has been prototyped by various companies and research groups however the operations are yet to be proven. In addition, there have been recent developments in battery design and thermal management to cut the costs of the pack and module components. Two examples are the CATL's cell-to-pack technology and the (BYD) "Blade Battery" that aim to remove the intermediary module components, thus reducing pack costs and increasing energy density by up to 20%.

As per the Bloomberg NEF Electric Vehicle Outlook 2020 executive summary, EV battery demand has been slower in 2020 and the shipments so far have been lower by 14% in comparison to 2019 for the same period. However, it is estimated that by 2030 the demand will grow to 1,755 GWh. It is also very likely that by 2024 the battery pack prices will go down below $ 100/kWh on a volume-weighted average basis, this is also attributed to the introduction of new cell chemistries and manufacturing equipment and techniques. Lithium supply looks sufficient for the 2020s, but new cobalt mining capacity will need to be enhanced to ensure the supply chain is not impacted.

Figure 3*:* Energy requirement for different vehicles by 2030



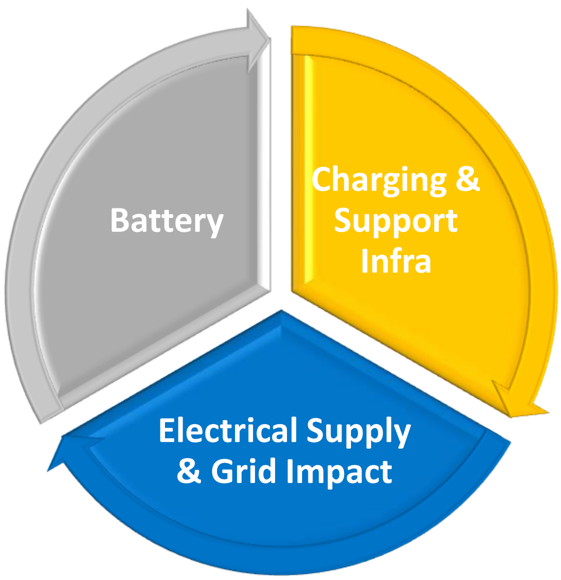
Source: BNEF EV Outlook 2020, Executive Summary

By 2030 the prices are further likely to go down to $ 61/kWh. By 2023, new technologies like NMCA will start to enter the EV market. This provides higher energy densities and a longer cycle life.

As an example, currently, the battery prices in India are around $ 250/kWh and battery prices account for about 40% of the vehicle cost. With the projected battery costs likely to touch $ 100/kWh at the minimum, the E-bus prices are likely to reduce by at least 20-25% by 2024-25.

The technology mix includes the following relevant components that need to be studied in detail to select the routes and depots for the electrification of the first 100 E-buses. Technology aspects look at the battery technology, charging stations and infrastructure, as well as electrical supply and the grid impact.

Figure 4*:* Components of E-Bus Technology



Source: Consultant Team

To determine battery composition and size, the following aspects need to be studied:

- Charging technology
    - Overnight charging vs Opportunity Charging
    - Charging standards
- Broad level feasibility assessment of bus routes in Jakarta and feasibility of E-buses and charging infrastructure.
- Availability of depot infrastructure for charging spaces
- Electric supply for charging infrastructure
- Impact on grid
- Finalization of E-bus and charging infrastructure specifications

1.8.2 Operational Needs - Key Questions to be answered

Some of the key questions that need to be answered for fitting E-buses into city operations include:

- How does the estimated range of battery- E-buses compare to the expected daily utilization of diesel or CNG buses for city operations/ services?
- How do route and operational characteristics affect the bus energy consumption and the range of E-buses?
- Which routes should be electrified first, based on the economic and operational assessment?
- Where and when should E-buses be charged?
- What will be electrical power consumption and the impact on the grid?
- Is a support infrastructure required at the depots to support the charging of E-buses?

The study looks at available data from TJ and market research (specification of battery sizes and price points) related to all three aspects for developing recommendations related to selection of routes and charger type, location of charging infrastructure to support specific goals and finally the impact on the grid and the necessary power supply.

2. ASSESSMENT OF THE PHASE 1: E-BUS PRE-TRIAL RESULTS

2.1 Introduction

The E-bus Trial runs were conducted from September to December 2019 with 2 buses of BYD through a local company, PT. Bakri Autoparts and 1 bus from PT. Mobil Anak Bangsa (MAB). Two types of buses, single (12 m) and medium (9 m) were deployed. MAB and the Chinese electric automaker BYD Automobile were among E-bus manufacturers that signed memorandums of understanding with TransJakarta to operate E-buses for this trial run.

According to the bus specification, the single bus deployed in the trial run has a length of 12.00 m, a width of 2.55 m height of 3.20 m and is equipped with 31 seats. To simulate maximum passenger loading, the E-bus was loaded with 16 tons (in gallons of water). The battery of the single bus, the BYD model “K-9”, consists of lithium iron phosphate and reaches a distance of 250 km (155 miles) for a single charge.

The trial runs were conducted in three locations: a) Monas of Central Jakarta, b) Ancol of North Jakarta and c) Taman Mini of Eastern Jakarta.

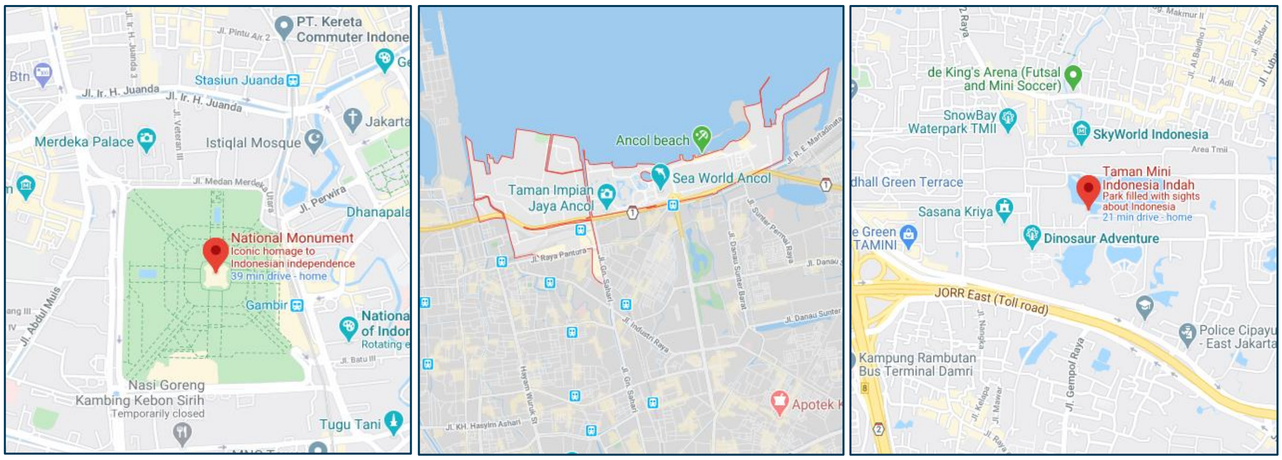
Figure 5*:* Images from E-bus pre-trial runs in Jakarta in 2019

Source: TransJakarta

2.2 Pre-Trial Details

All the pre-trial runs were conducted in the closed tourist areas. These locations were selected because the bus did not have permits to transport passenger commercially.

Figure 6: Location of E-bus pre-trial runs



Location 1. Monas (Central Jakarta) Location 2. Ancol (North Jakarta) Location 3. Taman Mini (Eastern Jakarta) ; Source: TransJakarta

The single bus operated for a total duration of 192 hours and 3 minutes over a total distance of 1,385.3 kms. The total battery consumption was 626.2% of its capacity of 324 kWh.

The medium size bus operated for a total duration of 204 hours and 38 minutes over a total distance of 1,509.1 kms. The total battery consumption was 899.1% of its capacity of 135 kWh.

Table 1: Operations of E-bus pre-trial runs

Bus Type	Battery Capacity (kWh)	Operation Hours (Total Hours)	Total Distance (km)	Battery Consumption (%)
Single (12m)	324	192:03:00	1,385.3	626.2%
Medium (9m)	135	204:38:00	1,509.1	899.1%

Source: PT. Trans Jakarta, March 2020

According to TJ for the single bus the maximum distance travelled during trial was 179 kms in 14 hours and the battery State-of-Charge (SoC) was 40%. For the medium bus, the maximum distance travelled during trial was 149 kms in 17 hours and the battery State-of-Charge (SoC) was 20%.

The total battery consumption is calculated by multiplying the battery capacity by the battery consumption percentage. The result for this pre-trial is a total battery capacity of 2,028.9 kWh for the single bus and 1,213.8 kWh for medium bus.

The energy consumption per km can be estimated about 1.465 kWh and 0.804 kWh for 12m and 9m bus respectively.

Table 2: Energy consumption during pre-trial runs of E-buses

Bus Type	Operation Hours (Total Hours)	Total Distance (km)	Battery Consumption (kWh)	Energy Consumption (kWh/km)	Mileage (Km/kWh)
Single (12m)	192:03:00	1,385.3	2,028.9	**1.465**	**0.683**
Medium (9m)	204:38:00	1,509.1	1,213.8	**0.804**	**1.244**

Source: Calculations based on data from PT. TransJakarta, March 2020

2.3 Recommendations for Phase 1 (Pre-Trial phase)

It is recommended that the extension of the pre-trial runs planned for the remainder of 2020 be carried on bus routes identified in the study with passengers on-board. It will be good to understand the performance of the E-buses in actual conditions along the selected routes, including the actual weather conditions. This will help in understanding the battery performance, available range and charging schedule. Based on this, the energy consumption and operations can clearly be understood, and the information will serve in due course as an input to the preparation of the tender documentation.

3. OVERVIEW OF CURRENT TRANSJAKARTA BUS OPERATIONS

3.1 Introduction

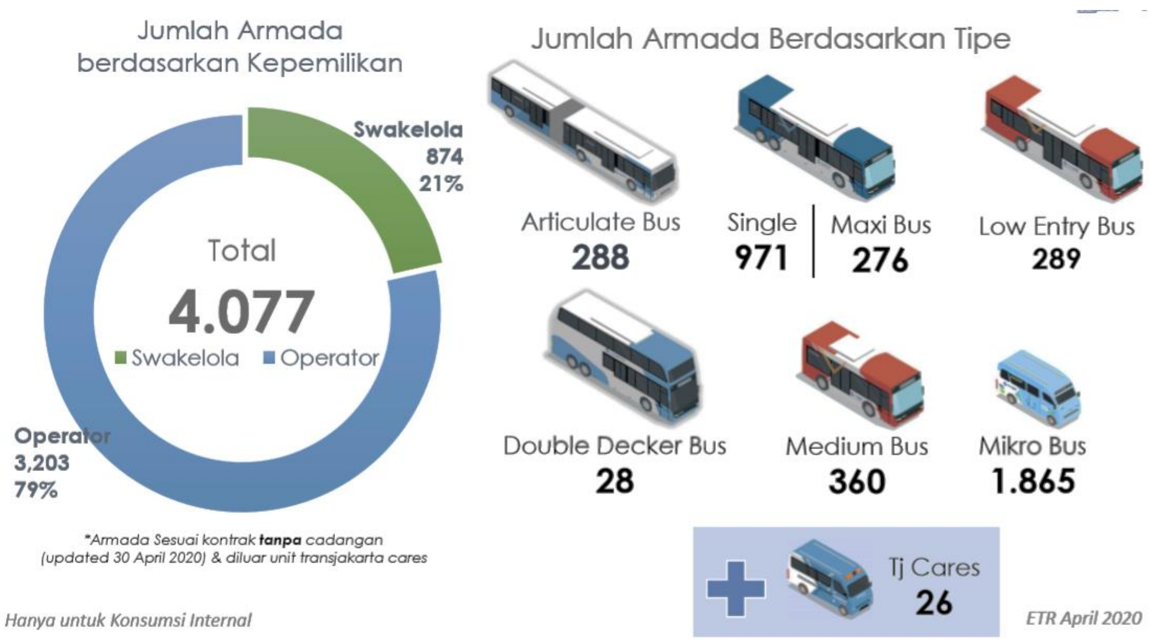
This section includes the following aspects: Bus Operations Data obtained from TJ and analysis with a focus on routes and depots.

3.2 Data Collection

Currently 4,077 buses operate on a daily basis in Jakarta. Of the total, 874 buses are self-managed while operators run 3,203 buses.

In addition, 26 TJ cares (to help transporting people with disabilities from certain points to nearest BRT stops) are operated in the City.

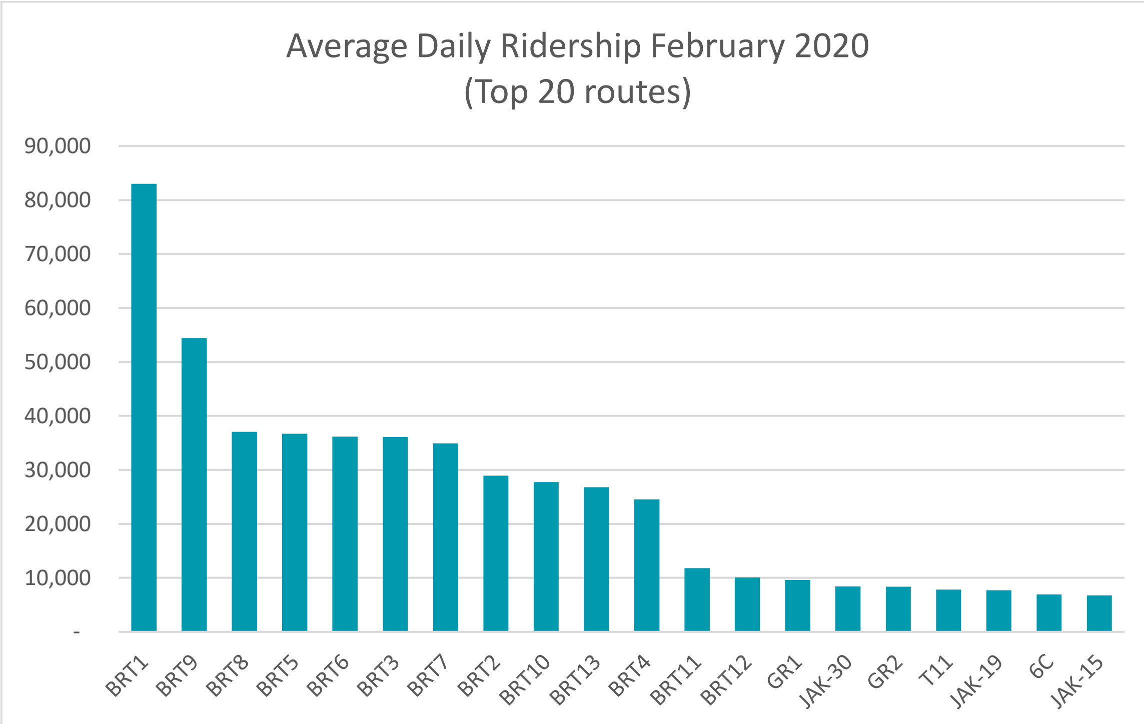
Figure 7: Types of bus operations



Source: TJ, 2020

Based on the data shared by TJ, February 3, witnessed 1,838 (maximum) number of buses operational in February. Based on the ridership for the entire month of February 2020, top 20 routes have been identified with highest average daily ridership.

Figure 8: Ridership for top 20 routes



Source: Consultants Estimates based on data from TJ February 2020

3.3 Depot Locations

Based on data from TJ, as shown in the table below, 15 depots are used by 9 operators. The average fleet utilization is about 78.3%. This indicates that either large number of buses is in maintenance or that the demand is much lower. The depot size for each location has been estimated based on 23 buses per acre taking into consideration parking, maintenance, administrative and driver facilities.

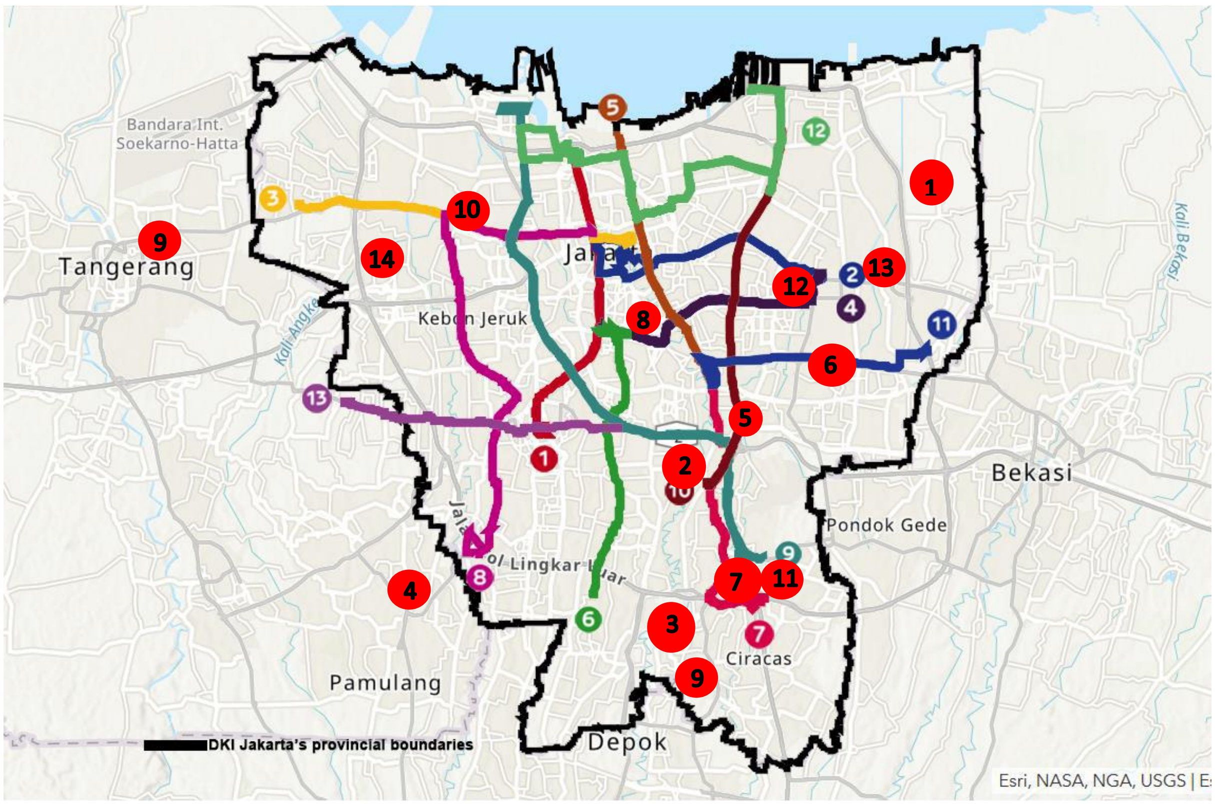
Table 3: Location of Depots and estimation of average size of depots

No	Depot	Operator	Fleet size	Average Operation	Average Depot Size (Estimated in acres)
1	Cakung	Perum PPD	100	81	4.3
2	Cawang	Perum PPD, TJ Swakelola	362	285	15.7
3	Cijantung	Mayasari Bakti, Kopaja	589	323	25.6
4	Ciputat	Perum PPD, Bianglala Metropolitan	197	182	8.6
5	Depok	Perum PPD	62	59	2.7
6	Klender	Mayasari Bakti, Steady Safe	205	258	8.9
7	Kp. Rambutan	TJ Swakelola	150	140	6.5
8	Pegangsaan	Pahala Kencana	15	14	0.7
9	Perintis	TJ Swakelola	132	123	5.7
10	Pesing	TJ Swakelola	96	6	4.2
11	Pinang Ranti	TJ Swakelola	169	144	7.3
12	Pulogadung	Perum PPD	80	72	3.5
13	Pupar	Perum Damri	46	44	2.0
14	Rawa Buaya	TJ Swakelola	90	58	3.9
15	Tangerang	Perum PPD	50	47	2.2
Total			2,343	1,836	

Source: Consultant Team, TJ data

The map below shows the location of BRT corridors and Depots in Jakarta. The southern and western part of the city has high concentration of depots.

Figure 9: BRT corridors and location of Depots



1 Existing Depot locations

The lines shown are different BRT corridors

Source: TransJakarta

4. REVIEW OF REFERENCE DOCUMENTS AND EXISTING E-BUS STUDIES

4.1 Introduction

This section includes the following aspects: Review of existing studies carried out for implementation of E-buses in Jakarta as well as a review of available literature on urban E-bus systems – Battery Chemistry.

4.2 Findings from Existing E-bus Studies

As per Grutter Consulting: 'it is recommended to install fast chargers for E-buses. Fast chargers would allow smaller batteries with less capacity, as they can partially be recharged manually with high-powered chargers for 15-30 minutes once or twice daily. Such E-buses would result in lower life-cycle TCOs than diesel or CNG Euro III units (under the assumption that conventional units also use Euro 3 fuel with 500ppm Sulphur)'.

Based on the Rebel Group study, battery- E-buses technology is nascent in Indonesia. The Phase-1 of the project aims to providing an understanding of the technology, of the integration of E-buses in current operations, of cost effective/sustainable solutions and of possible business model structures to develop a bankable Business Case that renders the lowest TCO cost per E-bus/km. The TransJakarta pilot tests are giving insights into the performance of different E-buses.

4.2.1 Consultants Comments for the 100 E-bus Trial Phase Preparation

The 100 E-bus Trial permits a more comprehensive route level analysis and review of route operation and charging requirements, which can vary considerably according to various factors. Hence the final recommendations on route charging (following further analysis during the Business Case phase) may differ.

It is recommended to conduct the Pre-trial phase with passenger loading and AC to understand the actual energy consumption and performance under weather conditions prevailing in Jakarta.

4.3 Battery Technology

Batteries have been the major energy source for EVs for a long time. Different battery technologies have been invented and adopted for different use. The most important criteria are to have high energy density and high-power density. High specific energy is required from a source to provide a long driving range whereas high specific power helps to increase the acceleration. The U.S. Advanced Battery Consortium (USABC) has set the performance for EV batteries as shown in the table below:

Table 4: Performance goal of EV batteries as set by USABC

	Parameters	Mid-Term	Long-Term
Primary	Energy density (C/3 discharge rate) (Wh/L)	135	300
	Specific energy (C/3 discharge rate) (Wh/kg)	80 (Desired: 100)	200
	Power density (W/l)	250	600
	Specific power (80% DOD/30 s) (W/kg)	150 (Desired: 200)	400
	Lifetime (year)	5	10
	Cycle life (80% DOD) (cycles)	600	1000
	Price (USD/kWh)	<150	<100
	Operating temperature (°C)	−30 to 65	−40 to 84
	Recharging time (hour)	<6	3 to 6
	Fast recharging time (40% to 80% SOC) (hour)	0.25	
Secondary	Self-discharge (%)	<15 (48 h)	<15 (month)
	Efficiency (C/3 discharge, 6 h charge) (%)	75	80
	Maintenance	No maintenance	No maintenance
	Resistance to abuse	Tolerance	Tolerance
	Thermal loss	3.2 W/kWh	3.2 W/kWh

Source: USABC

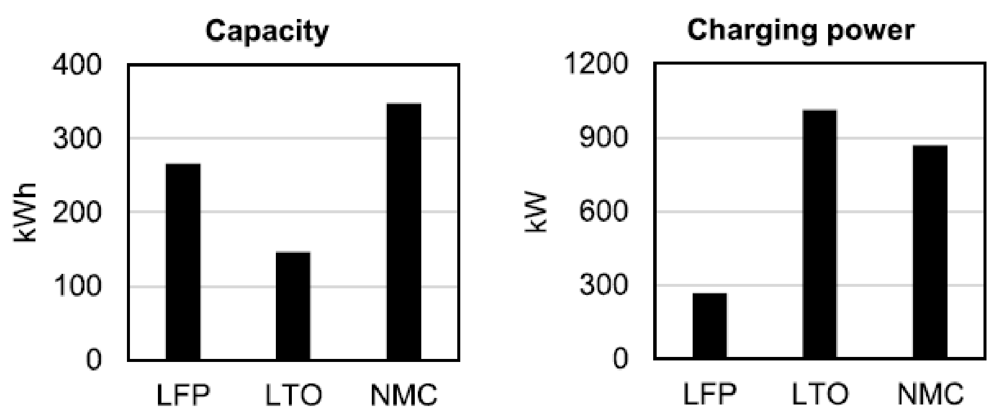
Batteries used in EVs consist of several electrochemical cells that are coupled in parallel and in series to form a battery with a specific voltage and capacity. Batteries age over time as a result of multiple charging and discharging cycles. The ageing of a battery causes a higher internal resistance and a loss of storage capacity. A battery is deemed not suitable for EV/bus application, if the remaining storage capacity is 80 % of the initial capacity**.**

4.3.1 Battery Chemistry

Currently, lithium iron phosphate (LFP), lithium titanium oxide (LTO) and lithium nickel manganese cobalt oxide (NMC) are the most common cell types encountered in E-buses.

- LTO permits the highest charging power of all technologies, however, owing to its comparatively low energy density, it has the lowest capacity. LTO is only applicable in opportunity-charging systems.
- NMC enables the largest capacity as well as high charging power and therefore lends itself both to AC and DC.
- LFP is only feasible in slow-charging situations.

Figure 10: Capacity and Charging Power of different battery chemistry



Source: Göhlich, Dietmar & Fay, Tu-Anh & Jefferies, Dominic & Lauth, Enrico & Kunith, Alexander & Zhang, Xudong. (2018). Design of urban E-bus systems. Design Science. 4. 10.1017/dsj.2018.10.

4.3.2 Battery Size/Capacity

The average mileage for the E-buses in Jakarta would range between 60,000 kms to 80,000 kms annually along different routes. There will be buses that would serve long distance and buses that would serve more as feeder services. The scheduled route km for the E-bus can vary from 180 km/day to 240 km/day over 16-hour operation period.

It is important to understand the actual battery capacity available for the actual operations. This will determine the exact range of the E-bus. This is crucial in understanding the replacement ratio (number of E-buses required to replace a diesel bus operating along a route), the need for opportunity charging and type of charging infrastructure.

The Grutter study does not look at route level analysis for determining the suitability of the routes for E-bus deployment. The technology selection depends on the routes and schedules. It is important to take into consideration the usable range after taking into consideration the minimum Depth of Discharge, use of AC and passenger loading on the performance of the battery. In addition, market research will help understand the options made available by OEM for E-buses. It is important to understand the battery chemistry, size, charging options offered by different OEM and the extent to which they can customize for TJ to serve the requirements.

ICCT study has shown that the theoretical range of a 320 kWh battery is about 382 kms. With a 20% SoC reserve consideration it comes down to 306 kms, and furthermore if it is an AC bus with 100% passenger loading the range is further reduced to 237 kms. Unless these factors are taken into consideration the operational planning will not be accurate. It is important for a transit agency to be aware of this, irrespective of the contracting model utilized.

Table 5: Factors for estimating range of E-buses

Reduction in Range	Factor to be used
Maintain 80% depth of discharge	0.8
100% passenger loading	0.85
AC Bus	0.92

Source: ICCT Simulation Study, Bengaluru

4.3.3 Charging Equipment

- Slow Charging is typically done at Depots while Fast Charging is done at Terminals and major points accessible by the buses in the city.
- Slow Charging is typically done overnight, whilst Fast Charging is prevalent more during the day-time, when the bus operations are at high levels.

Table 6: Comparison between Depot Charging Only vs Depot Charging + Opportunity Charging

Depot Charging Only/Slow Charging	Depot Charging + Opportunity Charging
• Lesser cost of charging infrastructure • May need extra fleet to cover along high demand corridors	• Need additional charging infrastructure. Cost may go up. • Adherence to service schedules with lesser fleet size

• High upfront cost due to large battery	• Lower battery size can be used resulting in lower bus cost

Source: Consultant Team

The applicability of depot only charging strategies is limited by the total number of available buses and the distance to travel to depots for charging.

Opportunity charging comprises the recharging at bus depots and at selected terminals. If the ratio between total mileage per day, Journey time, and Turn around or idle time at terminals with charging stations is kept within certain limits, opportunity charging can facilitate significantly higher mileages per day of operation without changing the mode of operation, i.e. additional drivers or buses are not necessary. Furthermore, opportunity charging requires smaller batteries, which increases the passenger capacity of the buses involved, while significantly reducing the capital cost.

However, opportunity charging requires additional charging infrastructure outside the bus depots (charging stations with high charging power), which makes the implementation significantly more complex and difficult. Furthermore, opportunity charging is not applicable on bus routes where long delays frequently occur. On the other hand, opportunity charging significantly reduces the amount of energy to be recharged at a bus depot and the grid connection power that is required.

4.3.4 General design of overnight charging and opportunity charging

The charging technologies are directly linked to the charging strategy applied, that primarily defines the time availability for recharging, energy requirement and necessary charging power. Different charging powers are used to define slow and fast chargers. For the purposed of our study, charging technologies are divided into:

- **Slow charging with a charging power of less than 50 kW (20 – 50 kW), and**
- **Fast charging with a charging power of 50-150 kW**

E-bus and charging infrastructure are required to be tested, integrated and validated before operation for optimum charging experience. Standards followed by both chargers and buses need to be same. Hence, ensuring compatibility will be the major issue. Charging infrastructure is a critical service for the operation of E-uses. Hence by having a dedicated operator for this may ensure best services for compliance, specifically to full scale operational route planning requirement, that vary for each E-bus operator.

The charging power defines the technology for connecting E-buses to the charging infrastructure. These are

- Plug-in systems, which consist of plugs and sockets or inlets (also referred to as "gun charging")
- Automated contact systems, and
- Inductive charging systems.

Standardization concerns three major aspects, which are

- The physical design of the connecting components,
- The charging mode (e.g. slow or fast charging), and
- The communication between the vehicle and the charging infrastructure.

The standards are necessary to enable the recharging of E-buses of different manufacturers at the same charging station or charging device. Currently, three standards compete globally, namely

- The Japanese CHAdeMO standard,
- The European Combined Charging Standard (CCS), which is also applied in North America, and
- The Chinese GB/T standard or protocol.

In addition, a new global standard called Chaoji is being developed, in collaboration between CHAdeMO Association (Japan) and China Electricity Council. Version 3.0 of the protocol was released on April 25, 2020. It is a 600-amp, 900-kW, bi-directional DC quick-charging standard.

The OppCharge standard is a non-official standard set-up by European bus and charging infrastructure manufacturers. It describes the DC charging of utility vehicles at charging stations with a charging power of more than 150 kW using automated contact systems.

4.4 MEMR Regulation 13/2020

Ministry of Energy and Mineral Resources (MEMR) Regulation no. 13/2020 allows private sector and enterprises to develop E-vehicle infrastructure, which one of them is recharging station (Stasiun Pengisian Kendaraan Listrik Umum/SPKLU). These enterprises must follow the procedure stated in the regulation.

TJ has a potential to develop charging stations, which for the first step is dedicated for the 100 e-bus trial. This has two-fold benefits, reducing burden of initial investment carried by bus operators as well as ensuring that bus operators will have equal electricity price for the E-buses. With the negotiated bulk price for electricity, TJ will be able to manage the contracting scheme, particularly related to electricity bill with bus operators. The bulk price and selling price of electricity is further regulated by MEMR. This opportunity and its benefits should be explored further.

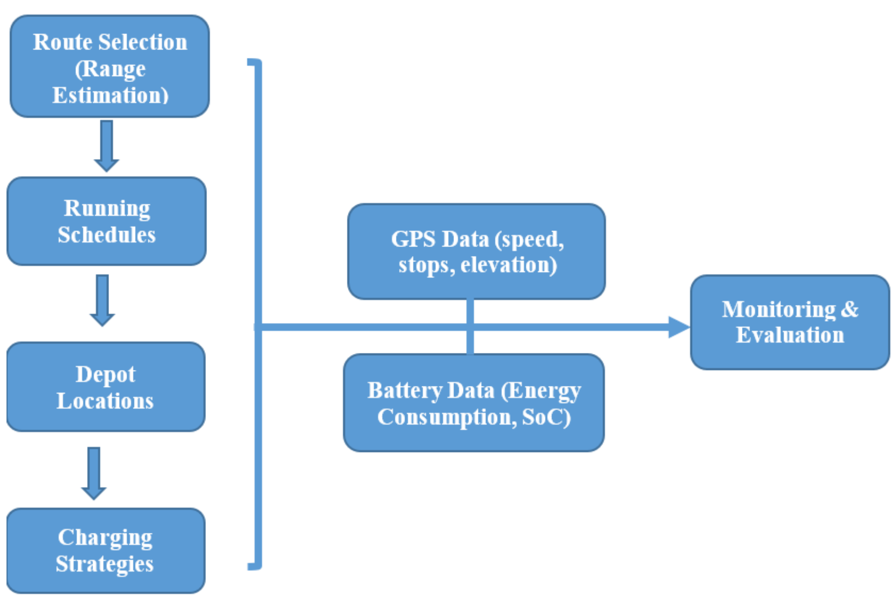
4.5 Recommendations

Multiple battery sizes ranging from 135 kWh to 324 kWh have been deployed in different cities across the world. The dominant battery chemistry that have been used have been LFP and NMC. The following guidelines should be followed in the E-bus transitioning:

- All routes need to be redesigned taking into consideration, range, charging infrastructure, and space and power availability, etc.;
- Route specific analysis is required to understand the exact charging strategy and bus battery requirement;
- There are issues related to battery and bus de-gradation. The city government should ensure proper contracting terms and conditions to engage with manufacturers for replacing the buses and batteries;
- A battery replacement clause is a must in the requirement (when battery goes below 80% efficiency) due to issues related to Battery Degradation;
- The charging infrastructure should be inter-operable. This could pose a problem if there are different variants of buses used in future;
- The bus operator needs to be selected first, so that the charging infrastructure company understands which charger to install.

The figure below presents the overall approach for deploying E-buses.

Figure 11*:* Approach for operationalizing and performance monitoring of E-buses



Source: Consultant Team

5. LESSONS LEARNED FROM E-BUS ROLLOUT IN INTERNATIONAL CITIES

5.1 Introduction

This section includes the following aspects: learning from around the world about the implementation of E-buses.

5.2 Singapore

Singapore aims at having a fully E-bus fleet by 2040. The first batch of 10 E-buses has already started plying Singapore's streets and 50 more vehicles will be added in 2020.

Public transport operators SMRT, Tower Transit and Go-Ahead Singapore were involved in the launch of these E-bus services. BYD, Yutong and ST Engineering manufacture buses. Up to 80 passengers can be welcomed on board, 28 seated and 52 standing.

ABB is supplying power to these vehicles by providing 450kW fast charging stations based on the opportunity charging (OppCharge) platform, the solution will allow the E-buses to be quickly partially recharged in less than ten minutes at key interchanges with an automated rooftop connection.

5.3 Pune, India

In January 2019, Pune became the first Indian city to adopt E-buses and Bhekrai Nagar the country's first all E-bus depot. As of November 2019, up to 133 EVs have been deployed across the city in the first phase of its E-bus programme. The buses are owned, operated, and maintained by their manufacturer, the Secunderabad-based Olectra Greentech and technical partner BYD.

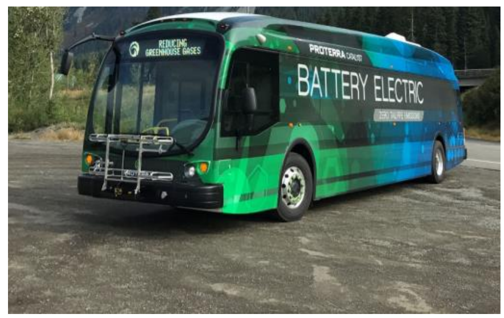
The city has engaged with the operator Olectra to operate the E-buses on a per-kilometre. Olectra is then responsible for running all operations, maintaining the bus, recruiting and training drivers.

5.4 Santiago, Chile

Chile has about 400 E-buses launched in Latin America's first E-bus corridor in Santiago with a range of up to 250 km.

In Transantiago, Santiago, Chile, the implementation of E-buses meant that the energy companies (ENEL & ENGIE) carried out the acquisition of the fleet and sublet it to the operators.

5.5 Los Angeles, USA



The city of Los Angeles will receive the first of a total of 155 E-buses to be delivered over the next two years starting in March 2020. The procurement is part of the California city's plan to fully electrify its bus fleet by the start of the 2028 Summer Olympics. The Los Angeles Department of Transportation (LADOT) had ordered 130 E-buses from BYD, another 25 from Proterra.

Proterra, a leading innovator in heavy-duty electric transportation, has been selected by the California Department of General Services as a vendor to supply Proterra® battery-E-buses and Proterra charging systems for the statewide contract.

5.6 Gothenburg, Sweden

Volvo Buses has received the largest single order for E-buses in Europe. Volvo Buses will deliver 157 electric articulated buses to Transdev starting in 2020. The buses will operate on a number of routes in Gothenburg. All of the buses will be of the recently launched 7900 Volvo Electric Articulated model. The Volvo Electric Articulated can carry 150 passengers. The buses will be charged at quick-charge stations along the route, using the industry common charging interface OppChargeTM.

5.7 Shenzhen, China

Shenzhen's plan to create an all-electric public bus fleet began in 2013. To achieve the goal, a Shenzhen public bus operator is granted a total of 500, 000 Yuan (US$72,150) worth of subsidies every year for each vehicle that it runs – 400,000 Yuan from Shenzhen authorities and 100,000 Yuan from the central government per vehicle to encourage the use of E-bus nationwide.

With the city's 16,000 E-buses the total subsidy costs are at an unparalleled rate of 8 billion Yuan a year for the government. Shenzhen City has 32 charging operators, and by 2020, Shenzhen City is expected to have 8,246 fast-charging points for E-buses, capable of charging between 16,500 and 24,738 pure E-buses.

Shenzhen city has currently 3 operating companies:

- Shenzhen Bus Group
- Shenzhen East Bus Group
- Shenzhen West Bus Group

Shenzhen Bus Group is the largest with around 6,000 E-buses. The Shenzhen East and Shenzhen West have combined E-bus strength of around 10,000 buses. In Shenzhen, the utility companies own most of the charging infrastructure. This partnership has resulted in charging stations built along bus routes and coordinated charging times during which buses fully charge overnight, when electricity demand (and price) is lower.

5.8 Learning from the International Experience

A methodical approach is needed for the implementation of E-buses. Based on the successful deployment of E-buses across the globe the following learning is applicable for transitioning to E-buses.

- Route Characteristics play an important role in rolling stock selection;
- Total Cost of Ownership needs to be calculated at the route level;
- Government fiscal incentives needed in the early push for E-bus deployment. China deployed a National Policy for deploying E-buses with subsidies;
- Infrastructure requirement cannot be an afterthought but needs to be planned in the very beginning;

- There is a need to plan for maintenance for E-buses;
- There is a need to understand vehicle availability in the market to avoid customization; and

New actors and models should be permitted- at Transantiago in Santiago, Chile, the implementation of E-buses meant that the energy companies (ENEL & ENGIE) carried out the acquisition of the fleet and sublet it to the operators.

6. BRIEF REVIEW OF E-BUS MANUFACTURERS

6.1 Introduction

This section includes the following aspects: preliminary market research around E-bus manufacturers and charging stations (see Annex 3). The following table summarizes the specification of E-buses by various manufacturers.

Table 7: Overview of E-bus manufacturers

Parameters	Volvo 7900 Electric	Zhengzhou Yutong Bus Co., Ltd. (NEW E12LF)	Zhongtong Bus Holding Co., Ltd. (LCK6125EV)	Proterra Catalyst 40 foot E2 series	BYD (K9)	Xiamen Golden Dragon Bus Co. Ltd. (Pivot E-12)
Passenger capacity /Seats	80-105	75+2 (wheelchair)	45+1	40+1	Up to 35 seats	35
Dimensions (Length, Width & Height)	Length - 12m Width – 2.55m Height – 3.28m	12m	Length - 11.99m Width – 2.5m Height – 3.6m	Length - 12.95m Width – 2.55m Height – 3.40m	Length - 12.0m Width – 2.5m Height – 3.4m	Length - 12.1m Width – 2.55m Height – 3.3m
Speed	80 kph	70-85 kph	90 kph	105 kmph	70 kmph	69 kmph
Power Train details	160kW Electric Motor		Three-phase AC synchronous motor	220 kW peak permanent magnet drive motor	AC Synchronous 300 kW (150 kW×2) 180 kW (90 kW×2)	Direct-driven permanent magnet synchronous motor

Details on Suspension system and braking system	Suspension system - Electronically controlled air Suspension with kneeling function Braking system - Electronic Braking System (EBS 5) with Brake Blending function		Suspension system – Air suspension 2/4 Braking system – Electric air pumper; dual-circuit air brake; front disc and rear drum brake; air drier; ABS; and rear automatic adjustment arm	Suspension system -Multi-Link Air Ride rear suspension Braking system - Front & rear air disk brake	Suspension system – Front and Rear Air Suspension with kneeling mechanism Braking system – Disc Brake with ABS	Air Suspension Brake: Front/Rear Drum Type
Gross Vehicle Weight	11,400-12,000 kg	19,100 kg	18,600 kg	15,000 kg	18,000 kg	19,000 kg
Charging System	Opportunity charging, overhead, conductive, Pantograph on pole	Plug-in	Slow Charging	Utilizes standard J1772-CCS plug-in chargers	AC Charging	Plug-n/Battery Swap
Charge Rate	300 kW	60 kW	120 kW	120 kW	80 kW	140 kW
Charging time	3-6 min	5.5h	3-4 hrs.	3-4 hrs.	4-5 hrs.	4-5 hrs.
Battery	High capacity 19 kWh Lithium-Ion battery	Lithium Iron Phosphate having energy of 324kWh	Lithium battery of 3.2V/20Ah	660 kWh	Lithium Iron Phosphate having energy of 324kWh	Lithium Iron Phosphate 345 KwH

Source: Consultant Team

6.2 Charging Stations

Based on the international market survey, several charging devices have been identified. However, it is typical of an E-bus manufacturer to partner with a charging station manufacturer when offering the solution. In addition, the location of charging stations needs to be identified at the depots for overnight charging.

6.3 Findings

The following findings would be helpful for TJ to take into consideration while transitioning into E-buses.

- Schedule and route plans are the key to E-bus deployment;
- Demand for 9m buses is on the higher side, compared to 12 m buses;
- At least, 6 to 7 months are required for development and inspection;
- Operators should provide minimum 380V point at one location in the depot or 20 KV line;
- Interoperability would be key rather than standardization of buses;
- Operators should not define the technology selection but rather the performance requirement;
- Subsidy schemes should continue for next 4-5 years till TCO parity is achieved;
- Costing will depend on provision for 20 KV line, wiring, line availability, distance of 20 KV line and transformer, distance from transformer to charger. etc.;
- The manpower requirement for EV's would be similar to IC engine buses. Additional resources like a high voltage engineer, an electronics engineer would be needed.

7. A PHASED APPROACH FOR THE DESIGN OF E-BUS DEVELOPMENT

7.1 Introduction

It is considered important to outline the basis for the electrification at the outset. A detailed road map for electrification needs to be implemented, ideally at the city level. This road map should take into account measures that will help to overcome challenges related to the adoption of E-buses. Based on learning from project worldwide; four major factors will help in moving towards the complete electrification of buses:

- National and local subsidies;
- Leases to reduce upfront investments;
- Optimized charging and operation; and
- Lifetime warranty of batteries.

Based on the above measures, Shenzhen has been able to achieve 100 percent electrification of their bus fleet of over 16,000 buses within 7 years.

7.2 Development of a Road Map

Accordingly, a 5-phase road map has been suggested, as highlighted below:

- **Phase 1- Continuation of trial phase (About 5-10 buses)** – where an initial set of buses is deployed to create a quick demonstration value; this phase has to be short;

- **Phase 2-Scale up phase (About 100 buses)** – where subsidy incentives and persuasion help to reach a tipping point;

- **Phase 3- Self-propelled phase (1000+ buses)** - where the technology has established itself and business models are in place towards large scale electrification;

- **Phase 4- Progressive Development of Charging Systems phase (1000-2500 buses)** - where the technology has established itself and where the ability to try new technologies and business models as a stepping stone towards large scale electrification exists

- **Phase 5- Progressive Development of Charging Systems and DKI e-fleet expansion -** where other vehicles such as Motorcycles, Trucks and all buses are being included in the assessment and electrification.

The support of CFF to TJ considers only Phase 2 above: the scaling up from the pre-trial phase in 2020 to the provision of the 100 E-buses and associated charging infrastructure trial, in 2021.

7.3 Phasing Plan Approach

A tentative phasing plan is provided in the Table below. The overriding objective has been to set the Phase 2 100 E-bus Trial phase in the context of a gradually developing rollout plan, whereby the lessons learned, and experiences obtained of each Phase feed into the following phase. Hence the magnitude and timing of later phases is likely to depend upon the success and outcome of the preceding phase.

Table 8: Phasing Plan with criteria for full electrification of E-buses

Phase	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Year	2020	2021	2022-2024	2025-2028	Beyond 2029
# Of buses	5-10	100	1,000	1,000 -2,500	All Buses
Support Team	CFF		Under Other Donor Support Programs		
Licensing	1) 2.5m wide buses only allowed as of now 2) Commercial permit (yellow plate) both BRT & Non-BRT Routes	Allow buses with width>2.5m and length 12m	Allow buses with width>2.5m and length 12m	Allow buses with width>2.5m and length 12m and 18m	Allow buses with width>2.5m and length 12m and 18m
Passengers Allowed	Passenger should be in the E-bus to test the demand factor	Yes	Yes	Yes	Yes
Route Selection	Select 2 or 3 routes	Operate out of 2-3 depots with 30-40 buses along 2-3 select routes	Discuss with TJ and DKI-Identify complete electrification of Depots	Discuss with TJ and DKI	Discuss with TJ and DKI
Bus Type	9m and 12m	12m and 9m	12m and 9m few 18m and supported by	12m and 9m few 18m and supported by	12m and 9m few 18m and supported by

Battery Capacity	>200 kWh	135-300 kWh	135-300 kWh	135-300 kWh	135-300 kWh
Battery Chemistry	LFP or NMC	LFP or NMC	LFP, LTO-LFP, NMC	Existing + New	Existing + New
Charging location	At Depots	At Depots + Opportunity Charging	At Depots + Opportunity Charging	At Depots + Opportunity Charging	At Depots + Opportunity Charging
Charging standard	Manufacturers choice with inter-operability	Manufacturers choice with inter-operability	Manufacturers choice with inter-operability	Manufacturers choice with inter-operability	Manufacturers choice with inter-operability
Charger Type	Charge Power (50-150 kW)	Charge Power (50-150 kW)	Charger Power (50-150 kW) and > 150 kW	Charger Power (50-150 kW) and > 150 kW	Charger Power (50-150 kW) and > 150 kW
Replacement Ratio (Target)	-	1.1	1.0	1.0	1.0
Range	150 km-250 km	150 km-300 km	150 km-300 km	150 km-300 km	150 km-300 km
Power Consumption	<1.3 kWh/Km	<1.4 kWh/Km	<1.2 kWh/Km	<1.2 kWh/Km	<1.2 kWh/Km
Procurement	7-10 E-buses - based on cooperation agreement between TJ and OEMs.	100 E-buses. (TBC)	Operators using Tender Process	Operators using Tender Process	Operators using Tender Process
Subsidy	None	Subsidy required	Zero	Zero	Zero

Source: Consultant Team

7.4 Goal Setting for Phases 1 and 2

The goal in Phases 1 and 2 for successful deployment of E-buses should be the following:

- Finalization of route selection;
- Development of charging locations at depots and terminals;
- Appropriate Contracting mechanisms to ensure risks are distributed to all stakeholders; and
- Performance monitoring and evaluation.

The following table below gives an overall guidance on the technology mix for full transitioning to E-buses for Phase 1 and 2. These details has been arrived based on market study with manufacturers and technology companies, learnings from the experience of different cities across the globe and research publication around EV deployment.

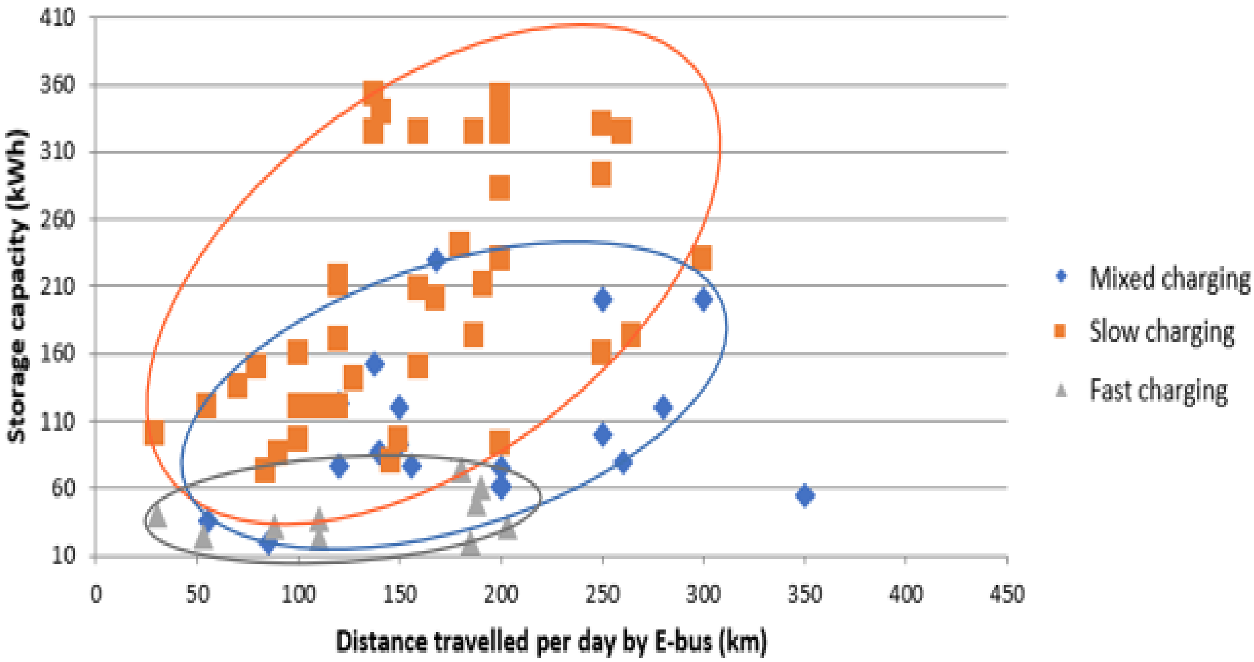
Table 9: Technology Roadmap for TJ

Parameters	Phase 1 and 2
Battery Technology	LFP and NMC
Battery Size	Bigger Battery: Daily utilization kms >200kms Medium size battery: Daily utilization kms 125kms-200kms Small size battery: Daily utilization kms 75kms-125 kms (Feeder services)
Charging Options	Combination of Depot Charging and Opportunity Charging: Based on range extension needed, headway and dead kms Thumb rule: 1 slow charger for three buses (1:3) 1 fast charger for five buses (1:5) (When the deployment is spread and there is not enough scale). However, needs to be determined based on actual operations.
Electric Motor Ratings	120 kW (minibus) / 160 kW (midi-bus) / 200 kW (standard bus)

Source: Consultant Team

The figure below gives a general guidance for selection of the charging strategy based on storage capacity of the battery and the distance travelled per day by an E-bus.

Figure 12: Charging strategy based on battery capacity and daily distance traveled by E-bus



Source: Manufacturers and UITP

With the initial deployment it will be important to monitor and evaluate the performance of the E-buses. The Table below provides a general outline of important data points to understand the O&M and in decision making for future deployment.

Table 10: Monitory and Evaluation Form for TJ

Data Item	Bus 1	Bus 2
Data Period		
Total mileage (in kms)- Daily		
Availability of the bus – How much time was it used for?		
Power Consumption- Daily (kWh/km)		
Average Speed including stops (kmph)		
Kms between road calls		
Total maintenance cost ($/km)		

Source: Consultant Team

8. ANALYSES OF CURRENT BUS OPERATIONS ON SELECTED TJ ROUTES

8.1 Introduction

This section focuses on selection of routes for the operation of first 100 E-buses, which takes into consideration the daily utilization kms, battery performance, depot locations and type of charger. Further analysis will take into consideration the replacement ratio for each of the routes.

8.2 Current Routes

For the purposes of this study, Micro buses have not been considered for the electrification. Therefore, the total number of buses considered is 2,212. As per data from TJ, 1,838 buses were operational on February 3, 2020.

The route analysis has been taken for the following corridors:

Table 11: Summary of operational bus routes

Route Description	Number of buses	Number of routes
BRT Routes operating on single corridor	430	13
BRT Routes operating across Multiple corridor	329	36
Non-BRT Routes	1,061	116
Total	1,820	165

Source: Consultant Team, based on TJ data February 2020

8.3 Routes selection for 100 E-bus Trial

The following factors form the basis for selection of the bus routes for electrification:

1. Passenger ridership- Routes with highest ridership per bus per day are to be selected. As these routes will have high earnings per km this will ensure that this will result in building confidence with operators to switch to E-buses.
2. Bus Fleet Availability- Routes with existing high number of buses deployed should be selected. This is to ensure that in the initial trials only 2-3 routes are chosen. This discussed approach will enable TJ and operators to get a complete understanding of the performance of the E-buses. In addition, it will help in simplifying the charging requirements at both the depot and along the route.

3. Replacement Ratio- This ratio is calculated as the ratio of the daily total kms travelled by a bus along specific route to the available or calculated range taking into consideration the depth of discharge, use of AC, passenger loading and battery degradation over time.
4. Total Cost of Ownership- TCO is the Present Value of capital cost plus the Present Value of operating costs. Capital costs including that of E-bus and charging infrastructure and operational costs are the major cost components that make up the input. Globally there are discussions and studies that compare the economic benefits of E-buses over other models through TCO and Life Cycle Costs. TCO provides an understanding of the various components that affect the overall economic performance of an E-bus over its lifetime. TCO is the key information that bus operators would need to know, since they will procure the E-buses. TCO is also key feature for DKI Jakarta to support the bus operators with Buy The Service system (IDR/km). TCO has been elaborated in full detail in the Annexure-2 and included within the Financial Feasibility Study report

A robust TCO takes into consideration the cost variation of the various components over the years such as inflation, fluctuations in the cost of an E-bus due to variation in battery cost, residual value or the salvage value of an E-bus and infrastructure after the period of service. The Total Cost of Ownership analysis helps in understanding the impact of different variables. TCO calculations provide city bus agencies with insights on E-bus performance and help them in taking right decisions on selection of bus technology, charging infrastructure, daily drive distance and staff deployment.

8.4 BRT Routes

The following BRT corridors have been considered for the evaluation for implementation of E-buses.

Table 12: Summary of BRT bus routes

BRT Corridor	Route length	Speed	Origin/Destination
1	12.9	13	BLOK M – KOTA
2	24.4	13	PULOGADUNG 1 – HARMONI
3	19	19	KALIDERES - PASAR BARU
4	11.85	15	PULOGADUNG 2 - DUKUH ATAS 2
5	13.5	14	KAMPUNG MELAYU – ANCOL
6	13.3	17	RAGUNAN - DUKUH ATAS 2
7	12.8	14	KAMPUNG RAMBUTAN - KAMPUNG MELAYU
8	26	19	LEBAK BULUS – HARMONI
9	29.9	18	PINANG RANTI – PLUIT
10	19.4	16	PGC 2 - TANJUNG PRIOK
11	15	18	PULOGEBANG - KAMPUNG MELAYU
12	23.75	17	PENJARINGAN - TANJUNG PRIOK
13	9.3	20	PURI BETA - BLOK M

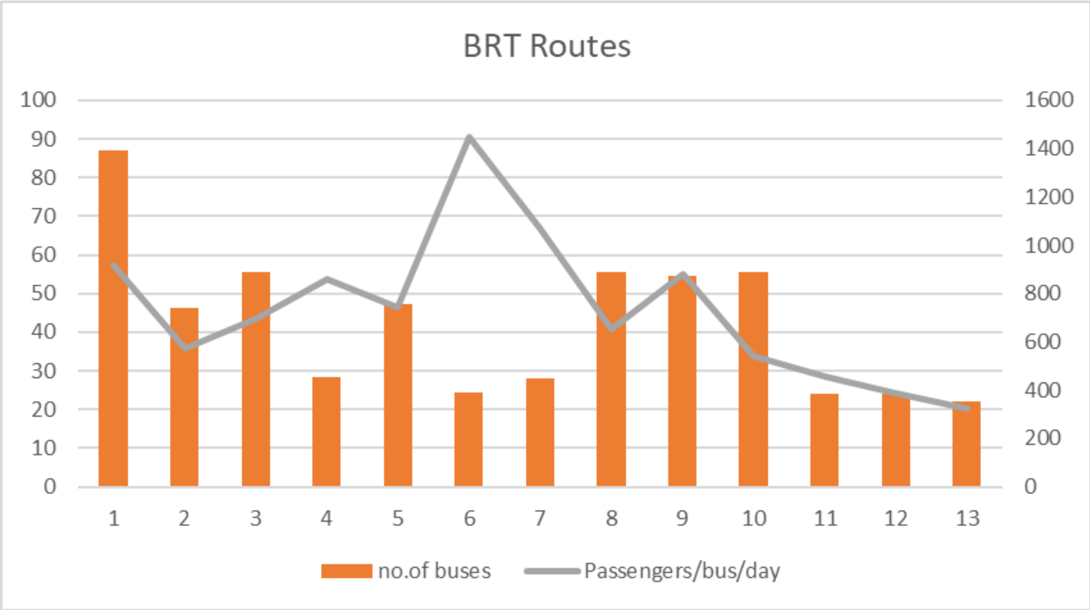
Source: Consultant Team, based on TJ data February 2020

8.4.1 Bus Utilization and Average Passengers

BRT routes operating along single corridor were analyzed for the implementation of the first E-buses. Based on the passengers/bus/day the following corridors are the top performing ones:

- BRT Corridor 6 with 1,451 passengers/bus/day
- BRT Corridor 7 with 1,071 passengers/bus/day
- BRT Corridor 1 with 918 passengers/bus/day
- BRT Corridor 9 with 882 passengers/bus/day
- BRT Corridor 4 with 858 passengers/bus/day

Figure 13: Passenger/bus/day and number of buses on BRT Corridors



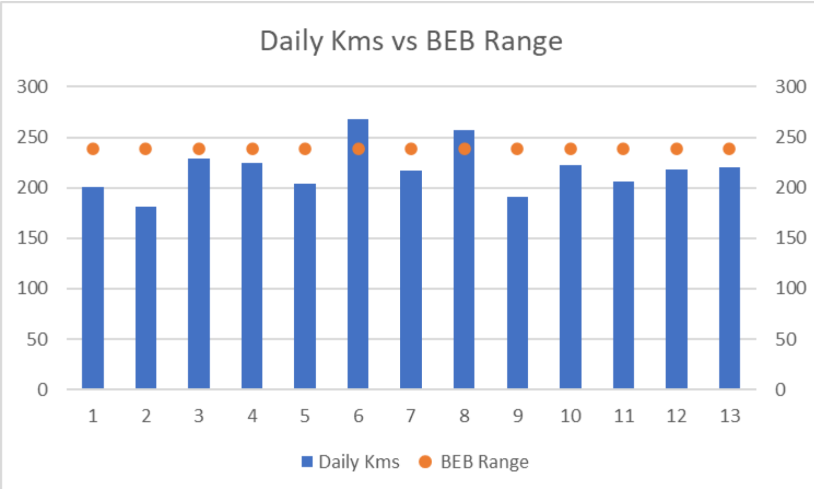
Source: Consultant Team

The figure below shows the daily utilization kms vs estimated BEB range taking into consideration the Depth of Discharge, passenger loading and AC on the battery performance.

BEB Range is the distance that an E-bus can travel in single charge of the battery. For a 324 kWh battery this comes to about 239 kms after taking into considerate Depth of Discharge, AC usage and passenger loading. Daily kms is the total kms travelled by a bus along specific route. Understanding the difference in the daily kms and the range available helps to plan the charging strategies.

All BRT routes except Routes 6 and 8 have the daily kms travelled lesser than range available in single range. Therefore, these routes will require opportunity charging. However, routes 2 and 9 have daily kms less than 200 kms indicating that a smaller battery size compared to 324 kWh would be enough.

Figure 14*:* Daily utilization vs BEB Range

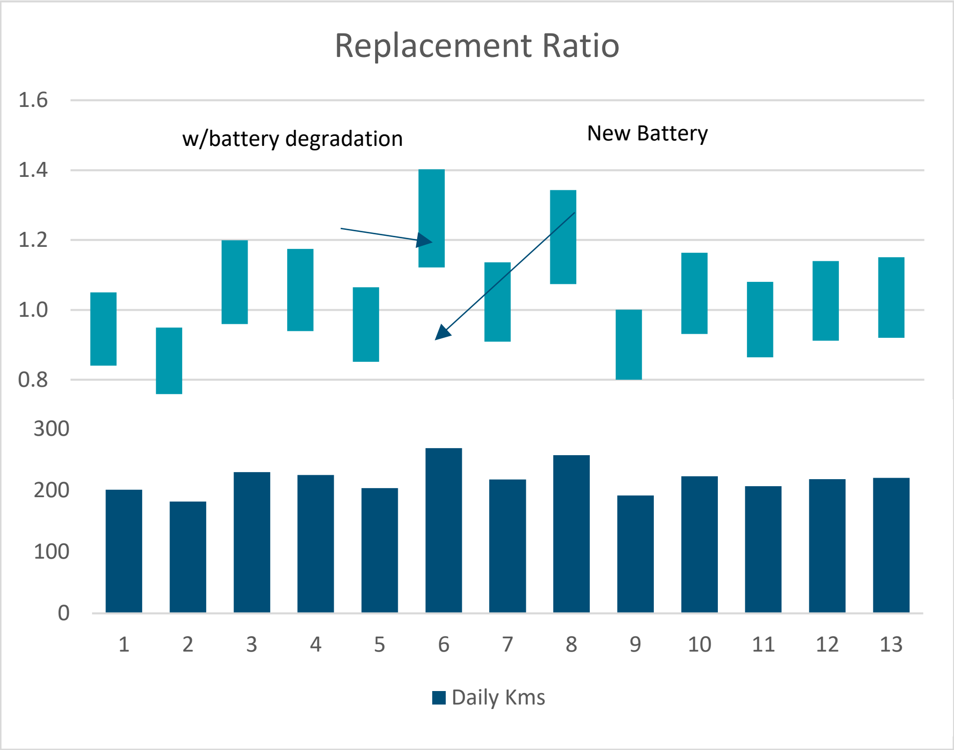


Source: Consultant Team

8.4.2 Replacement Ratio

Replacement ratio is calculated as the ratio of the daily kms travelled by a bus along specific route to the BEB range. As explained earlier, BEB Range is the distance that an E-bus can travel in single charge of the battery. For a 324 kWh battery this comes to about 239 kms after taking into consideration Depth of Discharge, AC usage and passenger loading. Routes with a replacement ration close to 1.0 are more suited for electrification. The replacement ratio has been estimated for each route based on the daily running kms and the estimated range of the battery (239 kms). As seen from the graph below, except routes 6 and 8 all of them have a replacement ratio of less than 1 and with battery degradation over time, routes 1, 2, 5 and 9 have replacement ratios close to 1.0. Other routes having higher replacement ratios, indicating the need for optimizing battery size and charging strategy.

Figure 15: Replacement Ratio for the BRT routes



8.4.3 TCO Calculation with Big Battery (BRT Routes)

TCO Analysis for E-buses with big battery size (324 kWh) was carried out for each of the 13 routes and was then compared to the TCO for diesel buses. As seen from the table below the TCO for E-buses is higher than for diesel buses by about 29 % (on average). The average TCO for E-buses is $ 1.32 whilst for diesel buses the average TCO is $ 1.02.

Table 13*:* TCO comparison of Diesel and Electric (Big Battery) Buses*

BRT Route	Big Battery E-bus* (USD)	Diesel Bus (USD)	TCO % Difference
1	1.40	1.06	32%
2	1.54	1.13	36%
3	1.25	0.98	28%
4	1.27	0.99	28%
5	1.38	1.05	31%
6	1.10	0.89	24%
7	1.31	1.01	30%
8	1.14	0.91	25%
9	1.47	1.09	35%
10	1.28	1.09	17%
11	1.37	1.04	32%
12	1.30	1.01	29%
13	1.29	1.00	29%

*Does not include environmental and health benefits

Assumptions:

Discount Rate: 6%, Loan Rate: 6.26%, Insurance and Legal: 1.5 %, EMI Years: 7, Number of Years for TCO assessment: 10, Number of bus running days: 338 Kms, Battery Size: 324 kWh;, Battery Cost: 100 USD/kWh, Capital Cost Bus: 370,000 USD, Diesel Bus: 2,160,950,000 IDR, Slow Charger: 13,700 USD, Charging Installation cost: 10%, Staff and Overhead Cost: IDR 382,377,713 per annum, Energy Cost for E-bus: 740 IDR/km, Diesel Cost: 5,150/lit, Energy Efficiency of E-bus: 0.77km/kWh, Energy efficiency of Diesel Bus: 2.03, Maintenance Cost for E-bus: 1800 IDR/km, Maintenance Cost for diesel bus: 5,450 IDR/km, two buses per slow charger.

Source: Consultant Team

8.4.4 TCO Calculation with Medium Battery (BRT Routes)

TCO Analysis for E-buses with medium battery size (180 kWh) was carried out for each of the 13 routes and was then compared to the TCO for diesel buses. As seen from the table below the TCO for E-buses is higher than for diesel buses by about 11 % (on average). The average TCO for E-buses is $ 1.13 whilst for diesel buses the average TCO is $ 1.02.

Table 14: TCO comparison of Diesel and Electric (Medium Battery) Buses*

BRT Route	Medium Battery E*-bus (USD)	Diesel Bus (USD)	TCO % Difference
1	1.20	1.06	13%
2	1.32	1.13	17%
3	1.07	0.98	9%
4	1.09	0.99	10%
5	1.19	1.05	13%
6	0.94	0.89	6%
7	1.12	1.01	11%
8	0.97	0.91	7%
9	1.26	1.09	16%
10	1.10	1.09	1%
11	1.17	1.04	13%
12	1.12	1.01	11%
13	1.11	1.00	11%

*Does not include environmental and health benefits

Assumptions:

Discount Rate: 6%, Loan Rate: 6.26%, Insurance and Legal: 1.5%, EMI Years: 7, Number of Years for TCO assessment: 10, Number of bus running days: 338 Kms, Battery Size: 180 kWh, Battery Cost: 100 USD/kWh, Capital Cost Bus: 300,000 USD, Diesel Bus: 2,160,950,000 IDR, Slow Charger: 13,700 USD, Fast Charger: 34,250 USD, Charging Installation cost: 10%, Staff and Overhead Cost: IDR 382,377,713 per annum**,** Energy Cost for E-bus: 740 IDR/km, Diesel Cost: 5,150/lit, Energy Efficiency of E-bus: 1km/kWh, Energy Efficiency of Diesel Bus: 2.03 km/litre, Maintenance Cost for E-bus: 1800 IDR/km, Maintenance Cost for diesel bus: 5,450 IDR/km, two buses per slow charger and five buses per fast charger.

Source: Consultant Team

8.4.5 Selection of routes based on different parameters

The table below shows the evaluation of different routes with respect to the number of buses operational, passenger/km/bus, and TCO to arrive at the most suitable routes for the electrification. In addition, it will be good to add earnings per km (EPKM) as a factor for further evaluation. Equal weightage was given for number of buses, pax/bus/day and TCO. As shown in the table below, each variable was then ranked, and the total score was calculated. Out of these, top 5 routes have been shortlisted as highlighted below. The shortlisted routes are 1, 3, 4, 6, 8 and 10.

Table 15: Selection of routes based on four evaluation parameters

BRT Route	Rank based on Number of Buses	Rank based on Pax/bus/day	Rank based on TCO % Difference	Total Score
1	1	3	11	15
2	7	9	13	29
3	2	7	4	13
4	8	5	5	18
5	6	6	9	21
6	10	1	2	13
7	9	2	8	19
8	3	8	3	14
9	5	4	12	21
10	4	10	1	15
11	11	11	10	32
12	12	12	6	30
13	13	13	7	33

8.5 Non-BRT Routes (SB and LE Buses)

37 Non-BRT routes were also analyzed. Some of these non-BRT routes have single and low-entry buses, whilst others have medium buses. Both the different categories have been separated and analysis carried out for each category.

The table below presents the analysis of the non-BRT routes with Single Buses or Low-Entry buses. The table lists the route number with the number of buses deployed, passenger/bus/day and daily kms travelled.

Table 16: Analysis of the Non-BRT routes with Single Bus or Low-Entry bus

Non-BRT Route	Buses	Pax/bus/day	Daily Kms
11A	8	75	230
12B	12	125	195
1A	17	237	251
1B	6	453	221
1F	7	157	180
1H	8	248	166
1N	9	187	186
1R	10	159	171
4B	31	206	144
4F	19	206	176
5A	15	97	183
5F	9	358	206
5M	9	116	189
6D	13	396	180
6H	33	106	258
7A	15	221	222
7B	20	241	176
7D	9	301	284
7E	5	96	192
9D	17	270	205
9E	13	188	170
GR1	9	814	227
GR2	10	838	101

8.5.1 TCO Calculation with Big and Medium Battery (Non- BRT Routes- SB and LE)

TCO analysis was calculated for each route with Big-Battery and Medium-Battery sizes. The Table below shows the comparison. The average TCO of E-buses with big battery size is $ 1.49, for E-buses with medium battery it is $ 1.26 and the TCO for diesel buses is $ 1.10. The average TCO of E-buses with bigger battery size is 36% higher when compared to the average TCO of diesel buses. Whilst the average TCO of E-buses with medium battery size is 13% higher when compared to the average TCO of diesel buses.

Table 17: Non-BRT Routes- TCO analysis for each route with Big-Battery and Medium-Battery

Non-BRT Route	Big Battery E-bus (USD)	Medium Battery E-bus (USD)	Diesel Bus (USD)	Difference between Big Battery and Diesel Bus	Difference between medium Battery and Diesel Bus
11A	1.24	1.06	0.98	27%	8%
12B	1.44	1.22	1.09	32%	12%
1A	1.16	0.98	0.94	23%	4%
1B	1.29	1.10	1.01	28%	9%
1F	1.55	1.32	1.15	35%	15%
1H	1.67	1.4	1.21	38%	16%
1N	1.51	1.28	1.12	35%	14%
1R	1.62	1.36	1.19	36%	14%
4B	1.99	1.59	1.03	93%	54%
4F	1.58	1.34	1.16	36%	16%
5A	1.53	1.30	1.13	35%	15%
5F	1.37	1.17	1.05	30%	11%
5M	1.48	1.26	1.11	33%	14%
6D	1.55	1.32	1.15	35%	15%
6H	1.14	0.96	0.92	24%	4%
7A	1.28	1.09	1.01	27%	8%
7B	1.58	1.34	1.16	36%	16%
7D	1.05	0.88	0.87	21%	1%
7E	1.46	1.24	1.1	33%	13%
9D	1.38	1.17	1.06	30%	10%
9E	1.63	1.37	1.19	37%	15%
GR1	1.26	1.07	0.99	27%	8%
GR2	2.65	2.21	1.73	53%	28%

Asumptions:

Discount Rate: 6%, Loan Rate: 6.26%, Insurance and Legal: 1.5%, EMI Years: 7, Number of Years for TCO assessment: 10, Number of bus running days: 338 Kms, Battery Size: 324 kWh and 180 kWh, Battery Cost: 100 USD/kWh, Capital Cost Bus: 300,000 USD, Diesel Bus: 2,228,561,317IDR, Slow Charger:13,700 USD, Fast Charger:34,250 USD, Charging Installation cost: 10%, Staff and Overhead Cost: IDR 382,377,713 per annum, Energy Cost for E-bus: 740 IDR/km, Diesel Cost: 5,150/lit, Energy Efficiency of E-bus: 1km/kWh, Energy Efficiency of Diesel Bus: 2.03 km/litre, Maintenance Cost for E-bus: 1800 IDR/km, Maintenance Cost for diesel bus: 5,450 IDR/km, two buses per slow charger and five buses per fast charger (when using180 kWh battery) otherwise two buses per slow charger (324 kWh Battery)

Source: Consultant Team

Selection of single non-BRT buses

Equal weightage was given for number of buses, pax/bus/day and TCO. As shown in the table below, each variable was then ranked, and overall total score was calculated. Out of these top 10 routes have been shortlisted as highlighted below. The shortlisted non-BRT routes are 1A, 6H, 7A, 7D, GR1, 9D, 5F, 6D, 7B and 1B.

Table 18: Ranking Non-BRT Routes

Non-BRT Route	Ranking for Buses	Ranking for pax/bus/day	Ranking for TCO	Overall Score
11A	20	23	6	49
12B	11	18	10	39
1A	5	10	2	17
1B	22	3	7	32
1F	21	17	16	54
1H	19	8	21	48
1N	15	15	13	43
1R	13	16	14	43
4B	2	13	23	38
4F	4	12	20	36
5A	8	21	17	46
5F	14	5	9	28
5M	16	19	12	47
6D	9	4	15	28
6H	1	20	3	24
7A	7	11	4	22
7B	3	9	19	31
7D	17	6	1	24
7E	23	22	11	56
9D	6	7	8	21
9E	10	14	18	42
GR1	18	2	5	25
GR2	12	1	22	35

8.6 Non-BRT Routes (Medium Buses)

The table below presents the analysis of the Non-BRT routes with Single Buses or Low-Entry buses.

Table 19: Non-BRT Routes, Medium Buses

Non-BRT Route	Buses	Pax/bus/day	Daily Kms
3E	7	281	253
9H	11	214	252
8E	9	191	228
7P	9	130	237
5N	11	108	239
3D	10	132	232
10K	8	250	215
8K	8	187	215
1Q	9	243	217
1M	8	229	218
11Q	15	161	217
11D	14	191	202
8D	12	236	192
1C	11	185	185

8.6.1 TCO Calculation Small Battery (Non- BRT Routes- MB)

TCO analysis was calculated for each route with small-Battery size(135 kWh). The Table below shows the comparison. The average TCO for E-buses is $ 0.94 and the TCO for diesel buses is $ 0.61. The average TCO of E-buses is 53% higher when compared to the average TCO of diesel buses.

Table 20*:* Non-BRT Routes, Medium Buses

Non-BRT Route	E-bus (USD)	Diesel Bus (USD)	% Difference
3E	0.84	0.57	47%
9H	0.85	0.57	49%
8E	0.92	0.61	51%
7P	0.89	0.59	51%
5N	0.89	0.59	51%
3D	0.91	0.6	52%
10K	0.97	0.63	54%
8K	0.97	0.63	54%
1Q	0.96	0.62	55%
1M	0.96	0.62	55%
11Q	0.96	0.62	55%
11D	1.02	0.65	57%
8D	1.07	0.68	57%
1C	1.11	0.69	61%

Asumptions:

Discount Rate: 6%, Loan Rate: 6.26%, Insurance and Legal: 1.5%, EMI Years: 7, Number of Years for TCO assessment: 10, Number of bus running days: 338 Kms, Battery Size: 135 kWh, Battery Cost: 100 USD/kWh, Capital Cost E-bus: 228,500 USD, Diesel Bus: 830,000,000 IDR, Slow Charger: 13,700 USD, Fast Charger: 34,250 USD, Charging Installation cost: 10%, Staff and Overhead Cost: IDR 382,377,713 per annum, Energy Cost for E-bus: 740 IDR/km, Diesel Cost: 5,150/lit, Energy Efficiency of E-bus: 1km/kWh, Energy Efficiency of Diesel Bus: 3.2 km/litre, Maintenance Cost for E-bus: 1800 IDR/km, Maintenance Cost for diesel bus: 3,000 IDR/km, two buses per slow charger and five buses per fast charger

Source: Consultant Team

8.6.2 Selection of non-BRT (medium) buses

Equal weightage was given for number of buses, pax/bus/day and TCO. As shown in the table below, each variable was then ranked, and the overall total score was calculated. Out of these, the top 3 routes were shortlisted as highlighted below. The three shortlisted non-BRT routes with medium buses are 3E, 9H and 8E.

Table 21*:* Three selected Non-BRT routes with medium buses

Non-BRT Route	Ranking for Buses	Ranking for pax/bus/day	Ranking for TCO	Overall Total
3E	14	1	1	16
9H	4	6	2	12
8E	8	8	3	19
7P	9	13	4	26
5N	5	14	5	24
3D	7	12	6	25
10K	11	2	7	20
8K	12	9	8	29
1Q	10	3	9	22
1M	13	5	10	28
11Q	1	11	11	23
11D	2	7	12	21
8D	3	4	13	20
1C	6	10	14	30

8.7 Recommendations of routes for 100 E-bus Trial Routes

Based on TCO calculation, Single bus with medium battery would be the prefered option. However taking into consideration that deploying electric buses is also an opportunity to rationalize the operations it is good to minimize the externalities. With TJ's plan to prioritize non-BRT route for the first E-bus deployment, an option to deploy big battery single should be explored. This is mainly due to the challenge to provide space for charging infrastructure on route should medium battery is used. The deployment of single bus with medium battery for BRT corridors may follow after the SOC profile of E-buses has been recorded and evaluated from the first deployment of E-buses on non-BRT route.

The deployment of single bus with big battery, on the other hand, has some considerations. The weight of the bus might reduce the number of passengers. The size of the bus also might need to be adjusted according to the regulation. This might result in procurement of additional of E-buses and custom order to comply with Indonesian regulation.

Related on routes selection, the table below summarizes the findings for the BRT and Non-BRT routes. The recommendations have been made from the shortlisted routes by further choosing the routes with high ridership.

Table 22*:* Route selection of BRT and Non-BRT Routes

Type	Shortlisted Routes	Recommendation
BRT	1, 3, 6, 8, 4 and 10	Complete transition for e-bus on the selected routes for deployment. Deploy about 60 buses.
Non-BRT (Single/Low Entry Bus)	1A, 6H, 7A, 7D, 9D, GR1, 5F, 6D, 7B and 1B	Complete transition for e-bus on the selected routes for deployment. Deploy about 40 buses.
Non-BRT (Medium Bus)	3E, 9H and 8E	The TCO difference is likely to increase by 53%. Not recommended in the 100 E-bus trial.

8.8 Outline Identification of the 100 E-bus Trial Route Operators

8.8.1 ToR Requirement

The ToR requires in Item 1.11 the selection of 1 or 2 PTO's for the 100 E-bus trial.

8.8.2 Key Operators along recommended Corridors- BRT

The goal of the selection of operator is to get an idea of who are the possible operators based on existing operations. This will help during market study to understand the willingness of operators to adopt E-buses and their understanding of the E-bus ecosystem.

The Team has identified the operators who are currently operating on the routes to be proposed for the E-bus Trial. This becomes the initial criteria for short listing the criteria. Based on market survey, the study team will assess the willingness of the shortlisted operators to switch to E-bus. In addition, their past performance, on-going contracts, financial situation and future expansions plans will be assessed along with TJ to finalize the operator selection process.

The table below represents the existing operators for the BRT routes. Mayasari Bakti (MYS), Damri, PPD and Steady Safe presently operate buses along the three corridors. The operators along these routes should be selected based upon the following assessment: Operational experience, financial situation (profitability/ balance sheet), on time performance of current non-E-bus operations, internal expertise on handling E-bus operations.

Table 23: Recommendations of Selected Operators for E-buses (BRT routes)

Route`	Operator
1	MYS, PPD, Steady Safe, SWA (TJ)
3	MYS, PPD, Steady Safe, SWA (TJ)
4	MYS, PPD, SWA (TJ)
6	MYS, Steady Safe
8	MYS, PPD, Steady Safe, Damri
10	MYS, PPD, Damri, Steady Safe, SWA (TJ)

Source: Consultant Team

8.8.3 Key Operators along recommended Corridors- Non-BRT

The table below represents the existing operators for the Non-BRT routes. MYS, SWA (TJ), PPD and Kopaja presently operate buses. The operators along these routes should be selected based upon the following assessment: Operational experience, financial situation (profitability/ balance sheet), on time performance of current non-E-bus operations, internal expertise on handling E-bus operations.

Table 24: Recommendations of Selected Operators for E-buses (Non-BRT routes)

Routes	Listed Operators	Major Operator
1A	PPD	PPD
7A	MYS, PPD, SWA	MYS
7D	PPD	PPD
GR1	SWA (TJ)	SWA (TJ)
6D	Kopaja, SWA (TJ)	Kopaja
1B	PPD	PPD
6H	Kopaja, PPD, Transwadaya	PPD
9D	PPD, SWA (TJ)	PPD
5F	SWA (TJ)	SWA (TJ)
GR2	SWA (TJ)	SWA (TJ)

Source: Consultant Team

9. RECOMMENDATIONS FOR DESIGN OF E-BUS POWER SUPPLY OPTIONS

9.1 Introduction

The following three aspects of the ToR are included in Chapter 9 accordingly:

1 General design of overnight charging scenario;
2 Identification of charging locations; and
3 Insights in grid connections possibilities for charging locations.

9.2 General design of overnight charging, fast charging and opportunity charging

Based on the assessment of routes and daily running kms the following charging strategy is recommended.

Table 25*:* Recommendations of charging strategies and chargers

Options with Battery size	Charging Strategy	Charger requirements and specifications
Big Battery	At Depots - Overnight charging to achieve a range of 230 kms	1 slow charger for two buses (50 kW)
Medium/Small Battery	Overnight charging at depots And Opportunity Charging (Fast Charging) at the terminals.	1 slow charger for two buses- (50 kW) 1 fast charger for five buses (About 150 KW)

9.2.1 Identification of Depot charging locations

Depots at Cawang, Cijantung, Ciputat and Pesing are shortlisted for E-buses. The criteria used have been the location of these depots and the size of the depots. However, further analysis is needed with respect to the distance to high-tension cable and installation of sub transformer from these depots and operator preference. It is however recommended that at the maximum only two depots be selected for the 100 E-bus trials. A detailed cost estimation needs to be completed.

Table 26: Recommendations for depots for the 100 E-bus Trial

No	Depot	Operator	Fleet size	Average Depot Size (Estimated in acres)
1	Cawang	Perum PPD, TJ Swakelola	362	15.7
2	Cijantung	Mayasari Bakti, Kopaja	589	25.6
3	Ciputat	Perum PPD, Bianglala Metropolitan	197	8.6
4	Pesing	TJ Swakelola	96	4.2

Source: Consultant Team

9.3 Insights in grid connections possibilities for charging locations

PLN is the nodal agency responsible for electricity distribution in Indonesia. Electric power distribution is the final stage in the delivery of electric power. It carries electricity from the transmission system to individual consumers. The transmission system in Indonesia consists of 500 kV, 225 kV (Sumatera), 150 kV, and 20 kV.

The distribution system consists of Medium Voltage Network ((JTM) and Low Voltage Network (JTR), Distribution Substation (GI), service connection, and apparatus. Distribution substations connect to the transmission system and the lower the transmission voltage to medium voltage. It is 20 kV with the use of a transformer.

1. JTM functions to supply electricity with 20kV from secondary substations or step-up transformer to medium voltage customers. (industry, big customers, etc.); and
2. JTR functions to supply electricity to TR (low voltage) consumers with a voltage of 220/380V.

9.3.1 Load estimation at Depots

The following assumptions has been made to calculate the load estimation at depots:

- A 120KW DC charger with a maximum of 15-20 number chargers at each depot
- A 120 KW DC charger can charge two buses to full charging during overnight charging (5-6 hours)
- A parallel factor of 80%, i.e. during the peak load scenario a maximum of 80% of the capacity will get charged simultaneously.
- A power factor of 90%

- Input output efficiency of the charger of 90%
- The load has been estimated based on the formula = No. of buses (including idle buses) x 120KW x parallel factor (80%) / power factor / efficiency
- The load at the depot has been limited to 4MVA connection so that it can be accommodated under an 20KV feeder.
- Thus, it is envisaged that each depot will have a 4MVA 20kV connection.

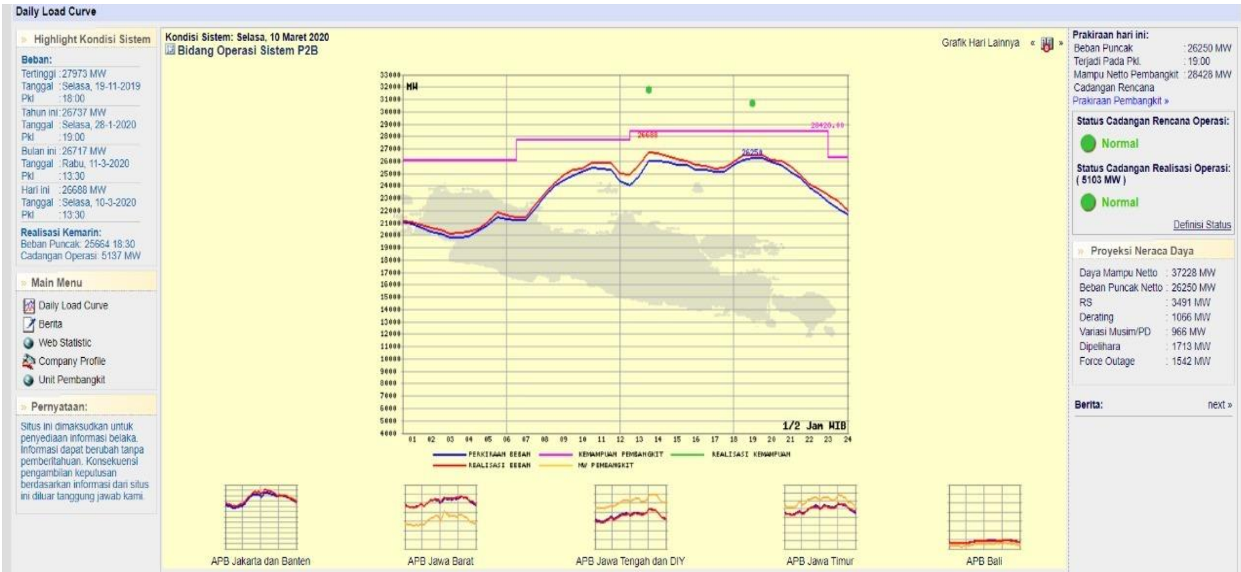
E-bus depots usually require a dedicated substation connected to the medium-voltage grid; large depots (>200 vehicles) may even need a high-voltage grid connection (60-132 kV) with a distribution station.

Table 27*:* Peak load data from Grid

Prakiraan Hari ini	Daily Forecast	March 10, 2020
Beban puncak	Peak Load	26,250 MW
Terjadi pada pkl	Occurred At	7:00 pm
Mampu Netto Pembangkit Cadangan Rencana	Capable of Net Reserve Generator Plan	28,428 MW

- Using energy consumption of 1.3-1.5 kWh/km for the 100 E-buses with an average running kms of 240 kms it is estimated that the energy required on a daily basis will be in the range of 31 Mwh to 36 Mwh. Most of this charging will be overnight charging.
- Assuming that about 15 % of the buses may needed to be charged simultaneously at terminals with 150 KW charger during day-time. The maximum load due to E-buses will be about 2.25 MW.
- Based on the data above it is clear that the impact on grid during the implementation of trial runs or running of 100 E-buses would be very minimal.

Figure 16: Image of the Grid Supply and Usage, March 10, 2020



9.4 Grid Aspects: some legal-technical requirements for EV's/E-bus in Indonesia

To ensure successful deployment of E-buses, it will be very important to ensure that the following two issues would be addressed:

9.4.1 Agreement on Tariff for bulk purchase with the Utility company

Given that E-bus deployment would require energy supply from the utility company, it will be important to agree upon preferential tariffs upfront. This should be negotiated based on number of buses being inducted and the location of the chargers. In addition, price points would have to be negotiated taking into consideration the energy consumption of E-buses, as there could be variations during summer months due to weather conditions.

9.4.2 Electrical Feeder line supply at Depots

The supply of feeder electrical at the depots where E-buses will be deployed and the available capacity of the feeder line taking into consideration the security standards and service levels need to be agreed upfront.

The responsibility for bringing the feeder line from an Underground or Overground High Tension and Low-Tension line and installation of a sub-station or transformer if required near depots should be the responsibility of the utility company.

9.5 Technical Recommendations

The following recommendations made in respect of charging specifications:

- Charging standard: Manufacturers preference
- Charging Power: 50-150 KW
- Inter-operability: Yes
- Grid Connection: 380 VAC
- Charging Locations: Depots at Cawang, Cijantung, Ciputat, and Pesing
- Availability of charging devices: 97 %
- Maximum time to recover: 24 hours (stations) / 72 h (devices)
- Length of cables for gun charging: max. 10 m, to be customized
- Maximum base area of charging devices: 1,000 x 1,200 mm for up to 150 kW charging

For the purpose of the technical feasibility study, 20KV substations with a maximum load of 4MVA have been considered. This sub-station requirement or a higher voltage sub-station requirement will be based on actual load requirements as well as the distance from specific host depot to the grid point from where the power can be drawn.

10. RECOMMENDATIONS FOR E-BUS FLEET AND VEHICLE STANDARDS

10.1 Introduction

The following three aspects of the ToR are included in Chapter 10:

1 Identification of 100 E-bus characteristics by route, based on operational insights;
2 Review of technical-legal requirements for the 100 E-bus Trial; and
3 Operational design for the Depot /fast charging scenarios.

This section summarizes the findings of the overall study with respect to battery technology, charging infrastructure and other specifications related to the vehicle. The final recommendations are presented in the recommendations section.

10.2 Fleet Aspects: Some technical-legal requirements for EV's/E-bus in Indonesia

The supporting regulation for Presidential EV regulation 55/2019 needs to mention EVs as a mode of transportation. This will serve as a legal umbrella for EV manufacturers and users as well as provide incentives for EV buyers. This regulation will emphasize the seriousness and intent of electrification in Indonesia and will help in establishing the supply chain and trials across different modes.

E-buses with higher battery capacity and 12m in length have a bus width greater than 2.5 meters. Current regulations do not permit the deployment of these wide buses on city streets. Therefore, it will be very important that a regulation is put in place on a priority basis, as most of the initial 100 E-bus Trial routes will require buses with bigger battery capacities, in order to reduce range anxiety and ensure smooth operations. **This regulation needs to be completed in the next 3-6 months to ensure implementation of E-buses along the selected routes.**

EV regulatory certificates – It will be an important legal (non-regulatory instrument) hurdle to overcome for local manufacturers who are partnering with global E-bus manufacturers to ensure that vehicle certification is obtained as per the Motor Vehicle Laws in Indonesia. The various components and the buses need to be tested to match the local standards. This is to ensure that that a framework is in place for certification and procedural delays do not delay EV adoption.

10.3 Technical Recommendations

The table below summarizes the specification for the vehicles and the associated battery technology and charging standards for 12 and 9 m buses.

Table 28: Recommendations for Vehicle technology for E-buses

S. No.	Parameter	Specification (12m Buses)	Specification (9m Buses)
1.	Propulsion System	Electrically Propelled Bus using Electric Propulsion System.	Electrically Propelled Bus using Electric Propulsion System.
2.	Type of Battery	Li-ion or Li-ion Phosphate Battery or Li-NMC or Superior.	Li-ion or Li-ion Phosphate Battery or Li-NMC or Superior.
3.	Battery Pack Rating and Energy/Power	1. No. of Motors / Batteries as per Manufacturer's design. 2. Power pack based on routes selected 3. Power consumption ≤ 1.4 kWh per km. 4. Electrical Re-generation required. 5. Charging Mode –as per manufacturers design. 6. Off-Board or On-Board Charging Required 7. Charging Time less than 3 hours. 8. Safety–Short circuit/ Over Temperature / Lightening Protection is mandatory.	1. No. of Motors / Batteries as per Manufacturer's design. 2. Power pack based on routes selected 3. Power consumption ≤ 1.0 kWh per km. 4. Electrical Re-generation required. 5. Charging Mode – As per manufacturers design. 6. Off-Board or On-Board Charging Required 7. Charging Time less than 2 hours. 8. Safety–Short circuit/ Over Temperature /Lightening Protection is mandatory.
4.	Battery Cooling System	Efficient & Robust Battery Cooling System to be provided for Minimum Maintenance.	Efficient & Robust Battery Cooling System to be provided for Minimum Maintenance.
5.	Battery Life	Battery Life – Life of Battery should be of minimum 7years.	Battery Life – Life of Battery should be of minimum 7years.
6.	Battery Charging System	As per Manufacturer's design with inter-operability	As per Manufacturer's design with inter-operability.

S. No.	Parameter	Specification (12m Buses)	Specification (9m Buses)
7.	Electrical Propulsion System.	Electrical Propulsion System / Sub Systems (Batteries) Temperature, Motor Speed in RPM, Vehicle Speed, Motor Percent Load (Torque), Diagnostic Message (Electrical Propulsion System Batteries, Cooling System, Motor, Traction Controller Specific), SOC with Vehicle Health Monitoring System (Battery Health + Regenerative Brake Charging).	Electrical Propulsion System / Sub Systems (Batteries) Temperature, Motor Speed in RPM, Vehicle Speed, Motor Percent Load (Torque), Diagnostic Message (Electrical Propulsion System Batteries, Cooling System, Motor, Traction Controller Specific), SOC with Vehicle Health Monitoring System (Battery Health + Regenerative Brake Charging).
8.	Electrical Propulsion System Location	As per Manufacturer's Design / Preferably Battery Location below floor.	As per Manufacturer's Design / Preferably Battery Location below floor.
9.	Charging Range	The bus should have a capacity of operating 240 kms minimum with 30 minutes recharging on actual condition with GVW and AC.	The bus should have a capacity of operating 180 Kms minimum with 30 minutes recharging on actual condition with GVW and AC
10.	Type of Bus	Bus Model should be approved as per government regulations and its amendments from time to time by any Government Approved Organization.	Bus Model should be approved as per government regulations and its amendments from time to time by any Government Approved Organization.

Source: Consultant team

11. NEXT STEPS

As noted, several important components of this Report will be elaborated further by analyses in the WP 2.2 Business Case and thereafter in the WP2.3 Procurement Phase. Further details of the Next Steps are included below.

11.1 Route Selection

The routes selected for electrification can be further fine-tuned in the Business Case analysis. However, it is recommended that 12m buses with higher battery capacity be deployed on BRT corridors. For Non-BRT routes, It is recommended to use single bus /low entry with medium battery (180 kwh).

11.2 Decisions by DKI Jakarta and TJ

A list of Key Decisions for DKI PIU would be:

- Finalize routes selected for deploying E-buses;
- Agree on the charging strategies and charger specifications;
- General agreement around fleet size and specifications (bus length, battery size and capacity); and
- Finalize outline selection of operators

11.3 Business Case

Some of the aspects that need further analysis such as testing of various route options and charging options based on bus schedules from actual operations will be completed in the Business case.

The Market Study for operators was carried out in July 2020. The results are indicated in the Table below. Some details of the questionnaire are provided in Annex 3. The main challenge for setting up contract structure with bus operator during the pilot of 100 e-bus is to create acceptable environment for e-bus. The Operator survey was conducted to clarify operators' aspirations for the roll out of the 100 E-bus trial. Surveys were conducted by the study team, supported by Transjakarta, to five E-bus prospective operators: Mayasari, DAMRI, PPD, Sinar Jaya, and Kopaja.

This work will be considered in the Business Case phase and further surveys or meetings may be undertaken[4], as appropriate.

[4] For example, meeting with PLN, contacts with OEM's.

Table 29: Findings from market study of operators

Parameters	Mayasari	Damri	PPD	Sinarjaya	Kopaja
Contract	1.Residue 0%	Profitable unit price from APM	1.← Same as Mayasari no-1 and 3	Scope of maintenance cost is clearly and fairly	1.Long term contract, such as 10-14 years contract
	2.Calculate Charging infrastructure on Capex		2.Price adjustment for imported spare parts		2.Contingency Plan for Pandemi
	3.TJ direct contract with APM for maintenance				
	4.Contingency Plan for Blackout				
Warranty	1.Buy Back Unit	Maintenance by APM, including spare parts, skill and technical knowledge sharing	← Same as Damri	Product Warranty by APM, including spare parts, skill and technical knowledge sharing	Product Warranty by APM, including spare parts and Battery
	2.Battery Energy Losses				
Charging & Battery	1.Opportunity Charger on route to reduce overnight charging time	-	APM provide Battery Management Information System	-	Provided and Operated by 3rd parties (APM)
	2.Availability Universal Connector type of Charging				
	3.Availability of Grid which supported by Government				
Policy and Incentive	Government's guarantee to run EV as long-term transportation system	← Same as Mayasari, refer to CNG	Incentive tariff from PLN	← Same as Mayasari, refer to CNG	Subsidy for investment from Government
Other	Long millage route	Government support for License such as Kieur and SKRB	1.← Same as Damri	-	← Same as Mayasari
Procurement	Bid follow BPBBJ	Propose to Government following PP38/2018	-	Select proven APM which have long experience on E-Bus	← Same as Mayasari
Charging	1.Use Cibubur and Jatiasih pool for EV	Overnight on Damri's pool, supported by BUMN (LEN) and PLN	Expand business as provider	-	1.Overnight Charing at Depo Cijantung
	2.Estimated Cost is 100 MRp/unit (@100 units) from consultant				2.← Same as PPD
Financial	80% from national bank's loan. Soft-loan which can achieve with TJ's contract average rate on 6,26%	National bank loan, ADB	1.National bank loan 2.Financial service provide by E-Bus Operator	National bank loan	National bank loan, such as Mandiri and BNI
Operation	Develop a system	1.Operate and take a maintenance on 1st priority	Planning will refer to data from TJ's trial	1.Uji Coba by themselves to take data for Operation Planning	-
		2.Cooperation with APM (KSO)		2.Maintenance by themselves supported by APM	

11.4 Procurement Phase: refine TCO model for Tender Process

Please refer to the recommendations in section 7.3 of the report showing the table that will become part of the tender documentation. The initial recommendations will be refined after the Business Case analysis has been completed.

12. ANNEX

Annex 1 Task 2.1 Preparatory Studies [Activity 2.1.1: Technical Feasibility Study]

The aim of the Technical Feasibility Study is to prepare the technical aspects of the project to a degree that allows the city to make correct decisions and potential bidders to prepare a robust proposal. The Technical Feasibility Study shall include the following components:

1. Review of TransJakarta test-results;
2. Detailed insights in current bus operation for TransJakarta;
3. Review of existing EV bus studies;
4. Market analysis for E-buses and charging infrastructure;
5. Selection of 1 or 2 PTO's for the 100 E-Bus Trial;
6. Insights in grid connection possibilities for charging locations in 3 scenario's, General design of overnight charging, fast charging and opportunity charging scenario's and Identification of charging locations for 3 scenario's[5]; and
7. Identification of 100 E-bus characteristics based on operational insights, Review of legal-technical-legal requirements for the 100 E-bus Trial and operational design for 3 scenarios.

Note 1:

Two separate tasks are carried forward from *Inception Phase* and are dealt with in this Report, namely:

1. Define outline geographical scope of the 100 E-bus Trial[6]; and
2. Define scalability of the 100 E-bus Trial[7].

Note 2:

Two tasks are carried forward from *Inception Phase* and are being dealt with other Consultant Reports or studies, namely:

1. Environmental impact study for 3 scenarios (for the 100 E-bus Trial): PM2.5, NOx, SO2, GHG WTW[8].
2. Evaluation of environmental impact by works (for the 100 E-bus Trial) including climate adaptation measures[9].

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5 The Consultants do not recommend opportunity charging for the 100 E-bus Trial or the Pre-Trial (Phases 1 and 2).

6 Recommendations are made in respect of E-bus routes and depots for the 100 E-bus Trials in Chapters 5 and 6 of this Report. These will need to be confirmed by DKI Jakarta and TJ before the Team commences work on the Business Case.

7 A scaled approach is suggested in Table 3 above. At the end of each Phase, a summary of implementation experience should be made, as input to the design of the subsequent E-bus rollout plan phase.

8 Item l) is being addressed in a GHG emissions reduction study being currently conducted by C40. (This C40 study report is expected to be available in August 2020).

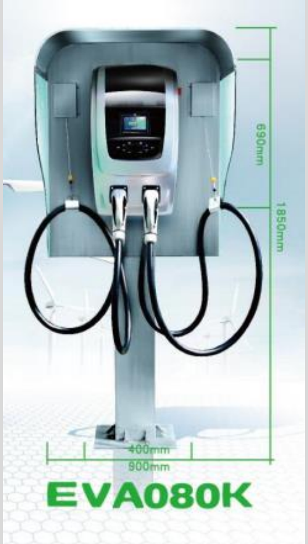
9 Item m) will be addressed in WP2.4 final Climate Proofing Report, due in October 2020.

Annex 2 E-bus Charging Devices

Details of E-bus Charging Devices are illustrated below.

Table 30: Overview of charging devices

S. No	Charging Devices	Charging Power
1.	Siemens -Off-board top down Pantograph -Charging via connector  	150/300/450 kW/600 kW 30 kW to 150 kW

2.	BYD AC Charging Adapter 	2 x 40 kW / 4 x 60 kW
3.	Heliox Bus Depot DC Charger 	50 kW / 150 kW
4.	Eko Energetyka Depot Charger 	40 kW / 60 kW / 80 / 100 / 120 kW or on request

5.	Schaltbau Refurbishment EVA400-Depot 	75 kW
6.	Shenzhen Haipengxin Electronics Co., Ltd. – HPXIN 	2 x 75 kW
7.	ABB HVC 	3 x 50 kW
8.	Proterra Power Control System 	60 / 125 kW

9.	Tritium Veefil 	50 kW (Fast chargers up to 475 kW)
10.	ABB Terra HP 	175 kW to 350 kW
11.	Kempower C-Series 	40-480 kW

12.	Guangdong Kangdewei Electric Co., Ltd 	120 kW intelligent DC EV charging for buses
13.	Eko Energetyka Quick Point City Charger 	Up to 1 MW
14.	Heliox Opportunity Charger 	300 kW

15.	Proterra Power Control System 500 kW  500 kW POWER CONTROL SYSTEM	500 kW
16.	Xcharge 	Up to 360 kW

Annex 3 Market Research Questions for E-bus Suppliers and/or Operators

Introduction

According to TJ, currently there are three major bus operators in Jakarta, as follows:

1. Mayasari (MYS). Mayasari has the second largest fleet and currently still has a quota of 300 buses to be filled. Mayasari also has a ceiling for bus procurement from a local Bank (BRI/Mandiri, tbc).
2. PPD is a state-owned company, the largest bus operator. Currently PPD operates 450 buses, however the buses are not PPD's own assets. PPD has an agreement with ZongTong, China for leasing (operating lease, tbc).
3. DAMRI. The Company does not have quota for bus procurement. DAMRI has been operating under a tender process with TJ since 2011. DAMRI has been very aggressively pursuing financing, from the ADB and other banks.

Another bus operator that has potential is Sinar Jaya. Currently their fleet is not as large as some of the other operators (143 bus quota), however Sinar Jaya is an upcoming bus operator with an innovative approach.

List of Technical Questions for Selected Operators

The list of 22 technical questions is provided below.

1. Certification/ Type test/ Approval/ Homologation certificate
2. Number of buses running successfully (with location/cities)
3. Manufacturing Capacity (per year)? How many buses can you manufacture in 1 year/ 1.5 years/ 2 years' time?
4. Supply lead time
5. Manufacturing location
6. Existing Tie-ups for propulsion technology, battery etc.
7. Battery Chemistry and Size
8. Battery Life (under slow charging/ fast charging)
9. Battery Weight
10. Whether battery chemistry supports fast charging?
11. Certification/ Type test
12. For a typical 16 hr. and 250km/day working, how many charge cycles of what duration are required?
13. Depot Requirement - provide details on Infrastructure required at the Depot (for a fleet of say 100 buses per depot)
14. Maintenance Capability – what is the existing capacity and how quickly can it be scaled up; What is the spare parts availability
15. Charging time (under different voltages i.e. fast vs slow)
16. Charging Infrastructure Requirement at Depots and Terminals
17. Technical constraints that are foreseen
18. Would you be keen to establish your own charging infrastructure?
19. Requirements from Transport Department in such a scenario?

20. What issues are foreseen if the Govt installs/ has installed its own charging infrastructure independent of the bus operator?
21. What are the Issues foreseen for the interoperability of charging infrastructure?
22. What would your interest be in E-bus operations?

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