This report will outline the Transjakarta updated long-term implementation phase that has integrated all the Transjakarta services based on financial, economic, and technical gap analysis

Building a Regulatory and Financial Basis for Transjakarta First Phase E-bus Deployment

Task 3.2 & 3.3: Report on Transjakarta E-Bus Integrated Long-Term Implementation Phase

December 31, 2022

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List of Abbreviations

AB	Articulated Bus
ACC	Annual Capital Costs
AOCC	Average Annual Operating Costs
APIC	Additional Paid in Capital
BAU	Business-As-Usual
BEV	Battery Electric Vehicle
BRT	Bus Rapid Transit
BUMD	*Badan Usaha Milik Daerah* (Regional-Owned Company)
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBD	Central Business District
CBU	Complete Build Unit
CFF	Cities Finances Facility
CNG	Compressed Natural Gas
CRF	Capital Recovery Factors
DD	Double Decker Bus
DKI	*Daerah Khusus Ibukota* (Special Capital Region of Jakarta)

E-bus	Electric Bus
EIRR	Economic Internal Rate of Return
EV	Electric Vehicle
GESI	Gender Equality and Social Inclusion
GVW	Gross Vehicle Weight
ICE	Internal Combustion Engine
IDR	Indonesian Rupiah
ITDP	Institute for Transportation and Development Policy
kg	kilogram
km	kilometre
kW	kilowatt
kWh	kilowatt per hour
kWp	kilowatt peak
LE	Low Entry Bus
LFP	Lithium Iron Phosphate
m	metre
MB	Medium Bus
MoU	Memorandum of Understanding

NMC	Nickel Manganese Cobalt
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OPEX	Operating Expense
PLN	*Perusahaan Listrik Negara* (State Electricity Company)
PSO	Public Service Obligation
PT	*Perseoran Terbatas* (Limited Company)
PV	Photovoltaics
Rp	Rupiah
SB	Single Bus
SKD	Semi Knocked Down
SoC	State of Charge
TCO	Total Cost Ownership
TJ	Transjakarta
UK PACT	UK Partnering for Accelerated Climate Transitions
UMP	*Upah Minimum Provinsi* (Province Minimum Wage)
UNEP-CTCN	United Nation Environment Programme-Climate Technology Centre and Network
USD	United States Dollar

Executive Summary

Introduction:

Transjakarta has set a target to electrify 100% of its fleets—equivalent to 10,047 fleets—in 2030 which is also mandated in the Governor Decree 1053/ 2022 on the Guidelines on Battery Electric Bus Deployment under the Transjakarta Services. In view of this target, Transjakarta has also developed the year-on-year electric bus share target started from 2022 to 2030 with 50% electrification target by 2027. However, there is no clear plan on how many electric buses they will deploy year-to-year, what types of fleets to be deployed each year, taking into account the ends of contract duration, technology readiness, and economic & financial analysis of the electrification.

In the past, ITDP has undertaken two studies, the UNEP-CTCN study for large scale e-bus implementation of 1724 large and medium buses and the UK Pact study for implementation of 3,300 e-microbuses. There is significant change from the fleet size considerations for the two studies and the current mandate for the e- bus quota in 2030. This study therefore focuses on the year-on-year e-bus deployment between 2022 and 2030 based on technical and economic & financial analysis. The study will also address the policy supports needed each year including the GESI milestones.

Methodology:

In order to develop the electrification roadmap for Transjakarta, the report starts with the analysis of Transjakarta present service, operational pattern, and operational planning and review of electrification target and current implementation. Previous studies on electrification roadmap and implementation phasing are reviewed and gaps are identified. Next, fleets' technology readiness including charging technology readiness and availability of infrastructure for charging is assessed and bus fleets typology is developed. Based on expected completion dates of current contracts and augmentation of fleet, the number of e-buses to be deployed each year for each e-bus typology is developed.

Financial readiness of e-bus technology is assessed using Total Cost of Ownership (TCO) per kilometre approach after carefully assessing the current costs for diesel buses and expected costs for E-buses. Using the TCO results, additional scenarios for e-bus roadmap are developed.

Based on the implementation roadmap, year-wise investment needed for both e-buses and related infrastructure as well as those for business-as-usual scenario (diesel/CNG buses) is developed. Transjakarta's financial capacity to support the roadmap is considered based on their revenue and cost trends and support from DKI Jakarta. Readiness of other factors such as operators, financiers/investors etc is also considered.

Deployment Plan and Roadmap

Transjakarta has several types of routes with different bus types. The bus typologies are selected for the bus type categories that Transjakarta is considering for electrification based on the market research for the available bus models and findings from the previous studies. These include 12-m single buses that operate on BRT and non-BRT routes, 12-m low entry buses that operate on non-BRT routes, 7-m medium bus, 18-m articulated buses, and 4-m microbuses. The double decker buses and the Royaltrans buses are not included as there is no clear plan about electrifying these services. The 13.5m maxi buses will be either retrofitted or replaced with 12m electric single buses.

Recommendations for Bus types and Charging Infrastructure:

- For the 12-m buses both single and low entry bus types, battery size of 324 kWh LFP battery with slow plug-in chargers up to 100 kW and fast chargers up to 200 kW are recommended. For these bus types, double gun chargers with 200 kW power are recommended for both depot overnight charging and terminal opportunity charging.
- The articulated buses can have battery size of 450 kWh with overnight charging by 200 kW plug-in chargers and fast charging by chargers up to 400 kW with either plug-in or pantographs.
- For the 7m medium buses, the current suitable model is the BYD C6 with a battery size of 135 kWh. In the later phases' buses with higher battery capacities of 150 kWh and higher but lighter weight may be available. The charger power for these is 100kW for both overnight and opportunity charging.
- The 4m microbus models are recommended for a battery size of around 42 kWh and charger power of 22 kW.

Based on the replacement schedule and the augmentation required each year, the electric bus procurement is calculated and adjusted taking into consideration Transjakarta's electrification strategy. Two scenarios A and B are developed for the implementation phase.

Scenario A:

This scenario follows Transjakarta's target which includes 100 medium buses and 100 single 12-m BRT buses to be procured in 2023 and the current procurement process for the 100 e-bus of which 26 are planned for 2023.

Table 1. Scenario A of Transjakarta's electrification for the implementation phase

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Articulated Bus		0	0	91	185	19	22	23	24
Low Entry	74	26	0	0	0	154	116	19	20
Single Bus		100	0	181	224	261	128	93	380
Medium bus		100	75	97	204	178	203	260	401
Microbus		0	100	200	400	600	1129	1800	2160

Total electric buses added yearly	**74**	**226**	**175**	**619**	**1063**	**1312**	**1691**	**2195**	**2985**
Cumulative electric buses	**74**	**300**	**475**	**1044**	**2057**	**3269**	**4867**	**7062**	**10047**
No. of diesel buses	3860	3634	3960	3978	3671	3288	2667	1622	0
Total number of buses	3934	3934	4435	5022	5728	6557	7534	8684	10047
% Electrification	**2%**	**8%**	**11%**	**21%**	**36%**	**50%**	**65%**	**81%**	**100%**

Scenario B:

This scenario considers a faster electrification plan and altering the previous scenario by accelerating the electrification of microbuses. The microbuses represent the dominant fleet size reaching around 60% of the total fleet size by 2030. The TCO for e-microbuses is also lower making this alternative economically viable.

Table 2. Scenario B of Transjakarta's electrification for the implementation phase

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Articulated Bus		0	0	91	185	19	22	23	24
Low Entry	74	26	0	0	0	154	116	19	20
Single Bus		100	0	0	305	261	128	93	480
Medium bus		100	75	97	204	178	203	260	401
Microbus		50	450	585	793	977	1129	1186	1219
Total electric buses added yearly	**74**	**276**	**525**	**823**	**1537**	**1689**	**1691**	**1581**	**2144**
Cumulative electric buses	**74**	**350**	**875**	**1648**	**3135**	**4724**	**6322**	**7903**	**10047**
% Electrification	**2%**	**9%**	**20%**	**33%**	**55%**	**72%**	**84%**	**91%**	**100%**

Financial analysis

The TCO analysis shows that the cost of deployment of single electric buses (low entry and high deck) is 15% lower than the comparable diesel buses. Similarly, the electric articulated buses TCO is lower than their diesel counterparts. **The retrofitted single buses however not found to be as effective as the new (procured) single buses in terms of TCO**, although some further analysis on the effectiveness of retrofitted single buses needs to be conducted due to lack of reliable data sources. However, for medium buses, the TCO for electric buses is still higher than the diesel buses and alternative models of medium buses with lighter weight and higher range needs to be explored for reduce the TCO below that of the diesel medium bus.

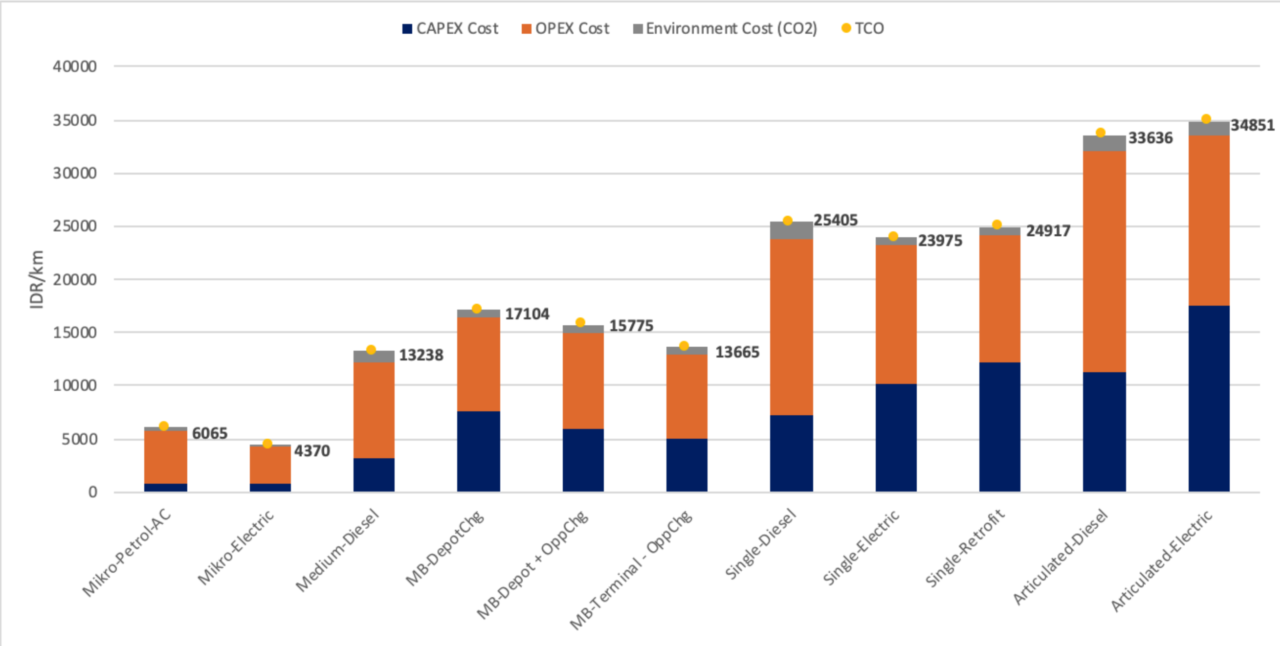

Figure 1. TCO comparison between Diesel/CNG and E-buses

It is seen that adoption of 100% electric buses by Transjakarta is expected to require a total investment of IDR 22 T between 2024 and 2030 as compared to a business-as-usual scenario investment of IDR 15 T during the same period i.e., 45% higher. However, as noted in section 7.2, the additional investment is more than made up due to lower operating costs resulting in overall lower costs (TCO) for electric buses as compared to diesel buses.

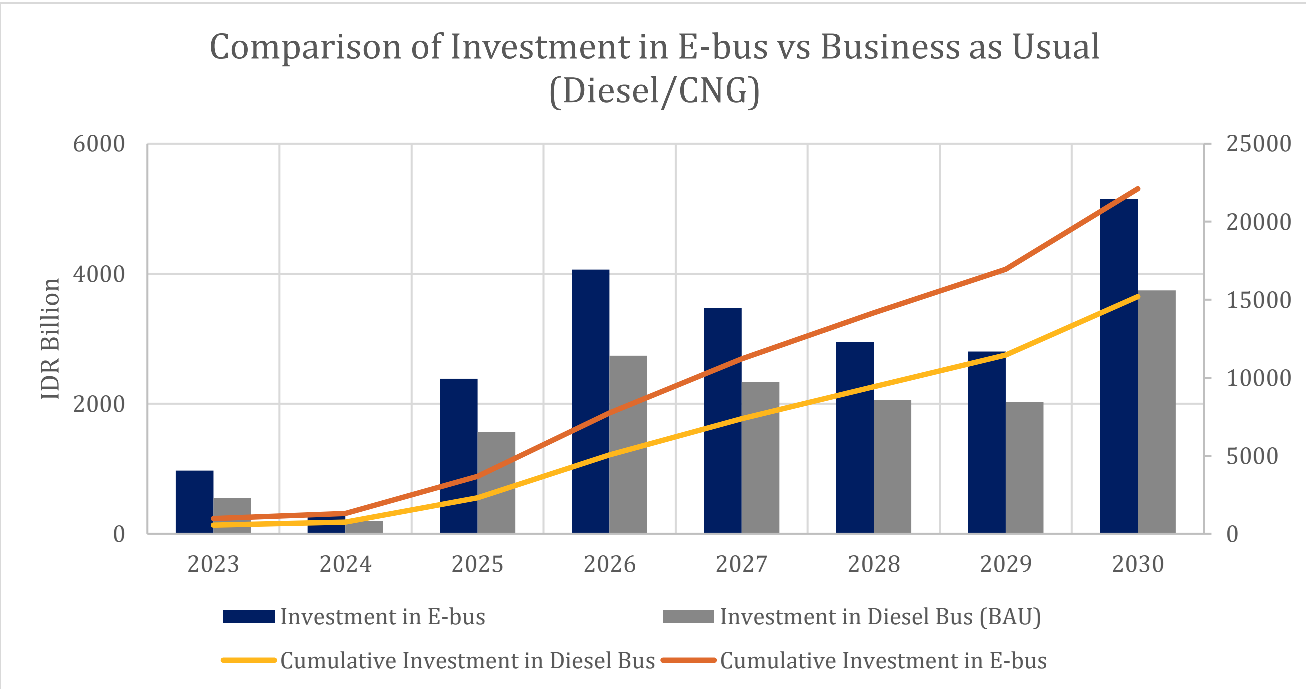

Figure 2. TCO investment comparison between E-buses and Diesel/CNG

Although Transjakarta is running profitable operations and has been increasing its investment in operating assets, it is nowhere close possessing the ability to finance the capital expenditure for over 10,000 electric buses and its charging infrastructure estimated over IDR 22 T i.e., more than 6 times the Net Current Assets of Transjakarta. Further, the decree from the Governor States that the financial support from the Government of Jakarta will be in the form of Rp/km and hence Transjakarta has to follow the current service contracting pattern under the BTS scheme.

Long Term Implementation Phase

Transjakarta is already aware of the contract expiration dates and procurement of e-buses requires 12-18 months period. Hence, Transjakarta needs to initiate the procurement process on time accordingly so that the e-buses can be delivered by the time the contracts for diesel buses expire.

It is expected that initially the e-buses will be imported as CBU (completely built unit) and gradually the indigenous manufacturing can take over to increase the local content. This will improve e-bus availability as well as costs as seen in other countries such as India.

The operators either have poor financial health or do not have adequate financial capacity to arrange the scale of financing needed to replace the current diesel buses as well as take up augmentations of the fleet by nearly 150% in next 7 years. Hence, alternative business models such as leasing needs to be implemented especially for medium and microbuses which are run by cooperatives of individual owner-operators.

Implementation of charging infrastructure for daytime opportunity charging needs to be implemented at strategic locations on priority to reduce both investment costs, bus idling and empty running.

1. Introduction

1.1. Background

Transjakarta has set a target to electrify 100% of its fleets – equivalent to 10,047 fleets – in 2030. This target has been strongly advocated and mandated through Governor Decree 1053/2022 on the Guidelines on Acceleration Program for Battery Electric Bus Deployment under the Transjakarta Services.

Transjakarta also developed the year-on-year electric bus share target from 2022 to 2030 – for which the Governor Decree states that 50% electrification should be achieved by 2027. However, it is not very clear yet how many e-buses should be deployed on a year-on-year basis and the type of buses to be deployed considering the existing contract duration, technology readiness, and economic & financial analysis of the electrification.

Through the UNEP-CTCN study, ITDP has developed Transjakarta e-bus implementation phase for 1,724 large and medium bus. Moreover, ITDP has also developed an implementation phase of 3,300 microbus, under the first year of this study. However, the large and medium bus electrification only considers the existing numbers which has not been projected into 2030, and the microbus implementation phase developed in the previous study used the old figures that is now being superseded by the current target developed by Transjakarta. Furthermore, according to the Head of Jakarta Transport Agency decree, which mandates the specific quota for both large bus, medium bus, and small bus, there is a significant change in how many electric microbuses needs to be deployed by the end of 2030.

Based on the previous studies, the total number to be electrified is 5,024 buses, which translates to only 50% from what have been mandated on the Governor Decree. Hence, there is a need to conduct a further study to incorporate the target set on the Governor Decree.

1.2. Objectives of The Report

This report will examine the implementation phase developed on previous study and incorporate the current target into the implementation phase, taking into account the technical and economic aspects. With that, Transjakarta will already have a comprehensive implementation phase, which integrates the 6,600-microbus electrification target as well as around 3,400 large and medium bus targets.

1.3. Scopes of The Report

Through the development of the implementation phase, the year-on-year e-bus deployment between 2022 and 2030 will be examined based on two fundamental aspects: **technical and economic & financial analysis**. Additionally, **policy supports** needed to be implemented each year, as well as **GESI milestones**, will be demonstrated on this report as well.

The assessment from the technical aspects takes into account the latest plan of Transjakarta's electrification, quota for each bus types in 2030, contract replacements, and technology readiness. The output is the bus types and its respective number of fleets that will be deployed each year, fleet provision options, charging infrastructure, charger power, battery technology, and number of charging facilities needs to be deployed each year.

In this report, detailed assessment on route-based analysis has not been taken into account, since the detailed technical plan, including route-level prioritisation, will be evaluated in the next output. Moreover, this assessment still gives indicative types of charging infrastructures that need to be deployed each year and the time frame for which Transjakarta or the Government of Jakarta need to procure additional land area for the charging activities. Similar to the route-level prioritisation, recommended terminal charging locations is developed in the next output.

The economic & financial analysis will determine the TCO/km for each type of e-bus, compared to diesel bus with the same models, to evaluate the TCO parity of the electric buses. The TCO/km parity will give ideas on types of fleets that, cost-wise, could have its electrification target being expedited, which further provide input to the technical analysis for developing another implementation phase scenario where the electrification target for a certain type of fleets is advanced compared to Transjakarta's target. Moreover, estimated total investment cost will also be calculated in this report.

1.4. Outline of the Report

This report will be divided into 9 sections. Section 2 will describe the methodology and the relation of this report to other activities under this project. Section 3 will provide the overview of Transjakarta. Section 4 will demonstrate the Transjakarta e-bus deployment plan and its current implementation.

To avoid redundancy in the analysis, the previous studies related to the electrification of Transjakarta will be scrutinised and a gap analysis will be performed in Section 5.

The technical analysis; financial & economic analysis; and other factors' analysis—such as OEMs readiness, operators' readiness, policy support, and GESI aspects for developing the implementation phase will successively be discussed in Section 6, 7, and 8. To end the report, the conclusion and way forward will be wrapped in the last section.

2. Methodology

The step-by-step methodology, including the respective sections on this report, is listed as follows:

1. Analyse the overview of Transjakarta service, operational pattern, and operational planning (Section 3);
2. Analyse e-bus deployment plan & the current implementation (Section 4);
3. Analyse of previous studies' result on Transjakarta electrification roadmap and implementation phase (UNEP-CTCN for BRT and non-BRT, UK PACT Phase-I for microbus), develop the gap analysis and key takeaways (Section 5);
4. Assess fleets' technology readiness and develop the fleets typology (Section 6.2);
5. Assess the number of e-buses to be deployed each year based on e-bus typology, Transjakarta's latest electrification target, quota for each bus types in 2030, and contract duration ends (Section 6.3);
6. Calculate the TCO/km of electric bus types and compare it with the TCO/km of comparable conventional fleets, to determine the type of e-bus fleet that could be expedited (Section 7.2);
7. Develop additional scenarios of the number of e-buses based on the TCO/km comparison results (Section 6.3);
8. Assess chargers' technology readiness and estimates the total of charging facilities needed (Section 6.4);
9. Estimate the total investment cost (Section 7.3);
10. Assess Transjakarta's financial capacity (Section 7.4);
11. Assess other factors' readiness (Section 8).

3. Overview of Transjakarta

3.1. General Overview of The Transjakarta Service

Transjakarta’s current operations include eight types of services along with seven types of bus fleets. A majority of these are owned and operated by several operators with a few buses and routes owned and operated by Transjakarta. Each route can have multiple fleet types which depends on the several factors such as demand, road characteristics, type and width of the road, and safety aspects, taking the bus GVW and turning radius into consideration. The 8 types of Transjakarta services are listed as follows:

1. BRT (Bus Rapid Transit): This service runs on a dedicated lane. There are currently 13 BRT corridors with 50 routes under the Transjakarta service, spanning over 251.2 kilometres.
2. Integration routes: The integration routes, sometimes called as non-BRT, is a Transjakarta regular routes which running fully outside the BRT system or in-and-out the BRT system (direct services). There are currently 52 integration routes operated.
3. Border routes: The Border or Transjakarta service operates between cities in the Greater Jakarta Area (“Jabodetabek”) and is integrated with the BRT service. There are currently 8 routes within this service.
4. Affordable housing routes: This service is aimed for affordable housing residents, providing them direct access to Transjakarta BRT corridors. There are 18 routes.
5. Mikrotrans: The Mikrotrans service is Transjakarta’s feeder system using microbuses. This service highly increases the coverage of Transjakarta’s service area. There are currently 80 Mikrotrans routes under Transjakarta service.
6. Royaltrans: Royaltrans service is a premium shuttle service for Greater Jakarta commuters. Different from other Transjakarta services, Royaltrans is not subsidised. There are currently 8 Royaltrans routes under the Transjakarta service.
7. Tourism routes: There are currently 2 tourism routes under Transjakarta service, using double-decker fleets.
8. Transcare: This is a special microbus service catered to serve people with disabilities with 26 buses under operation with no fixed routes.

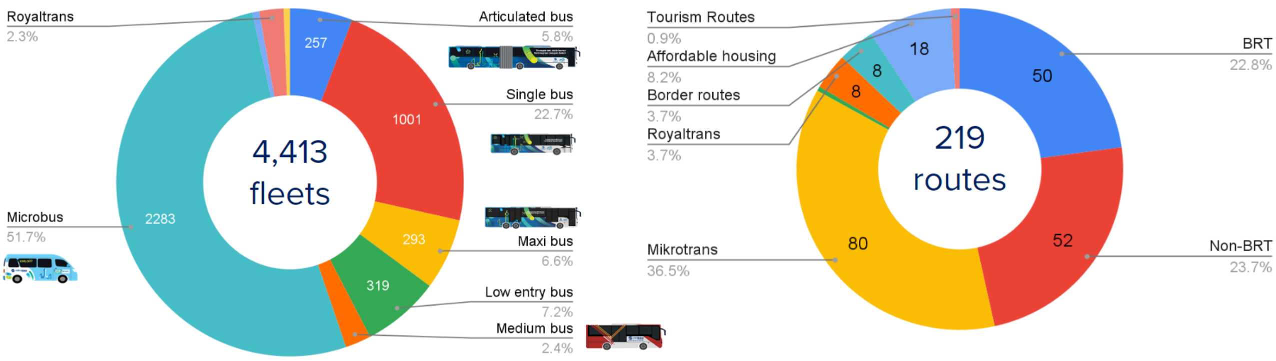

Figure 3. Transjakarta's current number of fleets and number of routes

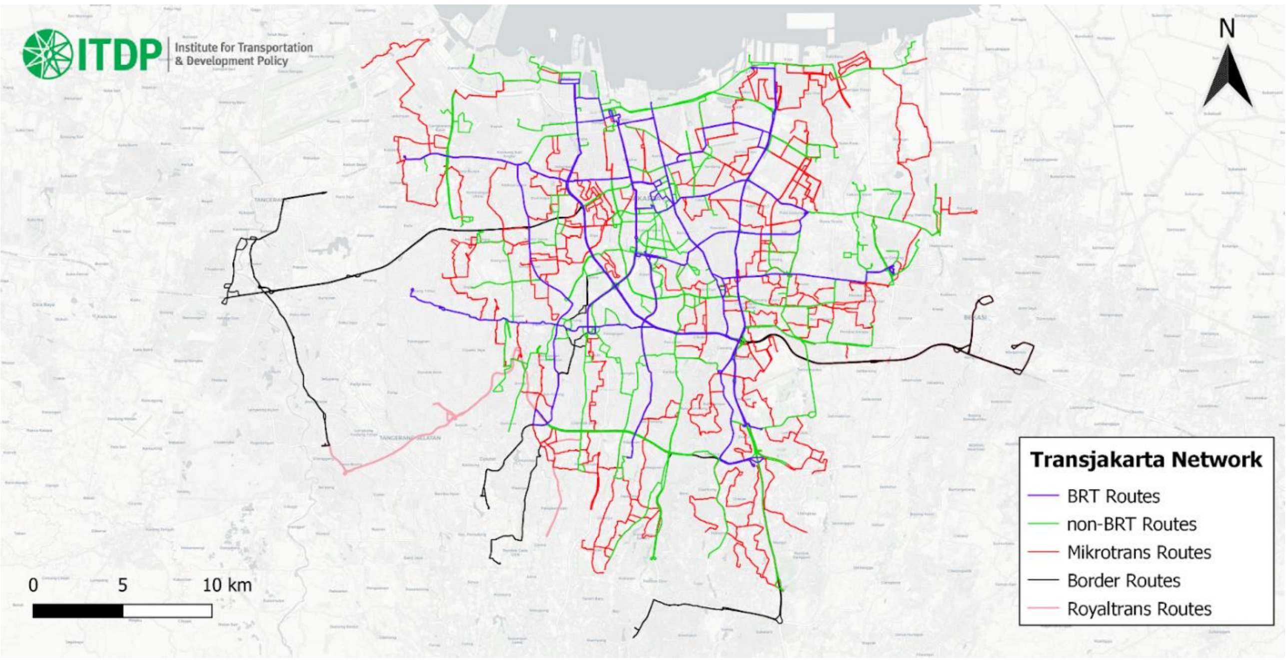

Figure 4. Current Transjakarta's network

Overall, Transjakarta has 4,413 buses, 18 operators, 219 routes, 8 service categories, demonstrated on the table below:

Table 3. Transjakarta's service based on bus type

Bus type & length	Number of buses	Service
Medium Bus (7-m)	268	Non-BRT, Affordable Housing
Single Bus (12-m)	965	BRT, Non-BRT Integration, Border Routes, Affordable Housing
Single low Entry (12-m)	319	Non-BRT, Border Routes
Maxi Bus (13.5-m)	293	BRT, Non-BRT, Border Routes
Double Decker	28	Tourism Routes
Articulated (18-m)	257	BRT
Microbus (4-m)	2129	Mikrotrans, Transcare

3.2. Daily Operational Pattern and Daily Operational Plan

Typically, Transjakarta services start the operation at 5am and finish at 10pm every day, even though Transjakarta also deployed midnight routes on the 13 main corridors. The fleet is split into buses which do all day service and buses which are pulled out from service during off peak hours. However, the splitting method is not applicable to Mikrotrans services.

Due to the split, about 40% of the buses do not operate during off-peak hours. The peak hours are from 6am to 9am and 4pm to 8pm. Starting from 8 pm to 10 pm, the buses start to finish their schedule in batches with priority given to buses with full-day service and longer schedules. The large and medium bus is going back to their respective depots, where the microbus fleets are going back to their drivers' house. On the way back to the depots, all the buses are required to refill their fuel tank. The last fleet is expected to arrive at its depot at 12am. The number and type of conventional (ICE) bus fleets running on a particular route is not fixed but varies on a daily basis.

The daily operational pattern for the current 30 Transjakarta electric bus fleets is similar to the other Transjakarta services. After going back from operations at around 10 pm, the fleets will recharge their battery at the operator's depot. Different from the conventional bus fleets, the number of e-bus running on each route is fixed since the operation is not as flexible as conventional bus fleets.

4. Electric Bus Deployment Plan & Current Implementation

4.1. Deployment Plan and Stages

4.1.1. Legal Basis on E-Bus Deployment

The Government of Indonesia has been encouraging deployment of electric vehicles in public transport including through Presidential Regulations No. 22/2017 and 55/2019. Jakarta is one of the most polluted cities in the world and hence the provincial government of Jakarta (DKI Jakarta) has also issued the following regulations to reduce transport sector emissions:

1. Jakarta Governor Instruction No. 66/2019 on Air Quality Control: Includes an instruction to accelerate public transport fleet renewal and to implement a more stringent emission standard for public transport fleet.

2. Governor's Regulation No.90/2021 on Local Low Carbon Development Plan: Electric bus deployment at BRT system, BEV adoption in government fleets, and charging infrastructure development are included as the detailed action plan to shift the transport sector to a more environmentally friendly fuel source.

3. Jakarta Regional Secretary Instruction No. 01/2021 on Regional Strategic Activities Acceleration Action Plan: Includes a mandate for Transjakarta to implement electric buses in 2021.

4. C40 Fossil Fuel Free Streets Declaration (2019): Jakarta pledged to implement 100 electric buses by 2020, to have 50% of Transjakarta fleet electric by 2025 and to only procure zero-emission buses by 2025, and to implement two low emission zones by 2021 as well as other "push" policy measures such as increased parking fare and congestion pricing by 2020.

More recently, the Government of Jakarta issued the Jakarta Governor Decree No. 1053/ 2022 dated October 14, 2022, which provides a basis regulation for accelerating the Battery Electric Bus implementation program under the Transjakarta services. Several important points on the Governor Decree are listed below:

- Transjakarta to acquire 10,047 electric buses by 2030 and to have at least 50% of its fleet electrified by 2027.

- The costs required for the deployment of the battery electric bus shall be charged to the Regional Revenue and Expenditure Budget of the DKI. Jakarta.

- charging facilities will be provided in the form of overnight charging, opportunity charging, and other types of charging technology at depots, terminals, or at other locations including on regional assets.

- procurement and/or financing of operator services Transjakarta is carried out with a payment scheme of Rupiah per kilometre (Rp/Km).
- The Jakarta Transport Agency is instructed to review and approve the battery electric buses implementation proposal that is proposed every year by PT. Transportasi Jakarta after the stipulation of Annual Regional Budget.

4.1.2. E-Bus Implementation Plan

Accordingly, Transjakarta has developed the procurement plan for electric buses. The target is not based on the number of e-bus to be deployed each year, giving a very dynamic fleets' realisation but rather based on the percentage of e-buses operating each year compared to the number of fleets. For example, if Transjakarta will have 5,000 fleets by 2023, with 6% deployment target, Transjakarta has to have 300 e-bus fleets operating. Figure 5 demonstrates the Transjakarta e-bus share target from 2022 to 2030. As mentioned in the previous part, The Governor Decree only put milestone in the year of 2027 and 2030, which is 50% and 100% respectively – meaning the other years are relatively flexible.

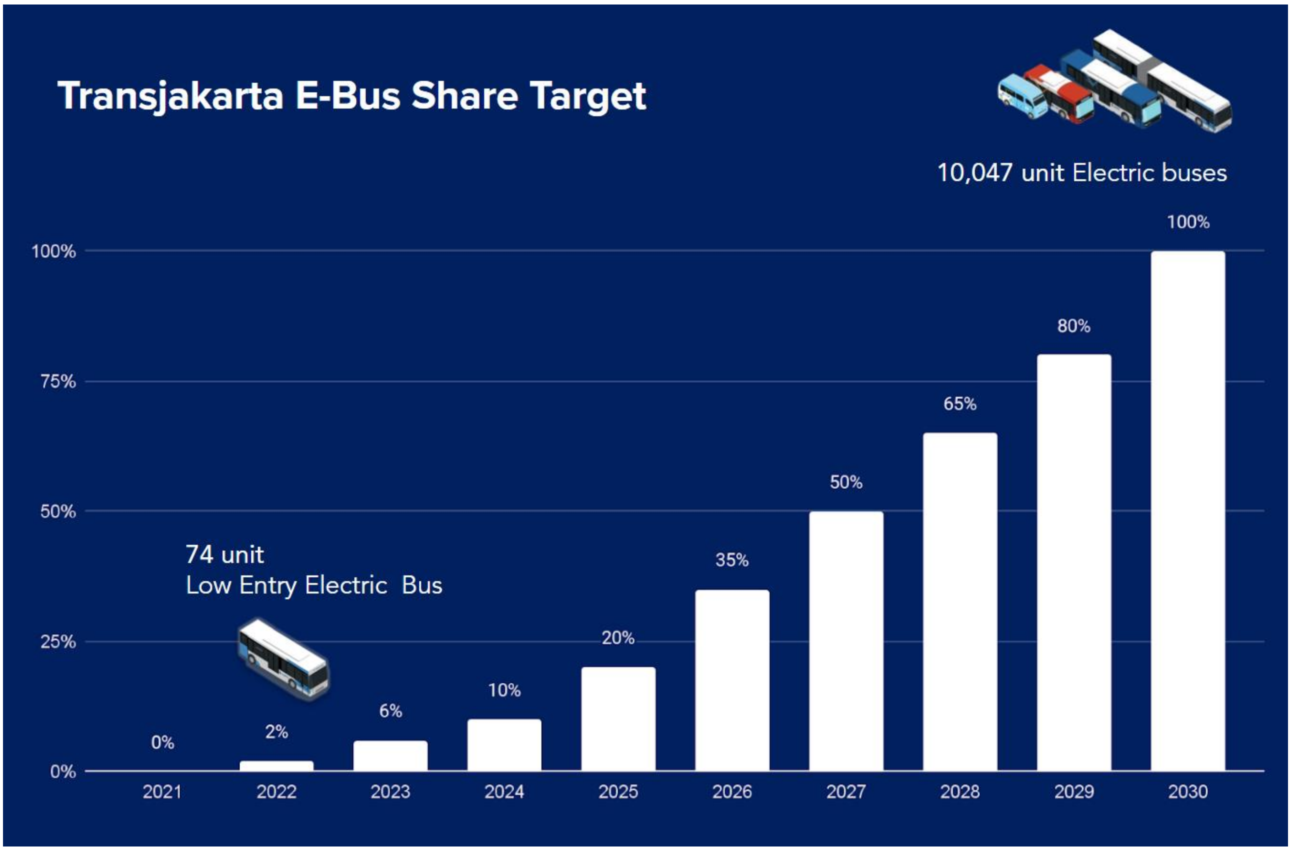

Figure 5. Transjakarta's E-bus share target

The following table shows the Transjakarta's electrification plan until 2025 by bus-type.

Table 4. Transjakarta's electrification strategy

2022	2023	2024	2025
Single low entry bus 12-m *Depot overnight charging*	Medium bus 8-m *Depot overnight charging*	Medium bus 8-m *Terminal opportunity charging & depot overnight*	Medium bus 8-m *Terminal opportunity charging & depot overnight charging*
	Single Bus BRT 12-m *Terminal opportunity charging & depot overnight charging*	Mikrotrans 4-m *Overnight charging*	Articulated bus 18-m *Terminal opportunity charging & depot overnight charging*

4.1.3. E-bus implementation Phase(s)

Typically, Transjakarta conducts three phases of electrification:

1. **Pre-trial phase**
   TJ conducted pre-trial of e-buses on road since 2019 with BYD K9 (low-floor 12-m) and C6 model. E-bus pre-trial is conducted for each e-bus model for 3-month before being commercially operated. Transjakarta obtained information on the level of battery consumption in the field and the conformity of each e-bus models with their needs from this phase. So far, 7 e-bus models have conducted pre-trial — 5 of them are low entry 12-m e-buses, 1 medium high deck low entry and 1 high deck BRT.

2. **Pilot phase**
   On the pilot phase, the e-bus has been commercially operated and carried out for 2 years. At the end of year 2, a review of the cost of maintenance and operation is conducted. Transjakarta set targets to electrify 100 low entry, 12-m e-bus starting in 2021. Currently, 30 low entry e-bus has been deployed, with other 70 is already in the pipeline.

3. **Full Implementation**
   The full implementation phase continues the pilot phase that has been developed, with the cost of maintenance and operation that has been reviewed and adjusted.

4.2. Current Progress of E-Bus Pre-trial Phase

In 2019, between September to December, Transjakarta conducted the first pre-trial for medium and single electric buses. The first pre-trial included three buses – BYD K9 12-m (324 kWh) single bus, BYD C6 7.4-m (135 kWh) medium bus, and MAB MD12E 12m single bus (a local manufacturer).

The buses were deployed at three locations, namely Ancol (North Jakarta), Taman Mini (East Jakarta) and the Monas - Bundaran HI route. Since the buses did not have permits to operate commercially yet at that time, the buses were loaded with gallons of water to simulate passenger weight. In 2020, Transjakarta conducted the second pre-trial for two months between July 6 to September 6 with passengers. BYD K9 12-m single bus and BYD C6 7.4-m medium bus were deployed on the non-BRT route (Balai Kota - Blok M).

Figure 6. Transjakarta's BYD C6 on pre-trial phase, 2020

Table 5. Transjakarta's pre-trial result

Bus	First Pre-Trial				Second Pre-Trial				
	Distance travelled (km)	Travel time (hour)	Energy (kWh)	Energy efficiency (kWh/km)	Distance travelled (km)	Travel time (hour)	No. of pax	Energy (kWh)	Energy efficiency (kWh/km)
Medium bus (BYD C6)	502	46.5	293.9	0.58	10,664	936.1	3,249	6,336	0.59
Single bus (BYD K9)	327	36	380	1.16	11,551	1,025.7	7,383	10,826	0.9

Source: UNEP study

In 2021, Transjakarta continued conducting pre-trial phase for Higher KLQ6125GEV-101. Similar to BYD K9, it has length of 12-m and run on Balai Kota – Blok M. Transjakarta has also recently launched 3 more low floor 12m e-buses from 3 different brands - Zhongtong, Skywell and Golden Dragon. These are running on route 5F (Kp. Melayu - Tanah Abang) on a pre-trial basis.

Figure 7. Higer KLQ6125GEC-101

In July 2022, Transjakarta has also signed an MoU (memorandum of understanding) with PT Mobil Anak Bangsa (MAB) for implementation of electric bus. It started with trials of 12-m high floor BRT electric bus on corridor 6B. The e-bus specifications include 315 kWh of battery capacity with a range of 250 km and a charging time of 1.5-2 hours. The electric bus is manufactured in Indonesia with 35% local components. The data from these trials is yet to be obtained and evaluated.

4.3. Current Progress of E-Bus Pilot

As part of the 100 electric buses target for the pilot phase, currently 30 electric buses have been procured and are being operated by an operator, Mayasari Bakti. The procurement process for the rest of 70 electric buses is currently underway, divided into several procurement packages, each of the packages contains around 20 e-bus.

By the time the analysis conducted, these buses are currently being operated on 2 routes, which are 1P: Blok M - Terminal Senen and 1N: Blok M - Tanah Abang[1]. Out of the 30 e-buses, 11 buses

[1] Since the end of September, e-bus fleets have been deployed on additional route, 6D: Tebet Station – Bundaran Senayan

are operating on route 1N (Tanah Abang - Blok M terminal), 16 buses are operating on route 1P (Senen Terminal - Blok M Terminal) and 3 buses reserved as spare buses.

The tables below present some of the operating parameters of the electric bus

Table 6. Pilot E-bus specification

Battery capacity	324 kWh
Range	250 km
Model	BYD K9 12-m Low floor
Peak motor torque	1100 Nm
Passenger capacity	31 (seating) + 12 (standing)

Table 7. Pilot E-bus operational parameters

Daily km per bus	200-250 km
Dead kms	50 km
No of round trips/ bus	7-8
Fuel efficiency	1 kWh/km
SoC reserve	20%
Charging strategy	Overnight only
Charger power	2 x 100 kW (double gun EVC)
Charging time	1.5 hours (0-100%)
Dead kms	~30-50 km

Since the buses have been running for a limited time, there have been no downtime or failure issues recorded yet. The pilot e-buses performance efficiency is evaluated based on the distance travelled with the amount of energy consumed or illustrated by km/SOC and km/kWh. It is observed to be around 3.4 and 1.1 respectively.

4.4. Key Takeaways

It is seen from the pilot results that the dead kms are much higher than estimated and this will cause a significant impact on the range and charging pattern for the electric buses. While overnight charging will happen at the depots, as the battery capacity decreasing over time, daytime opportunity charging at depots may not be feasible as it will increase the dead kms and also loss of time available for charging during off peak hours. Opportunity charging at terminals or other charging locations should be considered taking into account the terminal space availability and grid accessibility.

The pilot fleet can be gradually implemented based on availability of charging infrastructure. The timelines for procurement and operation of electric buses are also longer than the diesel buses ranging from 1 to 2 years. This timeline also depends on the lot size and scale of procurement and has to be considered in implementation plan.

5. Previous Studies' Results on Transjakarta Electrification Roadmap and Implementation Phase

5.1. Previous Studies' Results on Transjakarta Electrification Roadmap

Several studies have been done on the deployment of electric buses by Transjakarta in the recent years. More recently the C40-CFF study focused on the implementation plan of 100 pilot electric buses as a follow-up of the pre-trial stage. The UNEP-CTCN study developed a roadmap and investment plan for the electrification of 1,724 large and medium Transjakarta fleets along with the business model and a holistic investment plan, and the Year 1 of UK PACT EUM 124 study was focused on microbuses electrification. As a background for several assumptions and analysis done in this report, main findings and recommendations from these studies are presented in this section.

5.1.1. C40-CFF: Transjakarta 100 Pilot E-buses

The study was conducted from Feb 2020 - March 2021. The objective of the study was to prepare an implementation for 100 pilot electric buses, by conducting technical, institutional, legal, financial feasibility analysis and also the business and financial models to procure the pilot fleets.

The study included route level TCO analysis and selection of routes for the pilot project and identification of pilot project charging strategies and charger specifications, and specifications of the electric bus fleet for different bus types.

Findings and recommendations:

1. 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. 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.
2. The average TCO for medium buses with small batteries (135 kWh) is 53% higher when compared to the average TCO of diesel buses. This significant difference causes the recommendation to delay medium electric bus deployment until the battery cost is further reduced.
3. A five phased roadmap is recommended for the full-scale EV roll out of Transjakarta's entire fleet shown below.

Table 8. Five Phase Roadmap of Transjakarta's Full-scale EV by C40 Study

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) 2.5-m wide buses only allowed as of now 2) Commercial permit (yellow plate) both BRT & Non- BRT Routes	Allow buses with width > 2.5-m and length 12-m	Allow buses with width > 2.5-m and length 12-m	Allow buses with width > 2.5-m and length 12-m and 18-m	Allow buses with width > 2.5-m and length 12m & 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 The Government of Jakarta, identify complete electrification of Depots	Discuss with TJ and The Government of Jakarta	Discuss with TJ and The Government of Jakarta
Bus Type	9-m and 12-m	12-m and 9-m	12m and 9m few 18m	12m and 9m few 18m	12m and 9m few 18m

4. Recommendations on charging strategy:
    a. Overnight charging at depots for big battery (> 300kWh) buses, with bus-charger ratio of 2:1.
    b. Overnight charging at depots and opportunity fast charging at terminals for small to medium battery buses, with bus-charger ratio of 5:1.
5. Findings on financing strategy:
    a. Given the reduced revenue and budget due to the COVID-19 pandemics, self-financing opportunities by Transjakarta and the Government of Jakarta are limited.
    b. The initial investment cost for the 100 E-bus Trial project amounts to USD 44.3 million. The E-Bus fleet cost amounts to USD 29.5 million. The charging infrastructure and fast chargers amounts to some USD 6.6 million. A contingency allowance of USD 8.2 million has been identified.

c. Operator self-financing through the domestic banking sector or PT. SMI is recommended, however, recovery from the pandemic situation needs to be considered.

5.1.2. UNEP-CTCN: Electrification of Large and Medium Fleets

The main objective of the study was to develop a roadmap and investment plan to electrify large (> 12-m length – including single and articulated bus) and medium (7-m length) buses. This study also initially prepared the business model and financing mechanism. There are 1,724 fleets electrified in this study – based on all the existing number of large and medium fleets when the study conducted. The study has not taken into account the number of augmented fleets to be electrified by Transjakarta.

It also included identifying supporting policies requirement and actions required by the Government of Jakarta and the Government of Indonesia to facilitate the deployment of e-buses and related infrastructure. The study further included development of a feasibility study to integrate renewable energy supply to the mobility operations, including solar roofing for Transjakarta buses, stations, and depot and development of a methodology to evaluate the pilot e-bus deployment. The study also addressed the needs to incorporate GESI aspects into the e-bus implementation.

Findings and recommendations from the study could be divided into five categories: policy, technical, implementation plan, and financing, as described below:

Policy

Some key policy recommendations to the Government of Jakarta are as follows:

1. Give mandate and issue implementation target for electric bus deployment.
2. Adjust contractual regulations.
3. Provide fiscal and non-fiscal incentives for electric bus operations, while disincentivizing diesel buses.
4. Direct Regional-Owned Enterprises to support the financing of electric buses.
5. Provide incentives for charging infrastructure establishments.
6. Support land access for charging infrastructure and adjust building regulations.

Technical

1. The battery sizes considered were 180 kWh and 324 kWh for single buses, 450 kWh for articulated buses, and 135 kWh for medium buses. for BRT routes there will still be high deck single buses and articulated buses, and for non-BRT routes there will be high deck single buses, low entry single buses, and medium buses.
2. Four staging facilities are recommended to be established in North Jakarta, Pesing (West Jakarta), Pejaten (South Jakarta), and Pinang Ranti (East Jakarta). For routes which are not

viable to be assigned to the staging facilities, either more buses or bigger battery buses can be assigned, whichever option has the lowest TCO.

1. For this study, the depot chargers have 150 kW power, the terminal fast chargers have 450 kW power, and chargers at the staging facilities are 180 kW and 450 kW respectively for single and articulated buses.

Implementation plan

1. All the routes have been classified into 12 groups based on spatial proximity and shared charging facilities between the routes. Each group is assigned to one common opportunity charging facility. Four groups (1, 2, 3, 4) are assigned to staging facilities. The rest of the groups are assigned to either the common terminal or depot area for opportunity charging.
2. Five implementation phases are recommended based on technology readiness and the number of buses to be deployed each year.

	2021 - 2024		2024 - 2027		2027 - 2030
	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Infrastructure	• Transjakarta provides one staging facility • 5 charging points at terminal provided by Transjakarta • Overnight charging provided by operators	• 9 fast charging points at terminal provided by Transjakarta • Overnight charging provided by operators	• 10 fast charging points at terminal provided by Transjakarta • 2 staging facilities ready to be used • Overnight charging provided by operators	• 11 fast charging points at terminal provided by Transjakarta • 3 staging facilities ready to be used • Overnight charging provided by operators	• 12 fast charging points at terminal provided by Transjakarta • 4 staging facilities ready to be used • Overnight charging provided by operators
Charging Strategy	Overnight + Staging Facilities + Terminal Charging	Overnight + Terminal Charging	Overnight + Terminal Charging + Staging Facilities	Overnight + Terminal Charging + Staging Facilities	Overnight + Terminal Charging + Staging Facilities
Number of e-bus to be produced	234	493	416	257	325
Fleets and Charging Technology	• Single bus Depot: Plug in 150 kW Terminal: Pantograph 450kW Staging: Plug in 180 kW	• Single bus • Medium bus Depot: Plug in 150 kW Terminal: Pantograph 450kW Staging: Plug in 180 kW	• Single bus • Medium bus Depot: Plug in 150 kW Terminal: Pantograph 450kW Staging: Plug in 180 kw	• Single bus • Medium bus • Articulated bus Depot: Plug in 150 kW Terminal: Pantograph 450kW Staging: Plug in 180 kW	• Single bus • Medium bus • Articulated bus Depot: Plug in 150 kW Terminal: Pantograph 450kW Staging: Plug in 180 kW
Investment	• CAPEX: USD 117,744,467 • OPEX: USD 72,942,592 • TOTAL: USD 190,687,059	• CAPEX: USD 208,076,022 • OPEX: USD 117,155,160 • TOTAL: USD 325,231,182	• CAPEX: USD 247,227,487 • OPEX: USD 123,644,007 • TOTAL: USD 370,871,494	• CAPEX: USD 208,076,022 • OPEX: USD 117,155,160 • TOTAL: USD 325,231,182	• CAPEX: USD 139,924,597 • OPEX: USD 78,866,001 • TOTAL: USD 218,790,598
GHG Reduction (from business-as-usual)	• CO2eq: (17,475) ton • PM2.5 : (30.7) kg • SO2 : (19.3) kg • NOx : (691,9) kg	• CO2eq: (43,350) ton • PM2.5 : (72) kg • SO2 : (45) kg • NOx : (1,664) kg	• CO2eq: (68,861) ton • PM2.5 : (99) kg • SO2 : (61) kg • NOx : (2,431) kg	• CO2eq: (85,112) ton • PM2.5 : (122) kg • SO2 : (75) kg • NOx : (2869) kg	• CO2eq: (100,89) ton • PM2.5 : (137) kg • SO2 : (84) kg • NOx : (3,251) kg

Figure 8. Transjakarta implementation phase for 1,724 large bus and medium bus, UNEP-CTCN study

Financing

1. The preliminary financial calculation indicated that the investment costs vary for each implementation phase, due to difference in number of routes, number and type of buses, route length, and costs related to charging infrastructure, including staging facility costs. The following graph shows the total CAPEX and OPEX in each implementation phase.

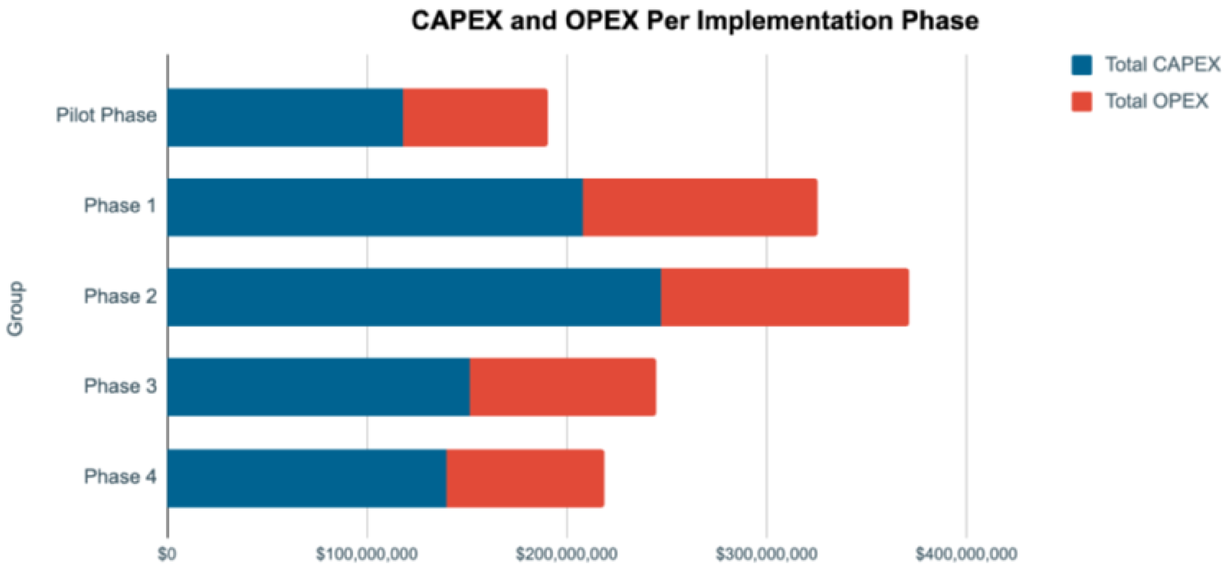

Figure 9. Total of CAPEX and OPEX in each implementation phase, UNEP-CTCN study

2. Several funding options are available to Transjakarta such as the Local Government's Capital (*Penyertaan Modal Daerah*), loans, grants, and other funding sources, such as reserve capitals (*kapitalisasi cadangan*), asset revaluation profits (*keuntungan revaluasi aset*), and Additional Paid-in Capital/ APIC (*agio saham*).
3. For bus operators, the on-lending scheme from the Government of Jakarta or the national government is currently not possible. So, loans from commercial banks or other financing companies are the most feasible option.

5.1.3. UK PACT EUM 124 Phase-I: Large-scale Electrification of Microbuses

The scope of the project included developing operational and charging plan for microbuses, TCO analysis, implementation phasing plan for electrification of microbuses starting from 2023 until 2030 along with solar PV integration and grid analysis. This study has considered Transjakarta's electrification plan on microbus – which is about 3,300 fleets in 2030 – even though the plan has been refined and the number of microbuses to be electrified is almost doubled to around 6,360 in 2030.

	2022 Pilot	2023 Phase I	2024 - 2025 Phase II	2026 - 2028 Phase III	2028 - 2030 Phase IV
Policy	Roadmap & institutional policy, demand creation policy		Environmental policy, infrastructure provision policy	Supply support policy	Land bank policy
E-Bus to be procured	50	507	974	928	850
Charging infrastructure	Existing Terminals (layover location)	Depots and existing terminals	Existing and new depots, existing and new terminals, parking bays	Existing and new depots, existing and new terminals, public charging stations & parking bays	Existing and new depots, existing and new terminals, public charging stations & parking bays
Charging strategy	Overnight + terminal charging	Overnight + terminal charging	Overnight + terminal charging	Overnight + terminal + staging charging (optional)	Overnight + terminal + staging charging (optional)
Battery and charging technology	LFP	LFP, NMC	LFP, NMC	LFP, NMC, or newer technologies	LFP, NMC, or newer technologies
	50 - 75 kWh	50 - 100 kWh, efficiency ~ 3 km/kWh	50 - 100 kWh, efficiency > 3.5 km/kWh	50 - 100 kWh, efficiency > 4 km/kWh	50 - 100 kWh, efficiency > 4 km/kWh
	DC 22 - 50 kW charger	DC 22 - 50 kW charger	DC 22 - 50 kW charger	DC 22 - 100 kW charger	DC 22 - 100 kW charger
Routes selection	New routes + based on pilot selection	Based on routes ranking	Based on routes ranking	Based on routes ranking	Based on routes ranking

Figure 10. Mikrotrans electrification roadmap, UK PACT EUM 124 Year-1 Study

Key Findings and recommendations:

1. The typical battery size for electric microbuses is around 50 kWh and with charger capacity ranging from 22 kW – 75 kW.
2. The layover locations for the microbus operations could be used as potential charging locations. Since depots are not available for microbuses, public spaces such as parking lots, malls, etc. could be explored for setting up potential overnight charging locations.
3. Three microbus models, Vivaro Vauxhall, Gelora from DFSK, and Foton Toano EV are shortlisted due to its compatibility with Transjakarta's requirements. TCO/km of the models were being analysed. The analysis shows the Gelora model's TCO/km is already lower than the ICE models.
4. The layover locations have been classified into seven groups for solar integration analysis to enable scale up of solar PV potential based on layover type (looping or non-looping and single and multiple routes).
5. Solar PV can accommodate for 5% up to 55% (on an annual basis) of the charging demand, with 20% solar penetration being the average, depending on the solar PV potential and charging profile at each location. Out of the seven charging location group representatives, the solar power potential ranges between 13.5~1,100 kWp, with Tanah Abang on-street layover and Tanjung Priok Terminal being two of the largest potential given its space availability.
6. The cost-benefit analysis also showed that the project is highly economically viable as shown in the table below.

Table 8. Result of Cost-Benefit Analysis, UK PACT EUM 124 Year-1 Study

Parameter	Value
EIRR	28.84%
NPV of Benefits	IDR 1,343 billion
NPV of Costs	IDR 697 billion
Cost Benefit Ratio	1.93

5.2. Gap Analysis and Key Takeaways

A thorough review of the previous studies were conducted, and gap analysis was performed. The following summarises the key takeaways that will be considered further when developing a comprehensive implementation plan in this study:

1. The CFF – C40 study focused on the 100 e-bus trial for a detailed analysis. The roadmap for large scale implementation is done at a broad level and does not identify the routes to be electrified in each phase. Microbus electrification is not also considered.
2. The UNEP study for the BRT and the Non-BRT services does not consider the integration of the microbuses in the electrification plan. Currently microbuses amount to more than 60% of Transjakarta's fleet size and are the feeder services to BRT and non-BRT routes. Hence, it is crucial to integrate all the service types into one roadmap.
3. The UK PACT Year 1 study developed the electrification roadmap based on obsolete implementation plan from Transjakarta, where only 3,300 electric microbuses will be deployed by 2030. The current implementation plan, which has taken into account fleets type quota from the Head of Jakarta Transport Agency decree, which has the target of more than 6,000 electric microbuses to be on the road by 2030.
4. The fleet typology and charging strategy scenario can be developed taking the UNEP study as the basis and will be adjusted accordingly.
5. The UNEP study proposed implementation of pilot phase that requires a staging facility. This poses additional challenges in terms of land acquisition, which is not feasible in the immediate to short term implementation.
6. The route grouping needs to be revised and terminal-based approach can be considered since the provision of additional charging locations may not be feasible in the near future.
7. The UK PACT Year 1 study for the microbus electrification identifies layover locations which are also grouped into several categories as potential charging locations. These can also be integrated into this study.

8. Trials for the new bus types such as articulated and retrofitted buses should be considered in the implementation phase.
9. Routes with high visibility and running in the CBD area with private vehicles' traffic restriction can be selected and prioritised for electrification in the pilot and initial phases.
10. The implementation phasing should consider mixed operational plan with diesel and electric buses. The daily operational plan for the diesel buses is very dynamic where the number and types of fleets are changing on a daily basis. This cannot be extended to the electric bus operations due to constraints on charging patterns, available range, and route specific energy consumption. The number of buses and the routes have to be predetermined for electric buses. Therefore, a mix of diesel and electric buses at route level has to be considered until the operations mature enough to cater to the dynamic operational pattern.

6. Technical Analysis for Developing Transjakarta E-Bus Long-term Implementation Phase

6.1. Methodology

The expected output from the technical aspects on the long-term implementation phase of Transjakarta e-buses are the type and number of e-bus, type and number of charging infrastructure, charger powers, and battery technology. Hence the technical analysis for the e-bus long term implementation involves the following key steps:

1. Assessing fleets’ technology readiness and defining the fleets typology
2. Estimating the number of e-bus to be deployed each year
3. Assessing battery and chargers’ technology readiness and identifying number of chargers to be deployed each year.
4. Assessing the charging strategy for each year of implementation.

At this stage, routes prioritisation and exact charging location to be prioritised first have not been considered yet. A more detailed technical analysis is conducted on Task 4.1 – Detailed Technical Plan report.

6.2. Fleets’ Technology Readiness and Fleets Typology

Given that Transjakarta has several types of services with different bus types, typologies of electric buses need to be identified that are suitable to replace the counter counterpart of diesel bus types considering the bus specifications, passenger capacity and gross vehicle weight limits. Based on the market research for the available bus models and findings from the previous UNEP study, the bus typologies presented in Table 9 are considered in this study. The battery capacity is heavily influenced by the governments' regulation on maximum Gross-Vehicle Weight allowed for each type of bus. The battery sizes are selected based on standard models available to avoid customisation which may cause longer procurement lead times. The bus typologies are selected for the bus type categories that Transjakarta is considering for electrification program. These include 12-m single buses that operate on BRT and non-BRT routes, 12-m low entry buses that operate on non-BRT routes, 7-m medium bus, 18-m articulated buses, and 4-m microbuses. Transjakarta does not have a clear plan yet to electrify double decker buses and the Royaltrans buses. Hence these are not considered in the bus typologies for electric buses. In addition, 13.5-m maxi buses are also not considered as a separate typology as these will be either retrofitted or replaced by electric single buses.

Table 9 below presents the bus typologies that will be used in this study. It also serves as a baseline and assumptions regarding the e-bus technology based on the market availability when this study is developed.

Table 9. Transjakarta's fleets typology

Bus typology								
Bus Type	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Type of Bus	**Single Bus (12-m)**		**Medium Bus (7-m)**		**Articulated (18-m)**	**Low Entry (12-m)**		**Microbus (4-m)**
Max GVW (kg)	16,000		8,000		26,000	16,000		5,000
Service Type	BRT, non-BRT		Non-BRT, affordable housing routes		BRT	Non-BRT		Mikrotrans, Transcare
Battery (kWh)	324	180	135	150	450	324	180	42
Energy consumption, including factors such as AC usage (kWh/km)	1.2	1	1	1	1.8	1.2	1	0.15
Full battery range (km)	270	180	135	150	250	270	180	280
SoC reserve	20%	20%	20%	20%	20%	20%	20%	20%
Estimated range with 20 %SoC reserve (km)	216	144	108	120	200	216	144	225
Battery degradation by year 8	20%	20%	20%	20%	20%	20%	20%	20%
Range at year 8 after degradation (km)	173	115	86	96	160	173	115	180

6.3. Number of E-bus to be Deployed Each Year

The estimated number of e-buses to be deployed each year is evaluated based on the following factors:

- Transjakarta's latest plan of electrification, as presented on the section 4 on this report.
- Quota for each bus type in 2030.
- Contract replacements.

Through the Head of Jakarta Transport Agency Decree, Jakarta Transport Agency has allocated quotas for each bus type in 2030. Table 10 below shows the quota split for each bus type for the 10,047 buses allocated in 2030.

Table 10. Quota allocation for each bus type in 2030

Bus type	Quota
Big bus	2,140
Medium Bus	1,518
Microbus	6,360
Transcare	29
Total	**10,047**

Big buses in the table above include the single bus (either high-deck or low entry), articulated bus, and the maxi bus – although maxi bus will be retrofitted to e-bus or substituted to the equivalent of single bus, so that there is no maxi bus running any longer in 2030.

In addition, Transjakarta's fleet also includes Royaltrans (10-m premium service bus) and the double decker buses for tourism purposes. These are special services run and owned by Transjakarta. Based on consultation with Transjakarta, these bus types are not considered for electrification.

Currently Transjakarta does not have any projected plan for the total number of buses by each bus type in each year until 2030. In order to determine the implementation phasing year on year, **an estimation of these numbers is made assuming a linear compounded annual growth rate (CAGR)** from the current fleet size in 2022. Additionally, for the big buses, the proportion of the articulated, low entry, and single buses is estimated based on the proportion of these bus types in the current fleet size. Low entry bus refers to single bus that is used for non-BRT routes, in which the stops are on the kerb side, not on the median.

From the discussion with Transjakarta, it is also understood that there will be no fleet augmentation in 2023. However, there will be replacement of buses for which the contracts have expired. For articulated buses, it is assumed that fleet augmentation is from 2025 onwards. The following table shows the estimated projection of the total fleet size (for both conventional and electric bus) by bus types until 2030.

Table 11. Total projected number of Transjakarta fleets, 2022 - 2030

Type of bus	2022	2023	2024	2025	2026	2027	2028	2029	2030
Articulated Bus	257	257	257	257	276	295	317	340	364
Low Entry	289	289	304	319	335	353	371	389	409

Single Bus	965	965	1,014	1,066	1,120	1,177	1,237	1,300	1,367
Medium Bus	268	268	343	440	564	722	925	1,185	1,518
Microbus	2,155	2,155	2,517	2,940	3,433	4,010	4,684	5,470	6,389
Total*	**3,934**	**3,934**	**4,435**	**5,022**	**5,728**	**6,557**	**7,534**	**8,684**	**10,047**

**Does not include Royaltrans, Double Decker, Maxi Bus*

While deploying electric buses, it is important to consider the contract terms of the existing operators. There are several operators whose contract will come to an end between 2023 and 2030. This provides an opportunity to introduce electric buses when new contract negotiations happen, and buses will be deployed – instead of ICE buses, electric buses should be deployed. The table below shows the ending contract year for each operator with existing number of buses allocated. Maximum contract period for conventional buses is 7 years except articulated buses which could have a contract period of up to 10 years in case the production kilometres have not been achieved from what have been stated in the contract. In order to achieve 100% electrification by 2030, **there should not be any diesel bus procurement after 2023**.

Table 12. Transjakarta fleets replacement as per contracts ending

Fleets owner	Type of bus	2022	2023	2024	2025	2026	2027	2028	2029	2030
Operators	AB					110				
	Maxi					100		152		
	MB	168								
	SB		418		80		110	58	30	
Swakelola (TJ owned)	MB						20			
	AB		91	20	31					
	DD		5		3	11	8	1		
	LE						190	98	1	
	SB		66			100	94	10		
	Maxi						24			
	Royal						50	50		
	Transcare		2		3	4	17			

Based on the replacement schedule and the augmentation required each year, the electric bus procurement is calculated and adjusted taking into consideration Transjakarta's electrification strategy as shown in section 4. Two scenarios A and B are developed for the implementation phase. Scenario A follows the electrification trajectory of Transjakarta's target while scenario B considers an accelerated approach to achieve the targets sooner than Transjakarta's projection.

6.3.1. Implementation Phase – Scenario A

As per the plan mentioned in section 4, 100 medium buses and 100 single 12-m BRT buses are planned to be procured in 2023. There are already 30 e-buses (12-m low entry) running on the road of Jakarta, and when this report is written it is expected to have 74 e-buses running by the end of 2022 – the other 26 in 2023. The following table shows the induction of electric buses, year wise. Since the articulated buses are planned to be electrified from 2025, trials for these should be considered in 2024. Trials for microbuses should also commence in 2023.

Table 13. Scenario A for Transjakarta's electrification

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Articulated Bus		0	0	91	185	19	22	23	24
Low Entry	74	26	0	0	0	154	116	19	20
Single Bus		100	0	181	224	261	128	93	380
Medium bus		100	75	97	204	178	203	260	401
Microbus		0	100	200	400	600	1,129	1,800	2,160
Total electric buses added yearly	**74**	**226**	**175**	**619**	**1,063**	**1,312**	**1,691**	**2,195**	**2,985**
Cumulative electric buses	**74**	**300**	**475**	**1,044**	**2,057**	**3,269**	**4,867**	**7,062**	**10,047**
Cumulative Articulated buses	***0***	***0***	***0***	***91***	***276***	***295***	***317***	***340***	***364***
Cumulative Low Entry	***74***	***100***	***100***	***100***	***100***	***254***	***370***	***389***	***409***
Cumulative Single Bus	***0***	***100***	***100***	***281***	***505***	***766***	***894***	***987***	***1367***
Cumulative Medium bus	***0***	***100***	***175***	***272***	***476***	***654***	***857***	***1,117***	***1,518***
Cumulative Microbus	***0***	***0***	***100***	***300***	***700***	***1,300***	***2,429***	***4,229***	***6,389***
No. of diesel buses	3,860	3,634	3,960	3,978	3,671	3,288	2,667	1,622	0
Total number of buses	3,934	3,934	4,435	5,022	5,728	6,557	7,534	8,684	10,047
% Electrification	**2%**	**8%**	**11%**	**21%**	**36%**	**50%**	**65%**	**81%**	**100%**

6.3.2. Implementation Phase – Scenario B

According to the Head of Transport Agency's decree, the quota for microbuses in 2030 is about 63% of the total fleet size. As per the analysis from Section 7, the TCO for microbuses is also lower than the TCO for their diesel counterparts. Hence, an alternative scenario is proposed to start trials for microbus electrification from 2023 onwards and accelerate their electrification. This achieves a faster electrification trajectory than the earlier scenario.

Table 14. Scenario B for Transjakarta's electrification

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Articulated Bus		0	0	91	185	19	22	23	24
Low Entry	74	26	0	0	0	154		19	20
Single Bus		100	0	0	305	261	128	93	480
Medium bus		100	75	97	204	178	203	260	401
Microbus		50	450	585	793	977	1,129	1,186	1,219
Total electric buses added yearly	**74**	**276**	**525**	**823**	**1,537**	**1,689**	**1,691**	**1,581**	**2,144**
Cumulative electric buses	**74**	**350**	**875**	**1,648**	**3,135**	**4,724**	**6,322**	**7,903**	**10,047**
Cumulative Articulated buses	***0***	***0***	***0***	***91***	***276***	***295***	***317***	***340***	***364***
Cumulative Low Entry	***74***	***100***	***100***	***100***	***100***	***254***	***370***	***389***	***409***
Cumulative Single Bus	***0***	***100***	***100***	***281***	***505***	***766***	***894***	***987***	***1,367***
Cumulative Medium bus	***0***	***100***	***175***	***272***	***476***	***654***	***857***	***1,117***	***1,518***
Cumulative Microbus	***0***	***50***	***500***	***1,085***	***1,878***	***2,855***	***3,984***	***5,170***	***6,389***
No. of diesel buses	3,860	3,584	3,560	3,374	2,593	1,833	1,212	781	0
Total number of buses	3,934	3,934	4,435	5,022	5,728	6,557	7,534	8,684	10,047
% Electrification	**2%**	**9%**	**20%**	**33%**	**55%**	**72%**	**84%**	**91%**	**100%**

6.4. Charger Technology Readiness & Charging Facilities

As described in Section 6.1 above that there are also other factors taken into account when developing the e-bus implementation phase, such as the battery technology, types of charging infrastructure, types of charger power, and fleets provision options (either the fleets will be provided by procuring the new ones or retrofitting the existing ones). This section will discuss the underlying rationale for recommending a specific technology on a specific period.

The battery technology in the initial phases is LFP since this is the predominant battery technology for buses available in the market specifically in Asian market. Though LFP will continue to be dominant, advanced chemistries such as NMC will also hold a major market share of around 40% by 2027/2028[2] [3]. In the future, e-buses with these advanced battery technologies will be

[2] https://www.idtechex.com/zh/research-report/li-ion-batteries-for-electric-buses-2018-2028/595
[3] https://www.interactanalysis.com/chinas-electric-bus-market-dominance-driving-demand-for-lithium-iron-phosphate-batteries/

available and these can be considered while also evaluating their economic viability. This can enable higher operational performance of e-buses with batteries of higher energy density, faster charging times, higher charger powers and lower energy consumption. The charging technology depends on the bus typology, the battery technology, and the techno-economic feasibility. The number of charging stations are estimated based on the charger to bus ratio for each bus type and type of charging i.e., overnight or opportunity charging.

6.4.1. Charger Power and Charger Per Bus Ratio

Charging technology, charger power, and the number of charging facilities to be deployed respective with the types of e-bus will be demonstrated on this part. The analysis is divided per the number of e-bus fleets since each e-bus type have different battery capacity, which result on different charger powers and charger per bus ratio.

12-m single electric bus (high-deck or low entry)

The 12-m single buses both high-deck and low entry with 324 kWh LFP battery can have slow plug-in chargers up to 100 kW with a charging time of about 3.5 hours for 0% to 100% SoC and fast chargers up to 200 kW with a charging time of 1.25 hours for 10% to 80% SoC. For these bus types, double gun chargers with 200 kW power are recommended for both depot overnight charging and terminal opportunity charging. A single bus can be charged at 200 kW with one gun, or two buses can be charged at 100 kW with two guns. With evolving battery technology, faster charging power can be explored in the future phases. For overnight charging, the time available for charging is assumed to be 7 hours, each charger can charge two buses in succession. With double gun chargers, the overnight depot charger to bus ratio is therefore 1:4. For opportunity charging, the terminal charger to bus ratio is estimated considering the opportunity charging requirement and the charger power as 1:10.

18-m articulated bus

The articulated buses with battery size of 450 kWh fast charging with charger power of up to 400 kW with a charging duration of about 1.5 hours from 10% to 80% SoC and for overnight charging, 200 kW plug-in chargers with a charging duration of about 3 hours from 0% to 100 % SoC are recommended. Considering the available time of 7 hours for overnight charging, the overnight charger to bus ratio is 1:2 and for terminal charging it is estimated as 1:10 considering the opportunity charge requirement and the fast charger power. Fast charging these buses at the terminals both plug-in and pantographs are viable options. Pantographs provide innovative solutions for setting up the charging infrastructure to provide a seamless circulation of buses while optimising space. The choice of pantograph vs plug-in for terminal charging needs to be further assessed on a case-by-case basis from a technical and economic perspective.

7-m medium buses

Currently, the bus type and model for the medium buses is largely influenced by the gross weight limitations in Indonesia. The current suitable model is the BYD C6 with a battery size of 135 kWh. In the later phases, buses with higher battery capacities of 150 kWh but lighter weight may be developed. The charger power recommended for both overnight and terminal charging is 100 kW. The charging duration for overnight charging is around 1.3 hours and 1.5 hours for the 135kWh and 150kWh respectively. Therefore, the charger to bus ratio is calculated as 1:5 and 1:4 for 135kWh and 150kWh battery sizes respectively. For terminal charging, the charger to bus ratio is estimated around 1:3 based on the opportunity charging requirement and the charger power.

4-m microbuses

Similarly, the current market is dominated by LFP batteries for electric microbus models. The initial phases are recommended based on the local model of Gelora EV from DFSK with a battery size of 42 kWh and charger power of 22 kW. It is assumed that the cost of each microbus includes one charger. Additional charger requirement is estimated with a charger to bus ratio of 1:10 with a charging time of 1.3hours for 10% to 80% SoC to account for opportunity charging or any contingencies. As the market evolves there will be scope for models with higher battery capacities and charger powers.

6.4.2. Charging Infrastructure Setup

The preferred charging strategy for the electric buses is overnight charging at depots with opportunity charging at terminals that are owned by the Government of Jakarta. Opportunity charging at existing terminals eliminates the need for land acquisition for setting up charging infrastructure and also provides an opportunity for developing the terminals as multi modal hubs. However, with Transjakarta's increasing fleet size and electrification, the current terminals will not be able to meet the charging infrastructure space requirement. Prior to 2027, the overall number of electric buses is less than the current fleet size. Also, an assessment of the available land at existing depots and terminals and the required land for the total number of buses each year also indicates additional land requirement from around 2027 onwards. Hence, the current space that are available in terminals and depots are still sufficient until 2027. In other words, additional charging locations need to be setup to accommodate the charging requirements that are proposed from 2027 onwards.

7. Financial and Economic Analysis for Developing the Transjakarta E-Bus Long-term Implementation Phase

7.1. Methodology

There are three activities related to economic and financial analysis developed under this study. The first activity that will be discussed in this section is the economic and financial analysis for e-bus implementation phase, which is based on the developed BRT and non-BRT electrification roadmap until 2030, including the total investment cost needed. The financial evaluation conducted in this report is still the overall implementation plan until 2030 that only contains TCO/km calculation and total investment needed. Hence, the financial feasibility analysis and cost benefit analysis will be conducted in a separate report, i.e. Output 4.5 report.

The second activity is the cost-benefit analysis for the first phase of the project implementation. The cost-benefit analysis that is developed as part of that activity will be more-detailed, taking into account the detailed technical plan that is developed in Output 4.

Lastly, the financial feasibility analysis is developed as part of the third activity, taking into account a more-detailed technical plan until 2025 for technical inputs and financial analysis, including the PSO requirement needed year by year (PSO from 2023 – 2025 could be estimated in more detail, where PSO from 2025 onwards is an estimation due to the long timeframe that will incur more variance). This financial feasibility analysis has also considered several possible commercial arrangements. The cost of fund of each structured financing scheme is also developed the financial feasibility analysis.

Evaluating the financing and economic aspects with regards to the e-bus long term implementation will involve the calculation of TCO/km to assess the readiness of each type of e-bus from the cost perspective. The TCO/km of each type of e-bus model will be compared to that of the conventional bus. The TCO/km calculation will become the consideration of ramping-up certain fleet models to be electrified.

The total investment cost each year will then be estimated using TCO/km and implementation phase from previous chapter as the inputs. The impacts of the implementation on the PSO will also be estimated, looking at current financial capability of Transjakarta. To conclude the steps, the implementation phase will be fine-tuned considering other factor's readiness.

7.2. TCO/km Calculation

It is evident that owning and operating a vehicle will incur costs that that occur in different points in time, especially in the context of switching over to Battery Electric Vehicles (BEVs) where the initial costs are much higher and operating costs are much lower than ICE vehicles. To compare these costs across time, the total cost of ownership (TCO) methodology uses the financial formula of the present discounted value. This way, every cost can be included in one cost indicator to present the full cost of each alternative which includes the total discounted cost of owning, operating, and maintaining an asset over the lifetime of the asset.

The TCO computation methodology proposed by Kumar and Chakraborty[4] is used in this report and explained as follows.

- The CAPEX is estimated including on road cost of vehicles adjusting for any taxes, registration charges etc. The cost of additional vehicles where replacement ratio is more than 1 as well as that of the charging infrastructure are also calculated and apportioned over the net ICE vehicles replaced. The annual capital cost is then calculated using a Capital Recovery Factor (CRF) which depends on the rate of discounting and life of the asset:

$$Annual\ capital\ costs\ (ACC) = \left(Capex - \frac{RV}{(1+r)^N}\right) * CRF$$

$$\text{Capital Recovery Factor } (CRF) = r\frac{(1+r)^N}{(1+r)^N - 1}$$

Equation 1. Formula for CAPEX Calculation

- The operating costs are estimated at constant prices, i.e., inflation is not considered. The discounted operating costs for each year are averaged over the life of the asset to arrive at Average Annual Operating Cost (AAOC) as shown below:

$$Average\ Annual\ Operating\ Costs\ (AAOC) = \frac{1}{N}\sum_{1}^{N}\frac{AOC}{(1+r)^n}$$

Equation 2. Formula for OPEX Calculation

- The annual capital cost and the average annual operating costs were then added up to determine the total annual costs. Finally, the costs per vehicle kilometer were determined by dividing the annual costs by the annual mileage.

$$\frac{TCO}{km} = \frac{ACC + AAOC}{AKT}$$

Equation 3. Formula for TCO Calculation

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[4] Kumar P, Chakrabarty S. Total Cost of Ownership Analysis of the Impact of Vehicle Usage on the Economic Viability of Electric Vehicles in India. Transportation Research Record. 2020;2674(11):563-572.

Where,

N = Lifetime of the vehicle in years; r = real discounting rate;
RV = Residual Value; AKT = Annual Kilometres Travelled by each vehicle net of empty kms.

7.2.1. Assumption Used for the Calculation

The assumptions for computing the TCO/km for electric or diesel buses can be categorised into:

- CAPEX assumptions
- Operating parameters and OPEX assumptions
- Other assumptions

The assumptions are based on several sources, such as:

1. E-Mobility Adoption Roadmap for The Indonesian Mass Transit Program, World Bank Study, January 2022
2. Investment Plan for Electric Bus Deployment of Transjakarta, CTCN-ITDP Study, March 2021
3. Financial Feasibility Study, Zero Emission Buses in Jakarta, C40-CFF, August 2020
4. Discussions with Transjakarta, OEMs, or bus operators
5. Consultant team's secondary sources & judgements

CAPEX Assumptions

The capital cost for electric buses consists of:

a. Procurement cost of the e-bus depending on size of the bus as well as battery size
b. Taxes and duties
c. Charging infrastructure cost, including grid connectivity and charger installation costs.
d. Replacement ratio
e. Life of the bus
f. Depot set up costs

The following assumptions have been made for various types of e-buses proposed to be deployed within Transjakarta service. The cost included on the table below only assuming depot charging only.

Table 15. CAPEX assumptions for various types of E-buses

Bus Types*	Articulated Bus	Single Bus**	Medium Bus	Microbus
Battery Size (kWh)	450	324	135	42
Landed Cost of bus (USD)	550,000	330,000	210,000	33,600
Cost per charger (USD)	58,000	58,000	29,000	17,000
Charger rating for overnight depot charging (kW)	200	200	80	20
Bus to Charger Ratio	2:1	4:1	5:1	1:1.1***
Replacement Ratio (ICE : E-Bus)	1:1	1:1	1:1.87	1:1
Life of e-Bus (years)	15	15	15	8

Cost of comparable Diesel bus (USD)	350,000	164,000	63,000	19,600
Life of ICE bus (years)	10	10	7	7

** All bus types analysed on this chapter is air-conditioned, including microbus*
*** Both high-deck or low entry electric bus*
**** In addition to one slow charger supplied with the vehicles, one additional fast charger for 10 microbuses.*

Additionally, the following assumptions were also used:

a. Based on the market study, the capital cost of a retrofitted single bus is assumed to be 65% of the cost of a new e-bus i.e., USD 215,000 plus residual value for the old diesel bus @ 20% of diesel bus cost. The 20% residual value for diesel bus cost is based on the residual value used on the owner cost estimate (HPS, *Harga Perkiraan Sendiri*) from Transjakarta.
b. Grid connection cost: IDR 10B for 10.4MVA connection[5].
c. Cost of depot for 100 single buses is estimated at USD 3M (20% less for diesel buses). For medium and articulated buses, the depot costs are assumed to be 75% and 150% respectively of the single buses due their relative sizes.
d. Based on discussions with operators, other CAPEX costs will include legal, admin and financing costs and is considered at 3.5% of the cost of the bus.
e. Charger installation cost: 10% of cost of chargers (C40 CFF, 2021)

<u>Operating Parameters and OPEX Assumptions</u>
The per kilometre operating cost of a bus are estimated based on following assumptions:

a. <u>Distance travelled for variable operating costs such as tyres/tubes, and brake pads</u>.

The average distance travelled by various categories of buses is as follows:

Table 16. Average distance travelled of each bus categories

Bus Types	Articulated Bus	Single Bus	Medium Bus	Microbus
kms/day	205	192	188	196

These are average running by operating buses excluding the spare buses. 20 km of empty running is assumed to be included in this, based on the contracts between Transjakarta and bus operators.

b. <u>Number of shifts operated</u>

It is assumed that 2 shifts of 7 hours steering duty is assumed for each operating bus (excluding spares/ replacement).

[5] World Bank Study

c. Relieving ratio including weekly/ annual holidays, redundancies: 1.2

d. Cost of energy (electricity or diesel)

Based on the special tariff negotiated by Transjakarta with PLN, the cost of electricity is assumed @ IDR 825/ kWh. The current cost of diesel for public transportation fleets in Jakarta is IDR 6800/ litre.

e. Fuel Efficiency

The fuel efficiency of different categories of buses is considered as follows:

Table 17. Fuel efficiency of each bus categories

Bus Types	Articulated Bus	Single Bus	Medium Bus	Microbus
Electricity (kWh/km)	2.3	1.2	1	0.18
Diesel (km/litre)	1.45	2.03	3.2	8.5

The above assumptions are based on discussions with OEMs, operators, trials run done by Transjakarta, a 2020 report by Sustainable Bus[6].

f. Maintenance Cost

The maintenance cost of different categories of buses is considered as follows:

Table 18. Maintenance cost of each bus categories

Bus Types	Articulated Bus	Single Bus	Medium Bus	Microbus
Electric (USD/ km)[7]	0.30	0.20	0.15	0.033
Diesel (USD/ km)[8]	0.63	0.36	0.19	0.061

The above parameters are considered based on discussions with OEMs, operators, and e-bus Pilot project by Transjakarta.

g. The cost of fare collection is excluded as the same is in the scope of Transjakarta and is common for diesel as well as electric buses and hence are excluded from the calculation of TCO.

h. Manpower Costs

- Drivers per bus (net): 2.4 (2 shifts x 1.2).

[6] Electric bus energy consumption in ViriCiti's spotlight. A report (sustainable-bus.com)
[7] IDR 3100/km for single bus (Source: Bakrie Auto Parts), 150% for articulated and 75% for medium bus
[8] Source: Transjakarta

- Driver Wage: IDR 271.75 million p.a. considering UMP of IDR 4,573,845, 2 x UMP for large/medium buses and IDR 140 million, 1 x UMP for microbus plus insurance per driver per month including perquisites, retirement benefits etc.
- Other administrative costs: 30% of driver costs (0 for microbus since the buses are mostly operated by individual owners or drivers appointed by them).

Other Assumptions

a. Battery is assumed to be replaced after 8 years.
b. Battery replacement cost: $100/kWh
c. Reserve fleet is assumed @ 10% for diesel and 5% for electric buses since e-buses require less maintenance due to much lesser number of moving parts.
d. Inflation: The TCO is computed for 2022 prices without considering any change in input prices such as energy cost, manpower costs, general inflation etc.
e. IDR/USD: 15,200, based on exchange rate on October 4, 2022.
f. Insurance Cost: 1.5% of CAPEX (HPS)
g. Maintenance Cost of Infrastructure: 2.5% (CFF C40, 2021)
h. The Social Cost of Carbon (SCC) is based on Interagency Working Group on Social Cost of Carbon, 2016 estimates as shown below:

Table 19. The social cost of carbon

Year	USD @ 2007 Prices	Value of 1 USD in current price	Value of 1 ton CO_2 in current price
2020	42	1.26	52.92
2025	46	1.46	67.16
2030	50	1.69	84.5

Accordingly, cost of 1 kg of CO_2 in 2023 is estimated at IDR 963.

i. Discounting Rate:

Table 20. The discounting rates

10-year Government Bond Yield	7.38%
Long term Inflation Expectation	3.29%
Real Discounting Rate	**4.09%**

Alternative scenarios

The following alternative scenarios have been evaluated for **medium bus**:

1. With opportunity charging at depot – during off peak hours some buses will come to the depot for charging and additional buses waiting at the depot will take their place. There will be additional dead km of 50 km for the buses which return for charging and resultant replacement ratio of 1.30. Also due to additional steering time, the manpower cost will also be higher.
2. With opportunity charging at terminal – in this case, the buses will return to one or two conveniently located charging stations at terminals. There will still be some additional dead km, but replacement ratio will be lower (1.10).

Similarly, retrofitting single buses will also be evaluated as opposed to new e-buses.

7.2.2. TCO/km Calculation Result

The following tables show the relative comparison of Total Cost of Operation during the life of the buses/contracts in IDR/km.

Table 21. Total cost of ownership comparison for petrol and electric

Microbus	Unit	Petrol	Electric
Replacement Ratio	Units	**--**	**1.0**
Investment/bus	IDR Mn.	357	503
Contract Period	Years	7	10
CAPEX Cost	IDR/km	735	882
OPEX Cost	IDR/km	4,942	3,373
Total TCO	IDR/km	**5,677**	**4,255**
% of Petrol TCO		--	75%
Social Cost of Carbon	IDR/km	387	115
TCO with Environment Cost	IDR/km	**6,065**	**4,370**

Table 22. Total cost of ownership comparison for diesel and electric

Medium Buses	Unit	Diesel	Electric		
			Depots overnight charging only	Overnight + opp. charging at depots	Depot overnight + terminal opp. charging
Replacement Ratio	Units	--	1.87	1.30	1.10
Investment/bus	IDR Mn.	**1,402**	**7,412**	**5,153**	**4,360**
Contract Period	Years	7	10	10	10
CAPEX Cost	IDR/km	3,149	13,558	9,425	7,975
OPEX Cost	IDR/km	9,061	9,511	9,259	8,208
Total TCO	IDR/km	**12,210**	**23,068**	**18,685**	**16,184**
% of Diesel TCO			189%	153%	133%
Social Cost of Carbon	IDR/km	1,028	798	820	665
TCO with Environment Cost	IDR/km	**13,238**	**23,866**	**19,505**	**16,848**

Considering the higher TCO for medium electric buses with the present assumptions/specs, the following alternative scenarios are evaluated to understand the improvements required in the medium electric bus to match the diesel bus TCO.

1. Lighter chassis with larger battery of 150 kWh capacity (135 kWh now).
2. Higher range of 150 km per charge as compared to 108 km now, due to higher battery capacity and lower vehicle weight.

3. Lower bus cost USD 130,000 as compared to USD 210,000 now[9].

Accordingly, the following TCO results is obtained:

Table 23. Total cost of ownership result for medium bus

Medium Bus – Alternative Scenario	Unit	Diesel	Electric		
			Depots overnight charging only	Overnight + opp. charging at depots	Depot overnight + terminal opp. charging
Replacement Ratio	Units	--	1.54	1.20	1.02
Investment/bus	IDR Mn.	**1,402**	**4,187**	**3,273**	**2,789**
Contract Period	Years	7 years	10 years	10 years	10 years
CAPEX Cost	IDR/km	3,149	7,658	5,987	5,102
OPEX Cost	IDR/km	9,061	8,705	8,968	7,912
Total TCO	IDR/km	**12,210**	16,363	14,955	13,013
% of Diesel TCO			134%	122%	107%
Social Cost of Carbon	IDR/km	1,028	741	820	651
TCO with Environment Cost	IDR/km	**13,238**	17,104	15,775	13,665

Table 24. Total cost of ownership result for single bus

Single Buses (High-deck and Low entry)	Unit	Diesel	Electric	
			New	Retrofit
Replacement Ratio	Units		**1**	**1**
Investment/bus	IDR Mn.	**3,253**	**5,699**	**4,878**
Contract Period	Years	7 years	10 years	7 years
CAPEX Cost	IDR/km	7,157	10,207	12,162
OPEX Cost	IDR/km	16,627	12,991	11,977
Total TCO	IDR/km	**23,784**	**23,198**	**24,139**
% of Diesel TCO		--	98%	**101%**
Social Cost of Carbon	IDR/km	1,621	777	777
TCO with Environment Cost	IDR/km	**25,405**	**23,975**	**24,917**

Table 25. Total cost of ownership result for articulated bus

Articulated Buses	Unit	Diesel	Electric
Replacement Ratio	Units	--	1
Investment/bus	IDR Mn.	6,680	10,423
Contract Period	Years	10 years	10 years
CAPEX Cost	IDR/km	11,206	17,485
OPEX Cost	IDR/km	20,935	16,122
Total TCO	IDR/km	32,140	33,607
% of Diesel TCO		--	105%
Social Cost of Carbon	IDR/km	1,495	1,244

[9] A scenario for electric bus cost based on assumptions to show where the Medium e-bus cost needs to be to achieve TCO parity.

TCO with Environment Cost	IDR/km	33,636	34,851

Finally, graph below represents the TCO/km of electric bus compared to single buses.

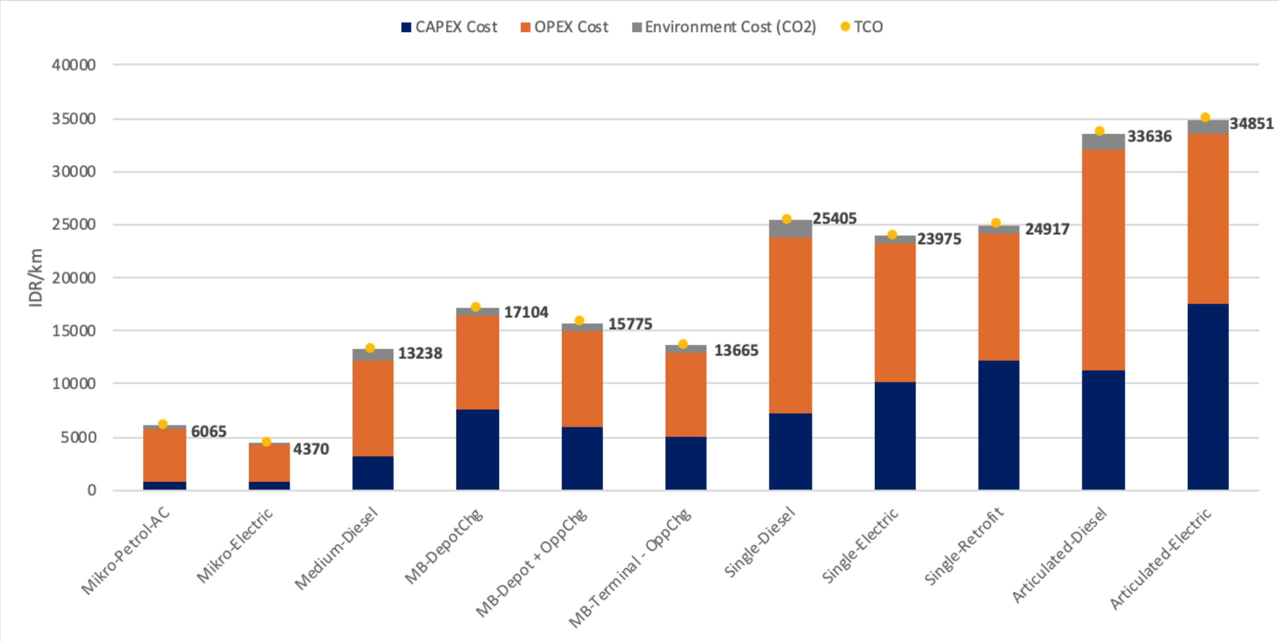

Figure 11. TCO comparison between diesel/CNG and electric buses

It is seen that the **Total Cost of Ownership of electric microbuses is already 25% lower than the comparable petrol buses** but with or without the environment costs and are ready for large scale deployment. In the case of medium buses, the lowest electric bus TCO is still 15-58% higher than the comparable diesel counterpart. However, with an alternate scenario of improved bus range and lower cost, it is possible to bring down the TCO of medium electric buses to even lower than the present diesel bus TCO.

The cost of deployment of single electric buses (low entry and high deck) is 15% lower than the comparable diesel buses. **The retrofitted single buses however not found to be as effective as the new (procured) single buses in terms of TCO**, although some further analysis on the effectiveness of retrofitted single buses needs to be conducted due to lack of reliable data sources. Similarly, the electric articulated buses TCO is slightly higher than their diesel counterparts.

The above analysis is carried out for average daily running of the buses. Further analysis and route level optimisation is possible to reduce the electric bus TCOs further.

7.3. Estimated Total Investment Cost

Based on the implementation roadmap recommended in section 6.3 (Scenario A), the total investment needed between 2023 and 2030 to completely electrify the Transjakarta fleet and also to augment the fleets from current 3,934 buses to targeted 10,047 buses is estimated on this section. For this purpose, in addition to the CAPEX assumptions made in section 7.2, the following additional assumptions are made:

1. Bus Purchase Cost: Due to increase in volumes, indigenisation, technological advancement as well as decrease in battery prices, it is assumed that the cost of the e-buses will reduce by 5% per year. In comparison, the diesel bus prices are expected to increase by 3.5% p.a. based on past trends on inflation for the manufacturing sector[10].
2. Exchange Rates: Based on last 10 years trends, the USD is expected to appreciate by 5% p.a. against the IDR.
3. Charger Costs: The charge costs are expected to remain more or less for same as increase in input prices will be counteracted by increase in volumes, indigenisation till 2025. Thereafter, increase @ 3.5% p.a. in line with manufacturing inflation is considered.
4. Depot Costs: The cost of depot for each additional bus is assumed at IDR 395 M for diesel buses and IDR 445 M for electric buses since electric buses required about 20% additional space for charging provisions[11]. The cost is expected to increase with inflation @ 3.5% p.a.
5. Land Costs: All land for depots as well as terminal infrastructure is assumed be leased and hence no investment is estimated for the same.

Accordingly, the investment plan is prepared as follows:

Table 26. Total cost of electric buses

Year	2023	2024	2025	2026	2027	2028	2029	2030
Articulated Bus	0	0	823	1673	171	198	206	215
Low Entry	128	0	0	0	750	563	92	96
Single Bus	491	0	885	1,094	1,270	622	450	1,832
Medium Bus	242	181	234	488	426	484	617	952
Microbus	0	50	99	199	302	548	878	1,056
Total	861	232	2,041	3,455	2,919	2,416	2,243	4,151

Price in IDR Billion

The investment required in charging infrastructure is estimated as follows:

[10] WHOLESALE PRICE INDEX (TABEL8_2.pdf) (bi.go.id)

[11] E-Mobility Adoption Road Map for Greater Bandung and Greater Medan Bus Rapid Transit System, ITDP-World Bank, 2022

Table 27. Total cost of charging infrastructure

Year	2023	2024	2025	2026	2027	2028	2029	2030
Chargers	93.3	31.6	221.9	415.6	367.7	328.8	331.9	674.4
Installation Cost	9.3	3.2	22.2	41.6	36.8	32.9	33.2	67.4
Grid Connection Cost	9.8	2.8	30.7	55.4	34.2	28.1	25.1	48.4
Total	**112.4**	**37.5**	**274.8**	**512.6**	**438.6**	**389.8**	**390.2**	**790.3**

Price in IDR Billion

Due to expansion of the fleet, there will also be requirement for depots. The cost of depot is estimated as follows:

Table 28. Total cost of depot for fleet augmentation

Year	2023	2024	2025	2026	2027	2028	2029	2030
Equivalent No of Single Buses	--	120	140	192	222	263	311	373
Cost of Diesel Bus Depot	--	49	59	84	101	123	151	187
Cost of Electric Bus Depot	--	55	67	95	113	139	170	211

Price in IDR Billion

Thus, the total investment required for electric buses and comparative investment needed in business-as-usual scenario with diesel buses is presented below:

Table 29. Total of investment needed for electric buses and comparative needed in Business as Usual (BAU)

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
Investment in Electric Buses Programme, In Billion IDR									
E-buses	861	232	2,041	3,455	2,919	2,416	2,243	4,151	**18,317**
Chargers	93	32	222	416	368	329	332	674	**2,465**
Charger Installation	9	3	22	42	37	33	33	67	**247**
Cost of grid connection	10	3	31	55	34	28	25	48	**234**
Depot Cost	0	55	67	95	113	139	170	211	**850**
Total Investment (A)	973	324	2,382	4,062	3,471	2,945	2,803	5,153	**22,113**
Investment in Diesel Buses (BAU), In Billion IDR									
Cost of diesel buses	550	146	1,504	2,653	2,227	1,934	1,875	3,556	**14,445**
Cost of Depot		49	59	84	101	123	151	187	**755**

Total Investment (B)	550	195	1,563	2,738	2,328	2,057	2,026	3,743	**15,200**
Incremental Investment (A-B)	423	129	819	1,324	1,143	887	777	1,409	**6,913**
	77%	66%	52%	48%	49%	43%	38%	38%	**45%**

It is seen that **adoption of 100% electric buses by Transjakarta is expected to require a total investment of IDR 22 T** as compared to a business-as-usual scenario investment of **IDR 15 T** i.e., **45% higher**. However, it is to be noted that this is only the total investment needed to deploy the e-bus, it has not considered the operating costs as described in section 7.2. It was described that when considering the operating costs, it will result in lower TCO as compared to diesel buses.

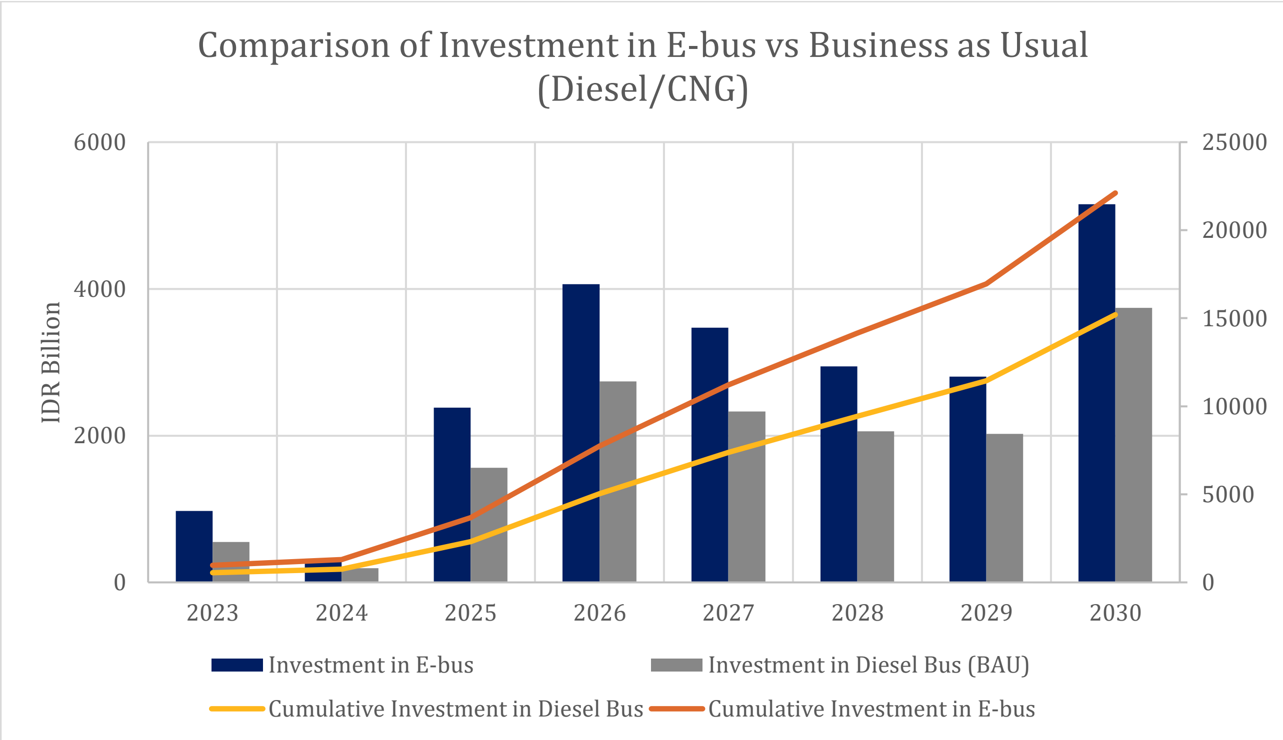

Figure 12. Comparison of investment in E-buses vs BAU

7.4. Transjakarta Financial Capacity

7.4.1. Assessment of Financial Capacity

Transjakarta is a regional owned company (BUMD) who is responsible for managing and operating various types of bus operations. Although it has its own fleet, most of the fleets are procured through buy the service contracts with the operators. The ticket fare charged to the passenger is inadequate to cover the operating costs. Through fare and non-fare box revenue, Transjakarta is able to recover only one-fifth of the operating costs and the remaining costs are covered through regional budget as shown in table below:

Table 30. Transjakarta's cashflow

Year	2017	2018	2019	2020	2021
Farebox & non-farebox revenue	457	537	715	349	298
Subsidy	1,293	2,078	2,588	2,723	2,765
Total revenue	1,750	2,615	3,303	3,072	3,063
Operating expenses	1,504	2,208	2,852	2,706	2,783
Net profit	246	407	451	366	280
Non-Current assets	1,075	1,294	2,385	3,660	3,500

Source: Annual Reports of Transjakarta | Price in IDR Billion

Considering all items in the table above, it is seen that Transjakarta is running profitable operations and has been increasing its investment in operating assets. However, it is not sufficient to finance the capital expenditure for over 10,000 electric buses and its associated charging infrastructure that is estimated to be over IDR 22 T i.e., more than 6 times the Net Current Assets of Transjakarta. Further, the decree from the Governor states that the financial support from the Government of Jakarta will be in the form of Rp/km and thus Transjakarta has to follow the current service contracting pattern under the BTS scheme.

7.4.2. Estimated Impact on TCO

The microbus, single buses and articulated buses have achieved TCO parity and in fact replacement of current diesel/CNG buses with electric buses will result in a more efficient cost of operations and subsidy requirements. Some more preparatory work and reduction in prices is required for medium buses to achieve the cost parity.

The TCO analysis presented in the previous sub-section shows that the TCO parity for microbuses is lower than that of diesel counterpart, while for single and articulated buses the parity is competitive. However, electrifying medium buses is not favourable at the moment with the assumptions mentioned previously, which means it would need to wait for the technology to be matured (large scale uptake and prices fall down) for it to have at least competitive TCO parity. Overall, it is expected that the impact of electrification program to PSO will be relatively positive. Additionally, looking at the trends it is expected the capital will fall down further in the coming years. The actual cost per km will depend on the specific implementation pattern. Further reduction can be achieved through making suitable operational changes considering electrification, deploying opportunity charging infrastructure, bulk procurement, and efficient financing mechanisms.

Detailed financial analysis and financial modelling will be demonstrated on Task 4.5 Report, including the impact of each fund channelling scheme and business models to the PSO.

8. Other Factors' Readiness

In addition to the technical and financial aspects, other factors that need to be considered for refining the implementation phase are listed as follows:

1. Contract end dates (for existing contracts)

The present diesel/CNG contracts expire between 2023 and 2029. Considering that TJ is targeting to have 100% electric fleet by 2030 and minimum contract duration is 7 years (except non-air-conditioned microbuses), TJ can insist on deployment of e-buses in place of diesel/CNG buses whose contracts are expiring.

2. Procurement duration

It is seen from procurement processes in other countries such as India, the timeline for deployment of e-buses in operations can be slightly longer than the diesel buses as shown below:

Table 31. Procurement timeline and duration

No	Event	Time (months from T_0)
1	Announcement of Tender	0
2	Bid Submission	3 months
3	Bid Award	4 months
4	Signing of Agreement	5 months
5	Financial Closure	8 months
6	Prototype Testing	11 months
7	Delivery	12-24 months

The above schedule will also depend on number of legs of procurement (leasing contract and operating contracts), scale of procurement (larger scale requires more time per procurement but overall, less time than multiple procurement processes), standardisation of the specifications, homologation procedures, etc.

3. OEMs' readiness

At present, Indonesia has several indigenous e-bus manufacturers, such as Mobil Anak Bangsa which has a manufacturing capacity of 50 e-buses per months but so far has manufactured about 20 units in total. Others are PT. INKA, which produced E-Inobus and Bus Listrik Merah Putih. Various OEMs in China, India, Europe, and other western countries are delivering progressively higher number of e-buses per year. The Global electric bus market size is estimated to be 112,041 units in 2022 and expected to reach 671,285 units by 2027[12]. Hence,

[12] Electric Bus Market, www.marketsandmarkets.com, March 2022

it appears that the requirement for e-buses for Transjakarta in the near future will have to be met from imports whether Complete Bus Unit (CBU) or Semi Knocked Down (SKD).

4. Operators' readiness

Besides the buses owned and operated by Transjakarta, 18 operators have also been employed to provide the bus services on "Buy The Service" model, the 7 operators provide more than 80% of the buses as of July 2022:

Table 32. Transjakarta's buses from each operator

Operator	No. of Buses	Type of Buses	Remarks
Mayasari Bakti	509	Large Bus	Private Operator
Perum PPD	600	Large Bus	State-Owned Enterprise
Koperasi Angkutan Jakarta (Kopaja)	104	Medium Bus	Cooperative
Koperasi Wahana Kalpika (KWK)	942	Microbus	Cooperative
Komilet Jaya	259	Microbus	Cooperative
Steady Safe	177	Large Bus	Private Operator
Koperasi Purimas Jaya	112	Microbus	Cooperative

While the private operators are willing to deploy the electric buses in small lots considering their financial capacity, the state owned operators are in considerable financial distress. Similarly, in case of the cooperatives which operate the medium and microbuses, they face difficulty in raising their share of down payment for the diesel buses and also arrange the remaining financing from banks. As a result, they are unable to scale up and fulfil the quota of buses allocated to them. Under such circumstances, it is very much suspected that these operators are unlikely to be able to raise the financing needed for electric bus deployment.

However, most operators are favourable to the idea of leasing the electric buses provided that their profitability is not affected and regulations permit.

5. Retrofitting readiness

The TCO analysis shows that **the retrofitted buses do not compete well with the new e-buses.** There are also several other factors that need to be considered before zeroing on retrofitting diesel/ CNG buses, such as:

1) Retrofitted buses need to be type tested/homologated for every combination of original bus model/retrofitting kit/battery and bear associated delays and costs.
2) The volume of buses that can be retrofitted will gradually decrease and as the business of retrofitting will cease to exist in about 10 years' time.
3) The original warranties from the bus manufacturers get voided and the retrofitting company provide limited and conditional warranties.
4) Current regulations allow only 10 years of maximum life for public transportation fleet in Jakarta. Calculating the life of retrofitted buses is not clear yet due to lack of regulation.

5) The retrofitting companies are typically much smaller than the OEMs and their ability to provide after sales support needs to be evaluated.
6) Safety aspects of the retrofitted vehicle in terms of fire, explosion, structural balance, etc. need to be evaluated.
7) The value of the bus that is being preserved through retrofitting is also an important aspect to be considered. A single (12-m) diesel bus in Indonesia costs about USD 150,000. After 7 years, the residual value is about 20% i.e., USD 30,000. As mentioned earlier, the cost of retrofitting is estimated around USD 200,000. Thus, together with the residual value of the old bus, the total cost of retrofitting is around 230,000 USD with an expected life of 7 years as compared to a new e-bus which costs about USD 330,000 (and falling) and can last 12-15 years.

6. Policy and Regulatory Supports

Due to it being new technology, there needs to be robust regulatory framework and policies in support of the electrification. Currently, there are limited policy and regulations exist pertaining the electrification. In order to accelerate the e-bus adoption, it is suggested to provide policies to all aspects of e-bus ecosystem from technical and financial aspects. For example, the regulation related the gross vehicle weight and life of e-bus that need to be amended to boost the upscale of e-bus. Additionally, monetary incentives could be an option to support the electrification program.

Moreover, several aspects on the technical implementations that needs policy and regulatory supports has been identified on **Output 2 – Regulatory Framework Report**. The policy and regulatory supports identified will be mapped based on the implementing years of the respective technology. Since Transjakarta will require the terminal charging infrastructure by 2023, a robust mandate for terminal charging infrastructure provisions need to be issued. In the same year, a strong legal basis needs to be stipulated since Transjakarta needs to stop procuring ICE fleets by 2023 in order to achieve 100% electrification in 2030. A more comprehensive regulations on bus retrofitting needs to be issued by 2024, since Transjakarta aims to retrofit their existing fleets by having pilot for retrofitted e-bus in 2024. In 2025, the government needs to issue technical standardisation for pantograph charging.

As it is estimated that the land area requirements will exceed the capacity of the current land areas on existing depots and terminals by 2026, a strong policy support on land provisions for additional charging locations need to be issued in that year. Moreover, as the battery guarantee of the current e-bus fleets operates under the pilot phase will expire by 2030, robust regulations on environmental protection due to e-bus battery waste need to be issued on the same year.

7. GESI Aspects

The e-bus technical specifications for medium bus, single bus, microbus, and articulated bus that will be implemented in the following years need to incorporate **universal fleets design** concept to ensure no one left behind during the implementation process. Moreover, to **ensure social inclusion of the e-bus programme for the existing operators**, it needs to be ensured that existing medium bus and microbus operators already have capacity on joining the e-bus programme.

9. Conclusion and Next Steps

9.1. Conclusion

Considering the implementation phase from technical; financial and economic; as well as other factors readiness, the integrated long-term implementation phase to accommodate 10,047 Transjakarta e-bus fleets shown at Table 33, which is summarised on following points:

1. Based on the implementation phase, trials for microbuses and articulated buses should be prioritised in 2023 and 2025 respectively to be able to achieve the set targets.
2. Higher battery size for the medium buses is recommended to reduce the replacement ratio and lower the TCO while also simplifying the operations
3. The microbus, single buses and articulated buses have achieved TCO parity and in fact replacement of current diesel/CNG buses with electric buses will result in cost of operations and subsidy requirements. Some more preparatory work and reduction in prices is required for medium buses to achieve the cost parity.
4. Global supplies of suitable e-buses are available for pilot/ initial deployment by Transjakarta and subsequent scaling up.
5. The operators are willing to operate electric buses provided their profitability is not affected. But financially, **with the current scheme, electric buses at the pace proposed by Transjakarta seems infeasible**. New financing solutions like separation of asset ownership and operation, new contractual structures like leasing of buses by Transjakarta and providing them to the operator for operating will have to be considered – some options of commercial arrangements are discussed in Output 4 Report.
6. Support from The Government Jakarta is needed in implementing the above-mentioned new business/ financial models to provide support to investors.

9.2. Next Steps

There are several steps that need to be taken forward as a result of the discussion in this report:

1. Depot and terminal planning should include mixed operational planning for diesel and electric buses.
2. Overnight charging facilities for microbuses need to be planned.
3. Grid impact on the peak power and total energy should be assessed and planned upfront.
4. Plan pilot projects for microbus and medium bus to be operational in 2024.
5. Scale up deployment of single buses.
6. Obtain expressions of interest from global manufacturers to provide various bus models on lease basis or form partnership with operators.

7. Prepare a plan to build opportunity charging facilities either through government investment or public private partnership model to order to make e-bus operations more cost effective.

*** Red scripts indicate a certain new technology will be introduced on the respective year***

Table 33. Transjakarta Long-Term Implementation Phase, 2022 - 2030

		2022	2023	2024	2025	2026	2027	2028	2029	2030
Bus type		Low entry 12 m	**Medium bus 8m, Single Bus BRT 12m**	Medium Bus 8m, **Microbus 4m**	Medium Bus 8m, **Articulated Bus 18m, Single bus 12m from retrofitted maxi bus**	Low entry, Medium Bus, Single Bus, Articulated Bus	Low entry, Medium Bus, Single Bus, Articulated Bus	Low entry, Medium Bus, Single Bus, Articulated Bus	Low entry, Medium Bus, Single Bus, Articulated Bus	Low entry, Medium Bus, Single Bus, Articulated Bus
Fleets provision options		Procuring new fleets	Procuring new fleets	Procuring new fleets	Procuring new fleets **+ retrofitting existing fleets**	Procuring new fleets + retrofitting existing fleets	Procuring new fleets + retrofitting existing fleets	Procuring new fleets + retrofitting existing fleets	Procuring new fleets + retrofitting existing fleets	Procuring new fleets + retrofitting existing fleets
number of buses	***Scenario A (cumulative unit & percentage)***	74	300	475	1044	2057	3269	4867	7062	10047
		2%	***8%***	***11%***	***21%***	***36%***	***50%***	***65%***	***81%***	***100%***
	Scenario B (cumulative unit & percentage)	74	350	875	1648	3135	4724	6322	7903	10047
		2%	***9%***	***20%***	***33%***	***55%***	***72%***	***84%***	***91%***	***100%***
Charging Infrastructure		Depot Charging	Depot charging & **terminal opportunity charging**	Depot charging & terminal opportunity charging	Depot charging & terminal opportunity charging	Depot charging & terminal opportunity charging	Depot charging, terminal opportunity charging, and **additional charging locations**	Depot charging, terminal opportunity charging, and additional charging locations	Depot charging, terminal opportunity charging, and additional charging locations	Depot charging, terminal opportunity charging, and additional charging locations
Charger power		Depot: plug-in 100 - 200 kW	Single Bus Depot: plug-in 100 - 200 kW, Terminal: plug in 200 kW	Microbus Depot plug-in 22 kW	Articulated Bus Depot: plug-in 200 kW, Terminal: plug-in/ pantograph 400 kW	Microbus Depot: plug-in 22 kW	Microbus Depot: plug-in 22 kW	Microbus Depot: plug-in 22 - 75 kW	Microbus Depot: plug-in 22 - 75 kW	Microbus Depot: plug-in 22 - 75 kW
						Articulated Bus Depot: plug-in 200 kW, Terminal: plug-in/ **pantograph 400 kW**	Articulated Bus Depot: plug-in 200 kW, Terminal: plug-in/ pantograph 400 kW	Articulated Bus Depot: plug-in 200 kW, Terminal: plug-in/ pantograph 400 kW and higher	Articulated Bus Depot: plug-in 200 kW, Terminal: plug-in/ pantograph	Articulated Bus Depot: plug-in 200 kW, Terminal: plug-in/ pantograph 400 kW and higher

								400 kW and higher	
		Medium Bus Depot: plug-in 80 kW, Terminal: plug-in 100 kW	Medium Bus Depot: plug-in 80 kW, Terminal: plug-in 100 kW	Medium Bus Depot: plug-in 80 kW, Terminal: plug-in 100 kW	Medium Bus Depot: plug-in 100 kW, Terminal: plug-in 150 kW	Medium Bus Depot: plug-in 100 kW, Terminal: plug-in 150 kW	Medium Bus Depot: plug-in 100 kW, Terminal: plug-in 150 kW	Medium Bus Depot: plug-in 100 kW, Terminal: plug-in 150 kW	Medium Bus Depot: plug-in 100 kW, Terminal: plug-in 150 kW
					Single Bus Depot: plug-in 100 kW, Terminal: plug in 200 kW	Single Bus Depot: plug-in 100 kW, Terminal: plug in 200+ kW	Single Bus Depot: plug-in 100 kW, Terminal: plug in/ panto up to 400 kW	Single Bus Depot: plug-in 100 kW, Terminal: plug in/panto up to 400 kW	Single Bus Depot: plug-in 100 kW, Terminal: plug in/panto up to 400 kW
Battery Technology	LFP	LFP	LFP	LFP	LFP	LFP & **Li-advanced chemistries**	LFP & Li-advanced chemistries	LFP & Li-advanced chemistries	LFP & Li-advanced chemistries
Number of charging infrastructure Scenario A		104	54	188	331	321	329	384	603
Number of plug-in 22 kW charger		0	10	20	40	60	113	180	216
Number of plug-in 100 kW charger		59	44	58	119	105	119	152	235
Number of plug-in 200 kW charger		45	0	110	172	156	97	52	152
Number of plug-in/ pantograph 400 kW		0	0	19	37	4	5	5	5

Estimated total investment cost (IDR Billion)		973	324	2382	4062	3471	2945	2803	5153
Cumulative total investment cost (IDR Billion)	973	324	2382	4062	3471	2945	2803	5153	22113
Number of charging infrastructure Scenario B	109	89	227	371	359	329	323	509	
Number of plug-in 22 kW charger	5	45	59	80	98	113	119	122	
Number of plug-in 100 kW charger	59	44	58	119	105	119	152	235	
Number of plug-in 200 kW charger	45	0	110	172	156	97	52	152	
Number of plug-in/pantograph 400 kW	0	0	19	37	4	5	5	5	
Policy Supports	Robust mandates for terminal charging provisions	Robust legal basis to stop procuring ICE fleets, revision of current GVW regulations	More comprehensive regulations on retrofitment	Technical standards of pantograph charging	Land provisions policy for additional charging locations				Robust regulations on environmental protection due to e-bus battery waste
GESI Aspects	Technical specifications of medium and single e-bus have incorporated universal fleets design concept	Technical specifications of microbus have incorporated universal fleets design concept	Technical specifications of articulated bus have incorporated universal fleets design concept						
	Medium bus operators have capacity to electrify their fleets	Microbus operators have capacity to electrify their fleets							

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For any enquiries, please get in touch via email at communications@ukpact.co.uk