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Evaluation of factors that affect total cost of ownership in support of Transjakarta's electric bus adoption plans

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Executive summary

Adopting zero-emission electric buses (e-buses) for public transit presents significant challenges for fleet owners and operators. Transjakarta, the largest bus transit system in Indonesia, has an ambitious plan to fully transition to e-buses by 2030. That transition requires a better understanding of the main factors that affect capital and operational costs of conventional and e-buses in local conditions. This study reviews those factors for the 12m e-bus in the Transjakarta system. Further, it provides operational and policy recommendations to bolster the competitiveness of e-bus technology. Finally, we apply total cost of ownership (TCO) methodology to both conventional and e-bus technologies to explore the main factors that affect costs (bus activity in annual kilometers driven, contract duration, fuel and electricity prices, and taxes and fees).

Our results show that:

» Placing e-buses in routes that require 13% higher activity would reduce their TCO/km by 9%.

» Maintaining contract durations for conventional buses and increasing them to 15 years for e-buses can erase the TCO/km gap between the technologies.

» Maintaining current energy subsidies for e-buses positively impacts TCO.

» Eliminating diesel fuel subsidies can further close the gap and make e-buses more attractive.

» Reducing or eliminating current taxes and fees on e-buses (which impose an 8% TCO load) through national fiscal policy would incentivize electric vehicle (EV) solutions for public transit.

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These results point to policy and procurement recommendations to operators and local and national authorities:

1. Adopt battery electric buses (BEBs) in routes that offer high operational demand to increase their annual operation and reduce TCO/km.
2. Consider national policy changes to increase contract durations for BEB operators to 15 years while maintaining current 7-year diesel bus contract terms. This follows international best practices and results in TCO/km values below those for conventional technologies.
3. Because fuel and energy prices heavily impact TCO, consider removing diesel fuel subsidies and retain subsidies for electricity prices for public transit use.
4. Strengthen and extend fiscal incentives that favor BEBs today in Jakarta. The national government should consider revising the tax code to eliminate taxes and fees on BEBs (e.g., value added tax, import tax, transfer fee, income tax, and vehicle tax) for public transit fleets imported and assembled in the country. At the same time, raise taxes on diesel and compressed natural gas (CNG) buses to offset lost BEB tax revenue.
5. Extend planned direct incentives for private EVs to public transit electrification.
6. Adopt a Low Emission Zone in greater Jakarta and other cities to restrict the operation of conventional public transit buses and expand the use of e-buses.

Introduction

The adoption of e-buses for public transit fleets is one of the most effective mechanisms to mitigate air-quality and greenhouse gas (GHG) emissions impacts from this sector in cities. The provincial government of Jakarta has committed to transition to zero emission road transport by adopting the Fossil Fuel Free Streets initiative carried out by C40 Cities. Under those commitments, the local government agreed that Jakarta's public transit bus operator, Transjakarta, would only procure zero-emission buses beginning in 2025 and that most areas of Jakarta would be vehicle emission-free.[1] In addition, Transjakarta has adopted goal to have an all-electric fleet by 2030. The provincial government also set a target to operate 10,047 e-buses by 2030, along with targets for charging infrastructure, procurement, and funding.[2] Furthermore, to reduce emissions by up to 50% and mitigate climate impacts, the government of Jakarta plans to expand public transportation and transition to EVs.[3]

Jakarta's transport decarbonization goals are also supported by national policy actions. In 2019, the president of Indonesia issued Presidential Decree No. 55/2019 on accelerating battery electric vehicles for road transport. This decree incentivized EVs and components manufacturing in Indonesia. It is supported by an array of ministerial regulations that fiscally incentivize manufacturers, consumers, and aspects of infrastructure development.

Indonesia's Ministry of Transportation (MoT) has issued a series of regulations to support EV adoption and has declared bus transit electrification goals.[4] Its regulatory agenda focuses on two areas: public transportation and technical regulations for EV deployment on Indonesian roads. The MoT has presented ambitious urban public transport electrification goals; they plan to operate e-buses in Bandung and Surabaya

1 C40 Cities, (2019), *Fossil Fuel Free Streets Declaration*, retrieved May 28, 2021, from https://www.c40.org/other/green-and-healthy-streets.

2 DKI Jakarta Province Governor's Decree, "Guidelines for the Acceleration of Battery-Based Electric Motorized Vehicles in Transjakarta Transportation Services" https://jdih.jakarta.go.id/uploads/default/produkhukum/KEPGUB_NO._1053_TAHUN_2022.pdf.

3 DKI Jakarta Province Governor Regulation 90/2021, "Climate Resilient Regional Low Carbon Development Plan," https://peraturan.bpk.go.id/Home/Details/184664/pergub-prov-dki-jakarta-no-90-tahun-2021.

4 Meeting with Directorate General of Land Transportation (March 10, 2021), Ministry of Transportation.

city under the Buy the Service (BTS) scheme. The electrification schedule starts with Jakarta as a pilot city and expands to 10 cities and 10 provincial capitals, culminating with 90% electrification of public transport fleets by 2030.

Adopting e-buses for public transit systems poses significant challenges for city authorities and operators investing in this relatively new technology. Public transit electrification goals calling for thousands more e-buses in Jakarta and other Indonesian cities over the next decade require addressing technical, operational, financial, and regulatory barriers.

Higher procurement costs compared to conventional diesel or CNG buses hinder e-bus adoption. Accordingly, this study analyzes the costs associated with procuring and operating e-buses compared to conventional buses. We also analyze the impact of fiscal loads that affect bus procurement to elucidate tax changes that could reduce cost gaps between e-buses and conventional ones. This study also explores how fuel and electricity prices impact operating costs.

The scope of this study is a fleet average TCO model applied to 12m single buses operating in the Transjakarta BRT system (while Transjakarta operates other bus types, the 12m bus is their priority for electrification). The data to run this analysis was provided by Transjakarta and complemented by ICCT data on e-bus costs.

Two reports were produced from this analysis: a consultancy report to Transjakarta and this report for the broader public. This public report does not contain information deemed confidential by Transjakarta (e.g., operational cost of maintenance per km). The results and conclusions of both reports are the same.

Background

Transjakarta overview and electrification plans

Transjakarta is the public transit bus operator of the integrated transit system in the Capital Region of Jakarta (DKI Jakarta). It manages the Bus Rapid Transit (BRT) system, established in 2004 (see Figure 1),[5] as well as a range of feeder bus routes (also called microtrans) and microbuses (also called angkots). The BRT system is integrated with the Jakarta Mass Rapid Transit (MRT) subway system, the Jakarta Light Rail Transit (LRT) system, and air-conditioned microbuses. The BRT system covers 244 km divided into 13 corridors (trunk routes). Feeder services reach 248 additional routes. Transjakarta serves a population of 30 million people in the Greater Jakarta area; it has a daily ridership of 1 million passengers.[6]

5 ITDP Indonesia, "Supporting Jakarta's Transition to E-mobility: Investment Plan for Electric Bus Deployment of Transjakarta," (2021), https://itdp-indonesia.org/publication/support-for-e-mobility-transition-in-jakarta/.

6 Transjakarta 2021, *Produk dan layanan*, viewed 12 August 2021, https://www.Transjakarta.co.id/produk-danlayanan/layanan-bus/Transjakarta/.

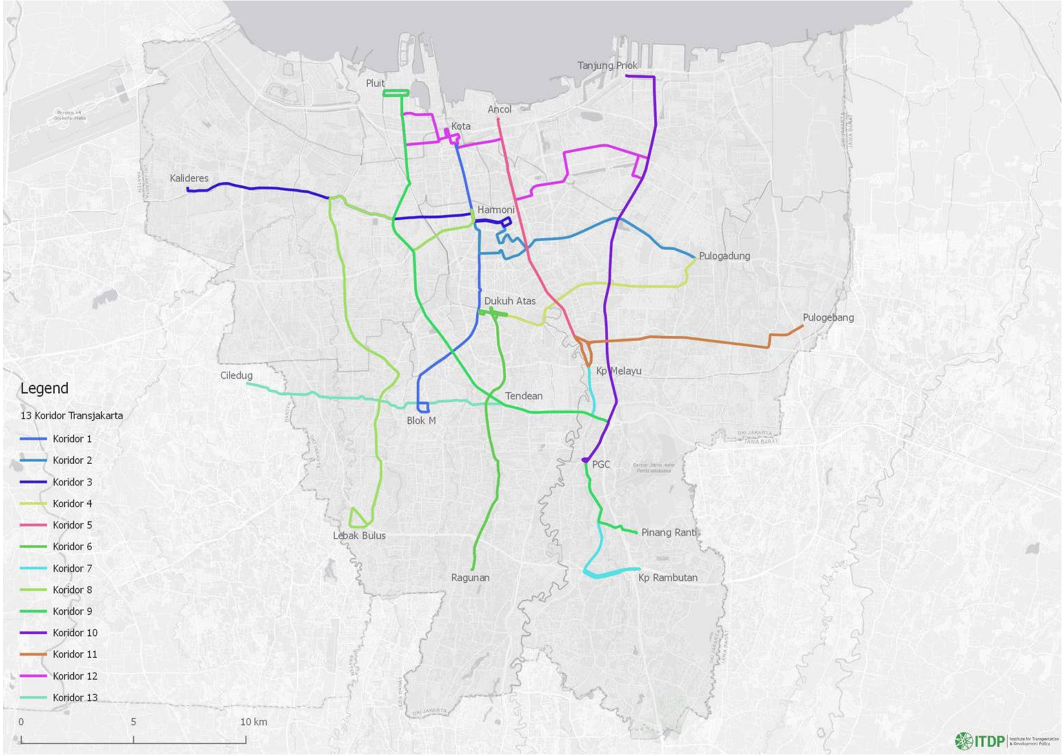


Figure 1. Transjakarta BRT system

Transjakarta owns and operates buses and provides service contracts to bus operators who must legally provide a minimum level of service to passengers (as set by Transjakarta and its overseeing body, the DKI Jakarta government). Transjakarta pays bus operators based on gross cost contracts (GCC) that set operational performance standards (kilometers driven) and prices (IDR/km). Operators must purchase, operate, and maintain buses and provide depots (though Transjakarta owns some depots).

The 4,415 buses in Transjakarta's fleet operate on both BRT and non-BRT service routes. Transjakarta operates a fleet of 1,461 buses on 32 BRT routes; those buses are articulated (18m), single (12m), and maxi-buses (12–13.5m). A fleet of 2,129 microbuses operate on microtrans routes. In 2019, Transjakarta cooperated with 18 third-party operators to provide services.

The current fleet is composed of diesel, CNG, and BEB powertrain technologies. Diesel and CNG buses meet various emission standards. Figure 2 presents the distribution of bus technologies by vehicle type (length) and emission standard (maxi-buses are in the 12m category).[7] This analysis focuses on 12m buses certified to meet EURO III standards for diesel and CNG.

7 We collected bus operational and maintenance data from Transjakarta officials in 2019/2020.

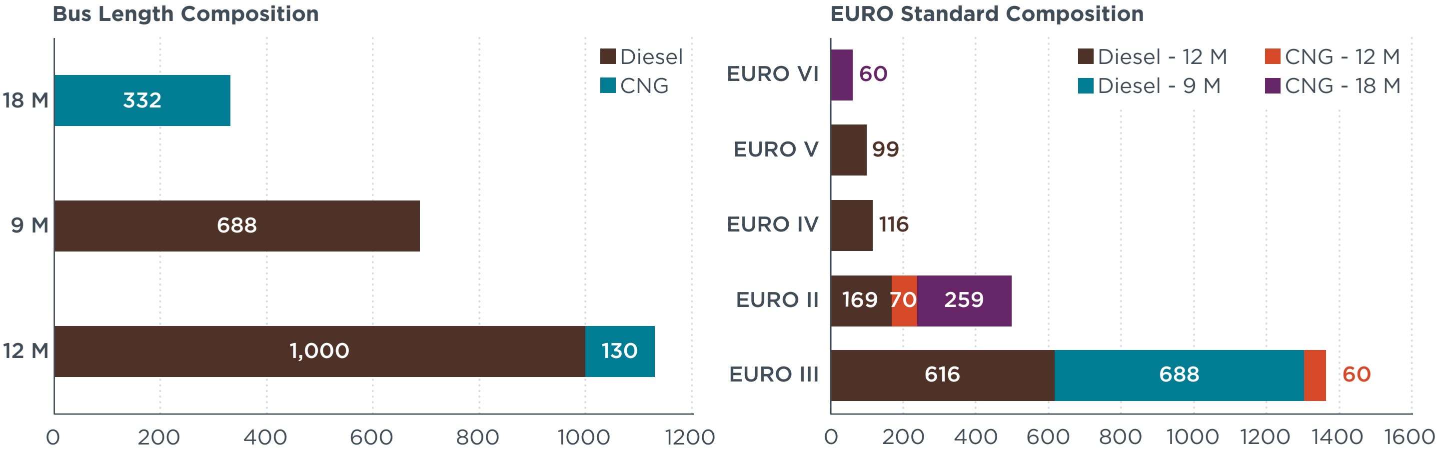


Figure 2. Bus length and Euro Standard Composition of Transjakarta buses

Transjakarta has an ambitious plan for e-bus adoption. It started with a pretrial phase in 2019–2020. A pilot phase in 2021–2022 focused on piloting 30 buses and developing a new business model to support the technology transition. As of June 2022, 30 e-buses were running on Transjakarta routes 1N (Blok M-Tanah Abang), 1R (Tanah abang-Terminal Senen), and 6N (Ragunan-Blok M). They operate on an overnight charging strategy at the depot and have an operating range of 200 km/day.[8]

The final implementation phase will scale up the plan. Transjakarta will acquire significant numbers of additional electric buses to fully electrify its fleet by 2030 (see Figure 3). New e-bus purchases by Transjakarta and third-party operators in the network will double Transjakarta's fleet size in the next decade. Transjakarta will focus on electrifying low entry (12m) and medium low entry (8m) buses until 2023. From 2023–2025, they will focus on high floor BRT (12m) and microtrans (5m) buses. In 2025 and beyond, they will focus on retrofitting existing internal combustion engine (ICE) buses to electric.[9]

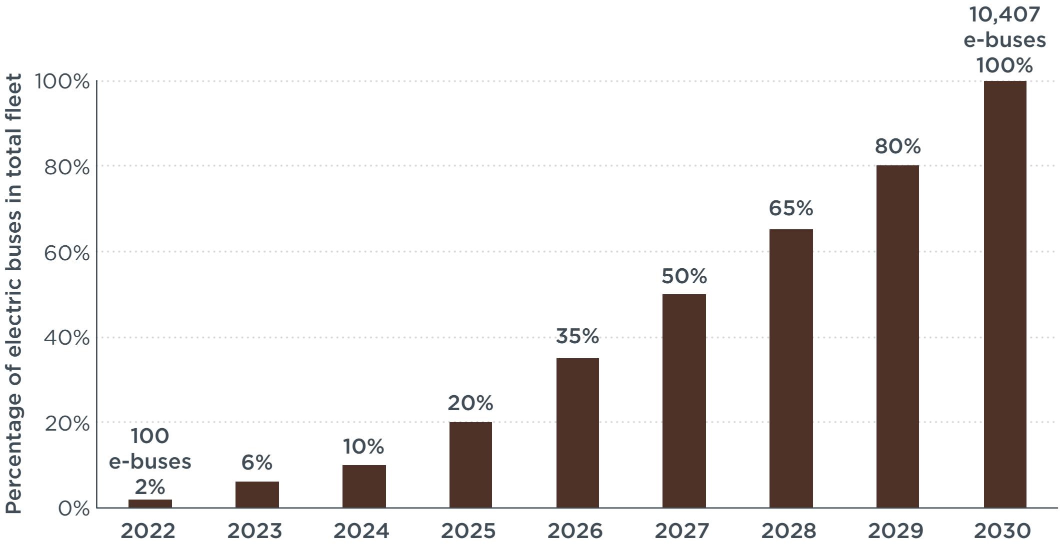


Figure 3. Transjakarta fleet growth and electrification targets

8 Interview with Transjakarta.

9 Data was shared by Transjakarta officials during the National Workshop on Accelerating Battery-Electric Vehicle Adoption 2022 in Indonesia. International Council on Clean Transportation. "Accelerating Battery-Electric Vehicles: Indonesia National Workshop – International Council on Clean Transportation," November 1, 2022. https://theicct.org/event/indonesia-workshop-sep22/.

Tax structure for electric and conventional buses

It costs more to purchase e-buses than conventional buses. That is the main challenge slowing e-bus adoption in Indonesian cities. One factor that affects purchase prices (and, to some extent, operational costs) is the fiscal load imposed on those vehicles. This section analyzes the tax structure that applies to bus purchases and operation; we later use this analysis to calculate fiscal loads and identify actions to close BEB TCO gaps.

The study differentiates two categories of taxes based on when they are paid: one-time taxes at acquisition and recurring taxes during use. In Indonesia, one-time taxes include value added taxes (VATs), import duties, luxury taxes, and transfer fees. Use taxes include recurring annual property taxes, the mandatory road accident fund, and vehicle test fees. Indonesia's government has already taken the steps to exempt transfer and vehicle taxes by 2024.[10]

One-time taxes and fees

VAT or goods and services tax (GST): The legal basis for the VAT is Act No. 8/1983, updated in 1994 (Act No. 11/1994), 2000 (Act No. 18/2000), and 2009 (Act No. 42/20090.[11] Both ICE and e-buses have a 10% VAT rate.

Import duty: Because most e-buses and their components are produced in China, import duties are calculated under the terms of the free trade agreement between China and ASEAN member countries. Ministry of Finance (MoF) Decree No. 26/2017 stipulates import duties in the ASEAN-China Free Trade Area (ACFTA): 5% for complete built up (CBU) e-buses and 40% for complete knocked down (CKD).[12] Diesel buses are also taxed at 5% for both CBUs and CKDs. E-bus CKDs are not covered by MoF's older rules that favor public transit bus taxes.

Luxury tax: Public transport vehicles, including buses, are free of luxury taxes. In October 2021, the Indonesian government enacted Government Regulation (GR) No. 74/2021 which stipulated that the luxury tax for either ICE or e-buses at a gross vehicle weight of 5–24 tons is 0%.[13]

Income tax: A special income tax is applied to imported goods or business activities in other fields (mostly mineral exports). This tax is regulated by MoF decree (PMK) No. 110/2018 on amendments to regulations of MoF decree No. 34/PMK.010/2017. Imported vehicles are included in the list of taxed goods at a rate of 7.5%.[14] The income tax is paid by sellers. Consequently, it increases vehicle purchase costs.

10 Government Law Number 1 of 2022, "Financial Relations between the Central Government and Local Governments," https://peraturan.bpk.go.id/Home/Details/195696/uu-no-1-tahun-2022.

11 Government Law Number 42 of 2009, "Third Amendment to Law Number 8 of 1983 Concerning Value Added Tax on Goods and Services and Sales Tax on Luxury Goods," https://peraturan.bpk.go.id/Home/Details/38787/uu-no-42-tahun-2009.

12 CBUs are understood to be complete buses that require no additional assembly; they are ready to be operated when they arrive at their destinations. CKDs are complete sets of parts needed to assemble a bus in the destination country.

13 Government Regulation 74/2021, "Amendments to Government Regulation 73/2019, Taxable Goods Categorized as Luxury in the Form of Used Motor Vehicles Sales Tax on Luxury Goods," https://peraturan.bpk.go.id/Home/Details/171112/pp-no-74-tahun-2021.

14 Ministry of Finance Decree 34/PMK.010/2017, "Amendments to MoF Decree No. 34/PMK.010/2017 on the Collection of Income Tax Article 22 in Relation With the Payment of the Delivery Goods and Import Activities or Other Business Activities," https://jdih.kemenkeu.go.id/fullText/2018/110~PMK.010~2018Per.pdf.

Transfer fees: Transfer fees are taxes imposed by local governments on vehicle sales. Jakarta's Local Act No. 6/2019 stipulates transfer fees of 12.5% for ICE buses.[15] There is no fee for e-buses, as stipulated in DKI Jakarta Governor Decree No. 3/2020.[16]

Recurring taxes and fees

Vehicle tax: The vehicle tax imposed on ICE buses is 1%; e-buses are exempt (according to DKI Jakarta Governor Decree No. 53/2020).[17]

Road accident fund: The road accident fund collects fees from passenger fares to cover the financial consequences of passenger accidents. Bus owner/operators pay 87,000 IDR annually based on MoF Decree No. 15/PMK.010/2017.

Vehicle test fees (KIR): Indonesian law[18] requires a roadworthiness test for each public transport vehicle every 6 months. The test includes smoke emissions roadworthiness and speedometer tests. Vehicle test fees are 92,000 IDR based on DKI Jakarta Provincial Regulation No. 1/2015.[19]

Table 1 summarizes all taxes and fees applied to conventional and e-buses. Indonesia's current tax structure offers no significant benefits to BEBs and discourages importing e-bus components for assembly.

Table 1. Summary of bus taxes and fees

Tax	Authority	Frequency	ICE rate	E-bus rate
VAT	National	One-time	10%	10%
Import duty	National	One-time	5%	CKD 40%; CBU 5%
Luxury tax	National	One-time	0%	0%
Income tax	National	One-time	7.5%	7.5%
Road accident fund	National	Recurring (Annual)	87,000 IDR	87,000 IDR
KIR	National	Recurring (Biannual)	92,000 IDR	92,000 IDR
Transfer fee	Local	One-time	12.5%	0%
Vehicle tax	Local	Recurring (Annual)	1%	0%

Fuel and electricity prices

In Indonesia, fuel and electricity prices are regulated by the Ministry of Energy and Mineral Resources (MEMR). State-owned enterprises (SOEs) for energy and fuel sales define prices for consumers. Perusahaan Listrik Negara (PLN) is the SOE distributor of electricity to consumers. In 2021, PLN provided a bulk price of 714 IDR/kWh (excluding taxes) to bus operators under the category of "Private Electricity Installations for Public Transportation". In the case of e-bus depo, the price of the electricity is 825 IDR/kWh including load factors and taxes. These are discounted tariffs for EV applications. In

15 DKI Jakarta Province Local Act 6/2019, "Instructions for Implementing Regional Regulation of Central Java Province Number 5/2017 Concerning Regional Property Management," https://peraturan.bpk.go.id/Home/Details/177662/pergub-prov-jawa-tengah-no-6-tahun-2019.

16 DKI Jakarta Governor Decree 3/2020, "Tax Incentives for Motorized Vehicle Title Transfer Fees on Battery Electric Vehicles for Road Transportation," https://peraturan.bpk.go.id/Home/Details/131358/pergub-prov-dki-jakarta-no-3-tahun-2020.

17 DKI Jakarta Governor Decree 53/2020, "Basic Calculation of Imposition of Motorized Vehicle Tax and Transfer Fee of Motorized Vehicles Manufactured Before 2020," https://peraturan.bpk.go.id/Home/Details/163322/pergub-prov-dki-jakarta-no-53-tahun-2020.

18 Government Law Number 22 of 2009, "Traffic and Road Transport," https://www.dpr.go.id/dokjdih/document/uu/UU_2009_22.pdf.

19 DKI Jakarta Province Local Act 1/2015, "Amendments to Regional Regulation 3/2012 Concerning Regional Retribution." https://peraturan.bpk.go.id/Home/Details/20855/perda-prov-dki-jakarta-no-1-tahun-2015.

contrast, the price for electricity for privately owned vehicle can rise to 2466 IDR/kWh at PLN charging stations.[20]

CNG vehicles are subsidized for the transportation sector; a flat tariff of 4500 IDR/L Gallon Gasoline Equivalent (GGE) is applied throughout Indonesia.[21] Perusahaan Gas Negara (PGN) is an SOE that produces and distributes this product to gas stations across Indonesia.

Pertamina, the SOE that supplies diesel fuel, has three brand names for diesel fuel in Indonesia: Biosolar (CN 48), Dexlite (CN 51), and Pertamina Dex (CN 53). The most common diesel used by heavy duty vehicles and public transport is Biosolar, a subsidized diesel with 30% biodiesel Fatty Acid Methyl Esters (FAME) content. Table 2 compares fuel and electricity prices and specifications (as of June 2022). [22] Biosolar is priced at 5,150 IDR/L; Pertamina Dex (non-subsidized diesel) is priced at 13,700 IDR/L, almost three times more. We explore the impacts of diesel price subsidies and electricity prices later.

Table 2. Fuel and electricity specifications

Unit	Biosolar	Pertamina Dex	Electricity	CNG
Price	6800 IDR/L	13,700 IDR/L	825 IDR/kWh	4500 IDR/L eq
Cetane number	48	53	-	-
Sulphur content (ppm)	500	300	-	-
FAME content (%)	30	0	-	-

Contract duration

Contract durations for bus services can significantly impact TCO values. Longer durations mean longer bus lifetimes, which increase lifetime operational distances (i.e., Vehicle Kilometers Traveled or VKT), which, in turn, can reduce TCO. Contract durations for public transit systems in Indonesia are traditionally set at 3 years. However, the adoption of e-buses is already changing durations in some systems. In Jakarta, a local policy (Governor Decree No. 74/2021) allows e-bus contracts to extend to 10 years.[23]

In other regions around the globe, e-bus contracts are generally 10–15 years (see Table 3). Extending contracts to 10 years (and possibly to 15 years in the future) would significantly reduce e-bus TCOs. For example, extended contract durations can reduce the impact of battery replacement costs (batteries must be replaced around years 7–8 of usage) and lower TCO/km compared to ICE buses.[24]

20 Perusahaan Listrik Negara, "Charging Infrastructure for Electric Buses," (2021), https://busworldsoutheastasia.org/sites/soasia/files/2021-07/Infrastruktur%20Pengisian%20Bus%20Listrik_Zulkifli%20Zaini_PLN%20Persero.pdf.

21 MEMR Decree 2932 K/12/MEM/2010, "Selling Price of Fuel Gas Used for Transportation in Jakarta Area," https://jdih.esdm.go.id/peraturan/Kepmen%20ESDM%202932%202010.pdf.

22 Directorat General of Oil and Gas Decree 0234.K/10/DJM.S/2019, "Standards and Quality (Specifications) of Diesel-Type Fuel Marketed Domestically Oil," https://migas.esdm.go.id/uploads/regulasi/regulasi-kkkl/2020/146.K-10-DJM-2020.pdf.

23 DKI Jakarta Governor Regulation 74/2021, "Second Amendment to Governor Regulation No. 96/2018 Concerning Integration of Feeder Transport Into Bus Rapid Transit System," https://jdih.jakarta.go.id/uploads/default/produkhukum/PERGUB_NO._74_TAHUN_2021.pdf.

24 Xie, Yihao, et al., "Guidelines for electric bus procurement in Jakarta," (ICCT: Washington, DC, 2023), https://theicct.org/wp-content/uploads/2023/01/asia-pacific-hvs-guidelines-jakarta-bus-jan23.pdf.

Table 3. Global bus contract durations

	E-bus contract duration (years)	Diesel bus contract duration (years)	Depot contract duration (years)
Indonesia (Jakarta)	10	7	N/A
India	10–16	7	10–12
Chile (Santiago)	10–14	5–7	25
China (Shenzhen)	8	8	N/A
Colombia (Bogotá)	14	10	25

Methodology

General practices for bus procurement often favor the technology with the lowest purchase price. This approach ignores indirect costs (e.g., the cost of owning and operating a vehicle over 7–15 years). Thus, purchase price is a poor measure of bus TCO and biases comparisons between different powertrain technologies. BEBs have higher initial purchase prices but are cheaper to operate and maintain over a lifetime compared to conventional buses.

This study calculated TCO to measure the total cost of a bus over its lifetime. TCO is the sum of the costs to acquire, operate, and maintain a vehicle and its fueling infrastructure over a period. By using TCO as a method to inform procurement, owner/operators could make more informed judgments about available technologies, leading to more sustainable and cost-efficient bus operation and maintenance. The methodology is based on ICCT's TCO analysis for public transit buses that has been adopted in several case studies of Latin American and Indian cities and was first introduced by Miller et al. in 2017 for soot-free urban bus fleets.[25] Table 4 describes the TCO components (excluding overhead) used in this study.

Table 4. TCO components and inputs

Main Components	Inputs
Fleet information	Fleet size, ownership terms
Capital costs	Purchase price, infrastructure costs, residual/scrappage value
Operations/ maintenance	Annual VKT, fuel/energy consumption, fuel/electricity price, Adblue consumption/price, maintenance costs
Midlife costs	Midlife costs (engine overhaul or battery replacement)
Staff	Staff costs (driver, checker, technician, operator)
Financial assumptions	Loan terms, interest rates, down payments, discount rates

Note: Costs calculated in this study exclude indirect (overhead/accidental) costs

Inputs and information sources

Capital costs

We obtained bus purchase prices from public vehicle price information published by the Ministry of Interior Affairs (MoIA) regulation 40/2021; we use base prices for tax calculations. Another source, the Lembaga Kebijakan Pengadaan Barang/Jasa Pemerintah (LKPP) e-catalogue, is an online site that provides a wide range of products needed by the government. We selected the price of buses for comparison after several interviews with Transjakarta officials. Our selections represent the 12m standard buses that are being used in the Transjakarta fleet: Mercedes Benz O 500 U 1726 AT (Diesel), Hino RK1JSNL-RHJ (CNG), and Higer KLQ6125GEV (Electric). Table 5 summarizes purchase cost data used in the TCO.

25 Miller, J., et al. "Financing the Transition to Soot-Free Urban Bus Fleets in 20 Megacities." (ICCT: Washington, DC, 2017), https://theicct.org/publication/financing-the-transition-to-soot-free-urban-bus-fleets-in-20-megacities/.

Table 5. Bus type and purchase price

Brand	Series	Type	Fuel	Price (IDR)	EURO	Battery Size
Mercedes Benz[26]	O500U1726AT	Single Bus 12m	Diesel	2,594,715,750	III	N/A
Hino[27]	RK1JSNL-RHJ	Single Bus 12m	CNG	2,007,000,000	III	N/A
Higer[28]	KLQ6125GEV	Single Bus 12m	Electric	5,500,000,000	N/A	324

Infrastructure costs are based on the price of one bus depot with the capacity of 150 buses. We obtained infrastructure costs for diesel and CNG buses from Transjakarta. We determined e-bus infrastructure costs using an ITDP Indonesia study of Transjakarta's e-bus deployment.[29] E-bus infrastructure costs include charger prices and grid connections. We assumed a 150 kW depot charger costs US$75,000/1,110,000,000 IDR per charger[30] with the ratio of three e-buses per charger.[31] The cost of 2 MW grid connections is also considered, the grid can connect to 10 depot chargers with 150 kW capacity, serving 30 e-bus. Table 6 summarizes infrastructure cost and scrappage data.

Table 6. Bus infrastructure cost and scrappage values

Fuel	Description	Note
Electric[32]	Depot charging	1 charger, 3 e-buses (Charging ratio 1:3)
Electric	Grid connection	2 MW grid capacity, 30 e-buses
Diesel/CNG	Depot	1 depot, 150 bus capacity
Electric	Scrappage	-
Diesel/CNG	Scrappage	-

Note: Information on diesel/CNG buses was obtained from Transjakarta in 2019; information on e-buses was obtained in 2022

Operating costs

Bus operating costs significantly impact TCO. They include energy consumption, energy/fuel prices, maintenance, and staffing costs. This study used data collected from Transjakarta in 2019 and other sources to define key inputs such as fuel and energy consumption, fuel and electricity prices, infrastructure maintenance costs, and bus maintenance costs. For e-bus components, additional interviews and a desk study supplemented our analysis. Table 7 summarizes operating costs.

26 E-Katalog 5.0, "Mercedes Benz Bus Besar (O 500 U 1726 A/T) (Laksana Cityline 37 Seats)(Thermoking Tk-1100 With Airpurifier) (Bus Low Entry) Off The Road," https://e-katalog.lkpp.go.id/katalog/produk/detail/1286810?lang=id&type=general.

27 Ministry of Home Affairs Regulation 40/2021, "Amendment to Regulation of the Minister of Home Affairs Number 1/2021 Concerning Calculation of the Basis for Imposition of Motorized Vehicle Tax and Transfer Fee of Motorized Vehicles in 2021," https://peraturan.bpk.go.id/Home/Details/185922/permendagri-no-40-tahun-2021.

28 Ministry of Home Affairs Regulation 40/2021.

29 ITDP Indonesia, "Support for E-mobility Transition in Jakarta, (2021), https://itdp-indonesia.org/publication/support-for-e-mobility-transition-in-jakarta/.

30 This study uses an exchange rate of 1 USD=14,800 IDR (the average rate in August 2022).

31 Interview with Transjakarta regarding charging strategy.

32 ITDP Indonesia, "Support for E-mobility."

Table 7. Bus operating costs

Input	Unit
Fuel Consumption	DLE/km
Fuel Price[33, 34]	IDR/DLE
Energy Consumption[35]	kWh/km
Electricity Price	IDR/kWh
Infrastructure Maintenance	IDR/Annual
Bus Maintenance	IDR/km
Staff Costs	IDR/km

Note: Information on diesel/CNG buses was obtained from Transjakarta in 2019; information on e- buses was obtained in 2022 and complemented with ITDP Indonesia's "Support for E-mobility" report.

Midlife costs include needed engine overhauls (for ICE buses) or battery replacements (for e-buses). For diesel and CNG powertrains, engines are overhauled biennially or when an engine reaches 200,000 km. Diesel and CNG buses in Transjakarta operate under 7-year contracts, thus each bus engine will be overhauled three times.

Our TCO analysis assumed that e-bus batteries would be replaced when a bus reaches service year 8. We based battery prices on the average 2020 price of lithium-ion batteries (157 US$/kWh).[36] The battery capacity of the Higer KLQ6125GEV e-bus is 326 kWh; the battery costs US$51,182 or 908,992,320 IDR (+20% included in the cost assumption for price fluctuations, shipping, and manufacturing). Table 8 summarizes midlife cost inputs (excluding e-bus renovation costs).

Table 8. Midlife cost inputs

Bus type	Note
Diesel/CNG[37]	Including biennial engine overhaul
Electric[38]	Based on 157 USD/kWh Li-ion price, 326 kWh battery capacity

Financial assumptions

We obtained financial information on bus procurement from Transjakarta[39] and the discount rate from the Bank of Indonesia. [40] Financial assumptions (shown in Table 9) for each bus type are identical (excluding assumptions used in our sensitivity analysis). The interest rate for e-buses could be higher, depending on bank negotiations.

33 MEMR Decree 37.K/HK.02/MEM.M/2022, "Concerning Special Assigned Fuel Oil Type," https://jdih.esdm.go.id/storage/document/SALINAN%20KEPMEN%2037%20TAHUN%202022%20TTG%20JBKP.pdf.

34 MEMR Decree No. 82.K/MG.01/MEM.M/2022, "Concerning Selling Value of Gas for Transportation Purposes," https://jdih.esdm.go.id/storage/document/Abstrak%20Kepmen%20ESDM%20No.%2082.K-MG.01-MEM.M-2022.pdf.

35 Indonesia e-Bus Manufacturers.

36 Mulholland, Eamonn, "Cost of Electric Commercial Vans and Pickup Trucks in the United States Through 2040," (ICCT: Washington, DC, 2023), https://theicct.org/sites/default/files/publications/cost-ev-vans-pickups-us-2040-jan22.pdf.

37 Transjakarta Bus Data, 2019.

38 ICCT, 2022.

39 Transjakarta Bus Data, 2022.

40 Bank Indonesia, "Inflation Data," https://www.bi.go.id/en/statistik/indikator/data-inflasi.aspx.

Table 9. Financial assumptions

Input
Loan Capital Expenditures
Loan Term (years)
% Interest Rate
% Down Payment
% Discount Rate

Taxes and fees

Table 10 summarizes the taxes and fees imposed on buses.

Table 10. Taxes and fees

Tax/Fee	Diesel/CNG	BEB	Notes	Description
VAT[41]	10%	10%	-	Goods and services tax
Import duty tax[42]	5%	5–40%	BEB CBU: 5% BEB CKD: 40%	Under the China-ASEAN free trade agreement
Transfer fee[43]	12.5%	0		Tariff for transfer fee of motorized vehicle
Vehicle annual tax[44]	1%	0%	Recurring	-
Road accident fund, annual[45]	87,000 IDR	87,000 IDR	Recurring	Mandatory fund
Vehicle Test Fee/KIR[46]	92,000 IDR	92,000 IDR	Recurring	Mandatory every 6 months

Sensitivity analysis

Our sensitivity analysis explores the influence of individual cost components on TCO estimates. It can also account for uncertainty in underlying data and assumptions. We compared our reference scenario to alternative scenarios (low and high) to consider different operational and financial conditions (see Table 11).

Table 11. Sensitivity cases

Sensitivity Cases	Bus Type	Baseline case	Case A	Case B
VKT (km/year)	All	71,000	80,000	-
Fuel subsidies (IDR/liter)	Diesel	6,800	13,700	18,900
Taxes and fees	Electric	No taxes	Current taxes	-
Energy Consumption (kWh/km)	Electric	1.3	0.9	1.0
Electricity Price (IDR/kWh)	Electric	825	731	2,466
Contract duration (years)	Electric	7	10	15

41 Government Law Number 43 of 2009, "The Third Amendment Of Law Number 8 Year 1983 On The Value Added Tax Of Goods And Services And Tax Of Luxury Goods Sale."

42 Ministry of Finance Decree 24/2005, 28/2007, and 26/2017.

43 DKI Jakarta Province Local Act 6/2019 and DKI Jakarta Province Governor Decree 3/2022.

44 DKI Jakarta Province Governor decree No. 53/2020.

45 DKI Jakarta Province Governor Regulation 33/1964 and 34/1965.

46 Indonesia Legislation 22/2009 and DKI Jakarta Province Governor Regulation 1/2015.

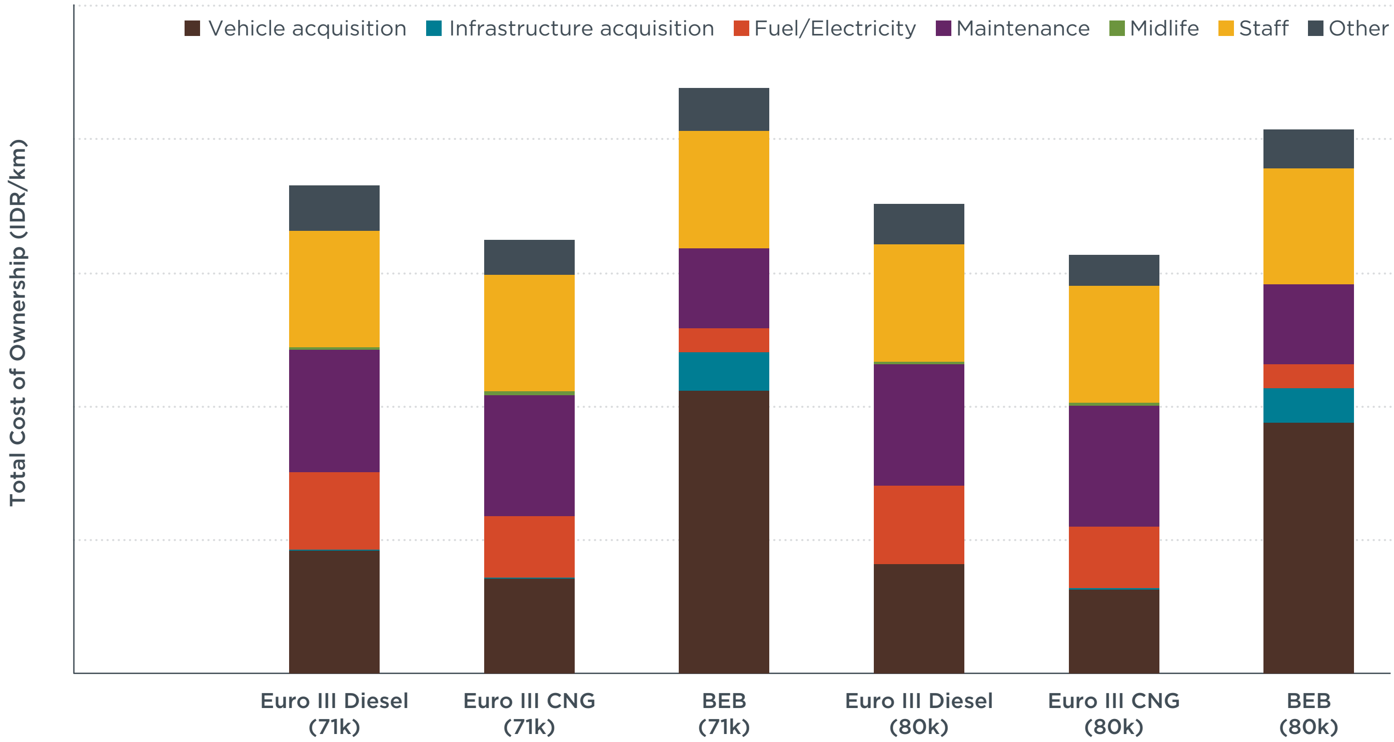
Results

Impact of VKT

Annual VKT is a parameter linked to contractual aspects of daily minimum utilization and illuminates bus utilization efficiency. VKT varies by individual routes and annual operational availability. Higher VKTs may indicate the optimization of bus operation on its routes, leading to lower TCO/km values.

As Figure 4 shows, we used Transjakarta's estimate of 71,000 km/year as the baseline case average bus utilization, and 80,000 km/year as the higher VKT annual case. Euro III Diesel with 71,000 km annual VKT will have 4% difference with 80,000 km/year VKT.

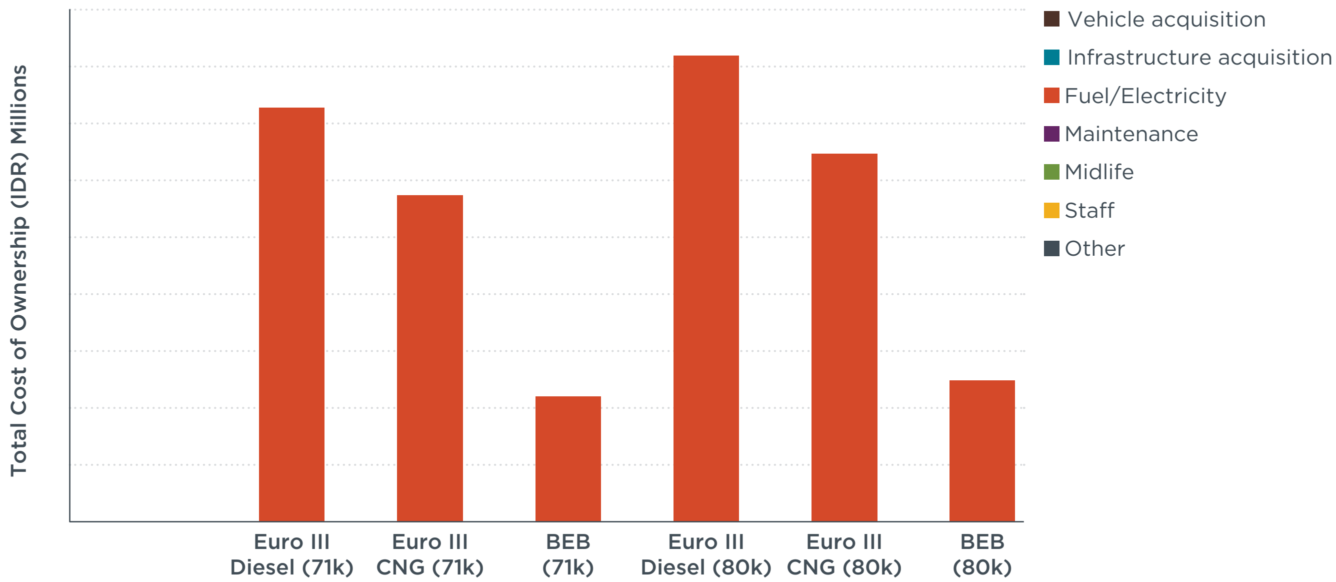
The TCO IDR/km for BEB is lower if the VKT value is higher. A BEB with 80,000 km annual TCO IDR/km is 9% lower than a BEB with 71,000 km/year. Meanwhile, CNG buses show the lowest TCO option to use (with 11–14% cost difference to the baseline diesel ratio).



Ratio to baseline diesel	**0**	**0.89**	**1.20**	**0.96**	**0.86**	**1.11**

Figure 4. Annual VKT impact on TCO/km

The price differential between the consumption of diesel and electricity is significant. For an e-bus at 71,000 km/year, energy spending is 70% less than diesel fuel spending across the bus's lifetime. For an e-bus at 80,000 km/year, energy savings reach up to 79% if compared to using diesel. As e-bus VKT rises, so do savings on energy/fuel spending (see Figure 5).



	Euro III Diesel (71k)	Euro III CNG (71k)	BEB (71k)	Euro III Diesel (80k)	Euro III CNG (80k)	BEB (80k)
Ratio to baseline diesel	**0**	**0.79**	**0.30**	**1.13**	**0.89**	**0.34**

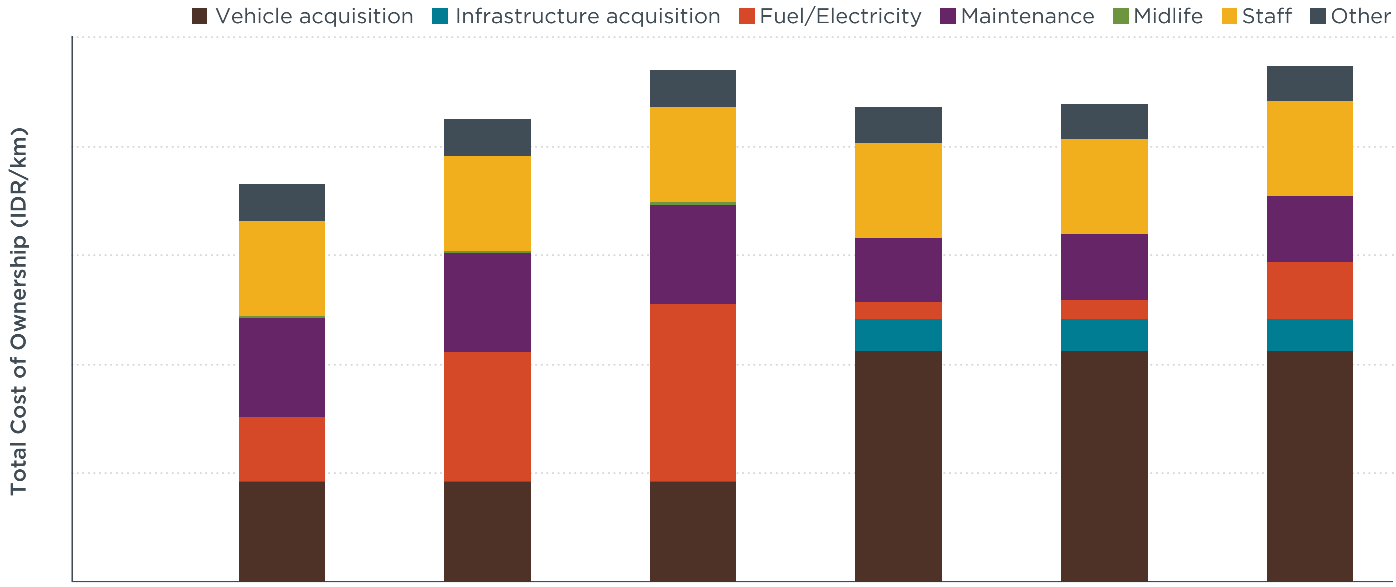
Figure 5. Annual VKT impact on fueling expenditure (IDR)

Impact of fuel and energy prices

We compared the TCO/km for each bus type for different fuel and electricity prices, matching their subsidized and unsubsidized values (see Figure 6). Until 2022, diesel fuel (biosolar CN 48) and electricity were subsidized for the public transport sector.

The TCO/km difference for buses operating with non-subsidized (NS) diesel is 16–28% higher than for subsidized diesel. The annual growth in the cost of NS diesel will also impact the TCO/km for diesel buses as fossil fuels prices trend higher.

The TCO/km for BEBs is still higher than for diesel buses, even with subsidized electricity. However, our analysis shows a 9–10% lower TCO/km for subsidizes cases (i.e., electricity at a bulk price of 731 IDR/kWh and electricity at the depo price of 825 IDR/kWh) compared to the price of NS diesel as of August 2022. NS electricity will raise the TCO/km of e-buses by 29% compared to diesel buses that use subsidized diesel.



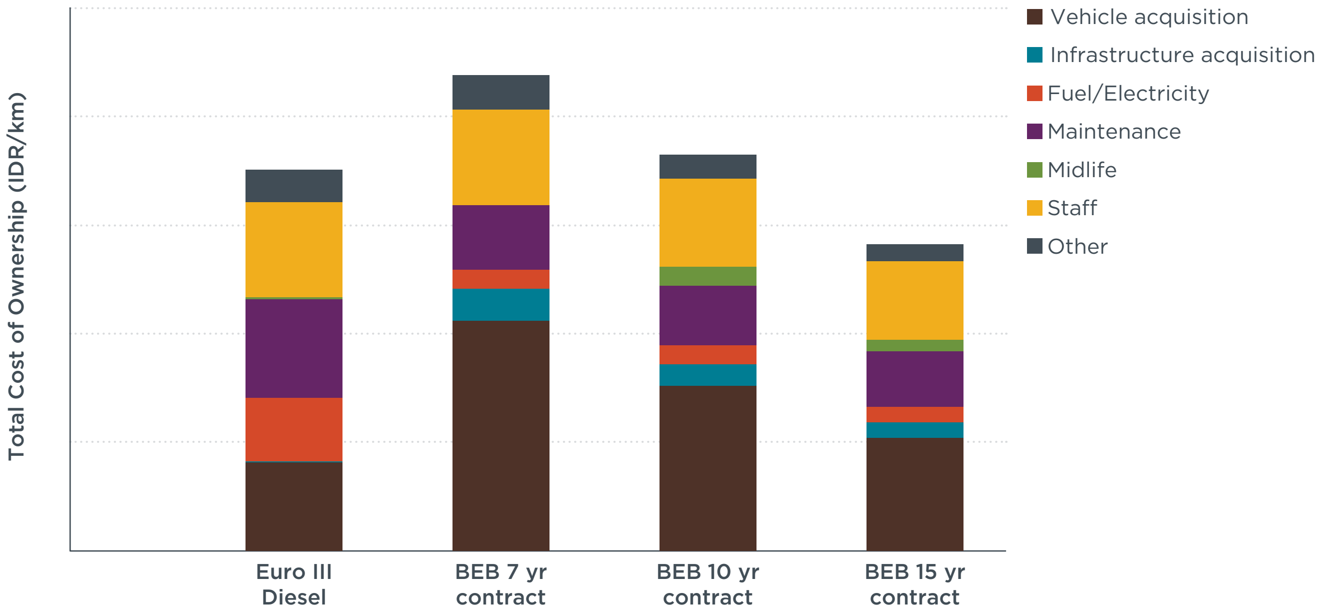
	Euro III Diesel	Euro III Diesel (NS-June)	Euro III Diesel (NS-Aug)	BEB Bulk Price	BEB Depo Price	BEB Non Subsidized
Ratio to baseline diesel	**0**	**1.16**	**1.28**	**1.19**	**1.20**	**1.29**

Note: NS means non-subsidized

Figure 6. Fuel and energy price impact on TCO/km

Contract duration

Extending the contract duration of e-buses to 10 or 15 years can significantly improve the TCO/km for e-buses. Indeed, TCO/km can be lower for e-buses than for diesel bus if e-bus contracts are extended to 15 years. As shown in Figure 7, extending e-bus contracts to 15 years can reduce TCO/km by 20% (compared to diesel buses operating under 7-year contracts). It is common practice to extend e-bus contract durations up to 15 years in Latin American countries (e.g., Chile, Colombia, and Mexico).[47] Longer contract durations help offset battery replacement costs and lower TCO/km. In Latin America, battery replacement costs are included in contract negotiations between bus owner and transit authorities, ensuring that the expense is known, planned for, and secured.



	Euro III Diesel	BEB 7 yr contract	BEB 10 yr contract	BEB 15 yr contract
Ratio to baseline diesel	**0**	**1.20**	**1.04**	**0.80**

Figure 7. Contract duration impact on TCO/km

(*Note:* the 7-year BEB TCO does not include battery replacement; the 10-year contract duration does not include the assumption of battery resale value. To better reflect real-world performance, VKT for diesel uses the high case and for BEB uses the baseline case)

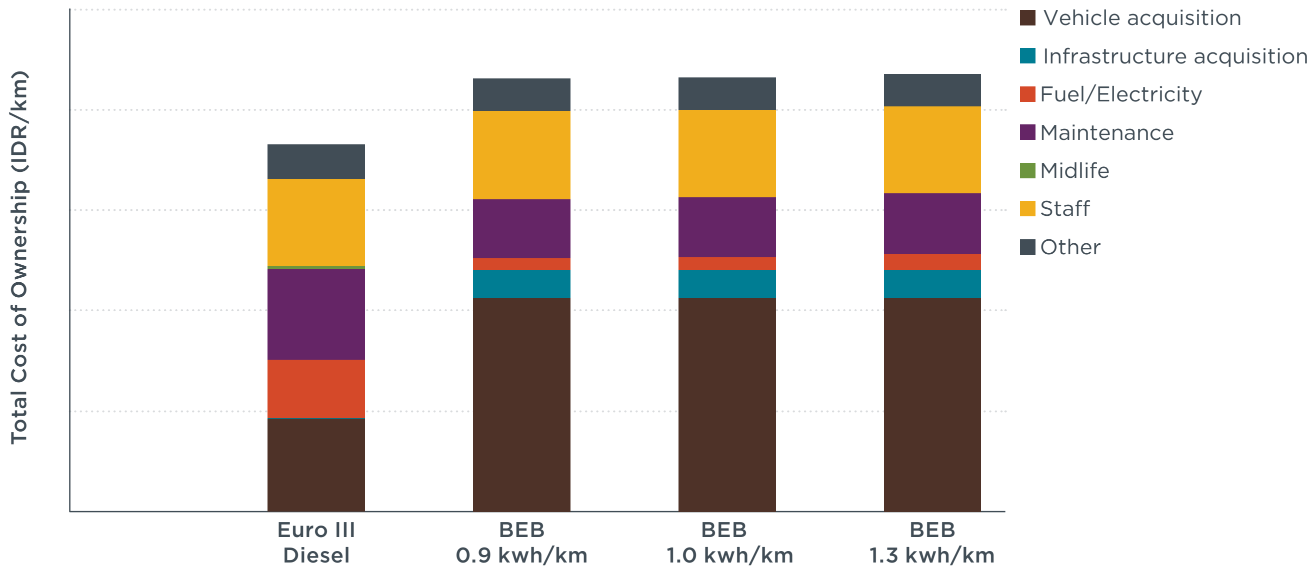
47 Xie, et al. (2023).

Energy consumption

Energy consumption varies by e-bus type and operational conditions. For example, the manufacturer BYD claims on its technical specification brochures that the 12m K9 e-bus consumes energy at 1.3 kWh/km.[48] However, data collected by Transjakarta shows that, in practice, the K9 bus consumes an average of 1.0 kWh/km; in contrast, the K9 bus operating in Santiago consumes 1.5 kWh/km.[49] Variations can be the result of different driving dynamics (average route speed, acceleration, number of stops), topography (road grade changes), passenger loading conditions, and air-conditioning use.

For example, according to ICCT research, passenger loading conditions can increase energy consumption on a 12m bus between 6–19% and air conditioning use can increase energy consumption between 13–29%.[50] To measure the impact of energy consumption variability in TCO/km results, we evaluated three cases of energy consumption: 0.9, 1.3, and 1.5 kWh/km (see Figure 8).

Energy consumption variation has a 1–2% impact on TCO/km. However, energy consumption greatly impacts e-bus charging strategies and route selection (these require detailed technical analyses).



Ratio to baseline diesel		**1.18**	**1.19**	**1.20**

Figure 8. Energy consumption impact on TCO/km

48 BYD Company Limited, "BYD K9 Economic Benefit Shenzen Case since 2011," https://e-katalog.lkpp.go.id/katalog/produk/detail/1490143.

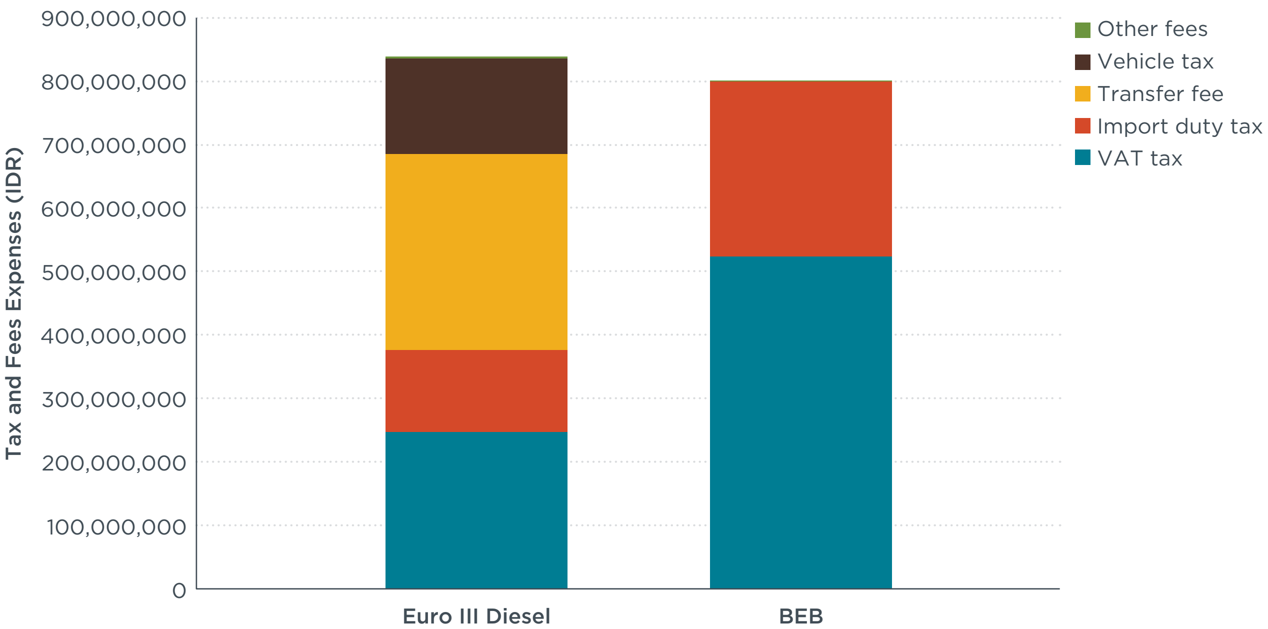
49 Ministerio de Transportes y Telecomunicaciones (2014), Resultados Consumo / Eficiencia Energética Buses Transporte Público Urbano Ciudad de Santiago Motor Eléctrico, https://www.mtt.gob.cl/archivos/5597.

50 Dallmann, Tim, et al., "Strategies for Deploying Zero-Emission Bus Fleets: Route-Level Energy Consumption and Driving Range Analysis," (ICCT: Washington, DC, 2021), https://theicct.org/wp-content/uploads/2021/12/Deploying-zero-emission-bus-fleets-jun2021.pdf.

Fiscal incentives

Fiscal incentives can close the price gap between e-buses and conventional buses and promote e-bus adoption. Again, there are two kinds of taxes and fees for vehicles in Indonesia, one-time and annual use-phase. This section evaluates the impact of eliminating taxes and fees on e-buses. We calculated annual use-phase taxes and fees on a 7-year timeframe (see Figure 9).

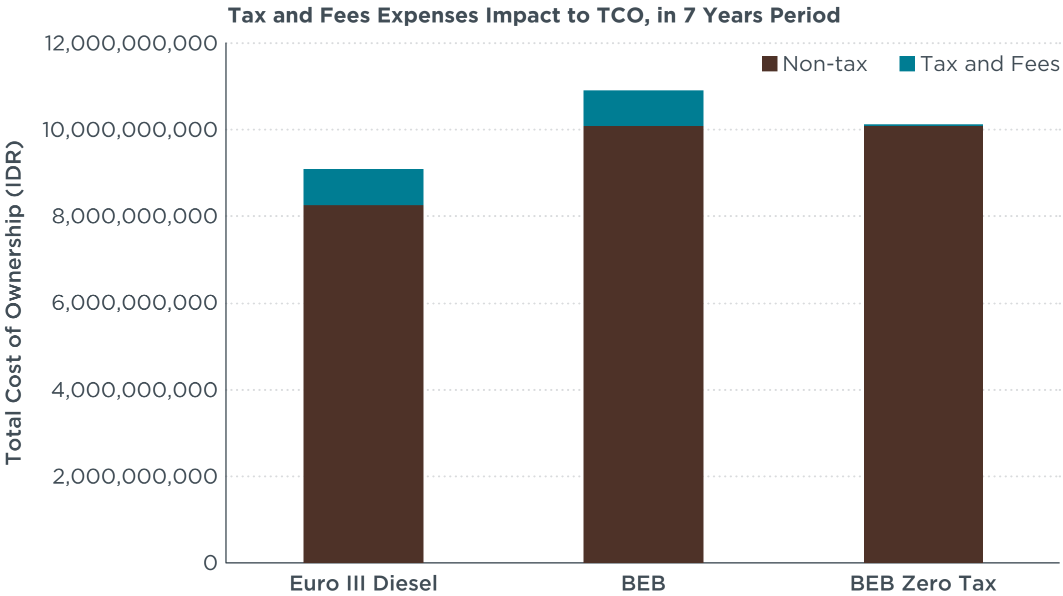
For public transport buses, VAT, import duties, transfer fees, vehicle taxes, retribution, and licensing fees are imposed. The most impactful e-bus taxes are import duties and VAT. Today, e-buses receive a 4% fiscal load benefit compared to conventional buses. This is driven by local exemptions provided by decree by Greater Jakarta's provincial government. For example, a provincial decree exempts e-buses from transfer fees and vehicle taxes. This lowers the fiscal load for e-buses compared to diesel buses. Other fees (road accident fund and vehicle test fees) contribute to 0.2% of TCO expenses.



Ratio to Baseline Diesel	0	0.96

Figure 9. Tax structure impact on diesel buses and BEBs over 7 years

Taxes and fees currently account for 11% of the TCO for diesel buses and 8% for e-buses. As Figure 10 shows, eliminating all taxes (which would require national policy action) would improve the TCO for e-buses by 9% (or around 800 million IDR) for the studied e-buses over a 7-year contract. Eliminating taxes could boost future BEB procurement.



Ratio to Baseline Diesel	**0**	**1.20**	**1.11**

Figure 10. Impact of tax and fees on TCO over 7 years

Conclusions and recommendations

Bus activity (i.e., VKT) impacts the financial picture of capital-intensive technologies like BEBs, which offer operational cost savings over conventional bus technologies. Relatively high BEB capital expenses, necessitate high utilization rates to make their TCO/km competitive with conventional technologies. Increasing annual utilization from 71,000 km/year to 80,000 km/year reduces the BEB TCO/km gap from 20% to 11%.

Fuel and energy price subsidies are critical to TCO/km evaluation. Under reference case conditions, currently subsidized energy prices offer a 9–10% TCO/km benefit with respect to unsubsidized energy price TCO/km evaluations. Removing diesel subsidies results in a 16–28% TCO/km increase for diesel buses, erasing the current TCO/km gap between diesel and BEB technology (at currently subsidized electricity prices).

A longer ownership period also reduces TCO/km across technologies, especially those with high capital investments. Again, high BEB utilization rates make their TCO/km more competitive. Utilization can be increased through extended contract periods or greater annual activity. The sensitivity of TCO/km estimates for each bus technology shows that extending ownership periods for BEBs from 7 to 10 years reduces TCO/km by 21%; extending contracts from 7 to 15 years reduces TCO/km by 44%. This longer 15-year contract places BEBs on a lower TCO valuation—by 20%—than the baseline diesel technology on a 7-year contract.

Taxes and fees account for an important 9–11% share of TCO. E-buses in DKI Jakarta Province benefit today from transfer fee and vehicle tax exemptions. For a 12m e-bus, that amounts to a 4% benefit compared to a similar diesel bus. By removing all national and local taxes and fees for BEBs, TCO would be reduced 9% compared to baseline diesel buses.

Recommendations

The results of the TCO and sensitivity analysis point to short- and longer-term policy and procurement recommendations.

In the short-term:

1. Adopt BEBs in routes with high operational demand to increase annual operation and reduce TCO. At 71,000 km/year, BEBs would require additional incentives to secure lower TCO than conventional buses. Increasing operation to 80,000 km/year would reduce the TCO/km gap with diesel buses but would require detailed technical and financial analysis to ensure that battery capacity can meet travel demand. These operational changes can be led by Transjakarta in coordination with operators.
2. Increase contract duration from 10 to 15 years for BEB operators to increase lifetime travel. This results in TCO/km values for BEBs below conventional technologies and follows international best practices. The MoT should consider issuing a ministerial decree to set 15-year contract durations for BEB operators; diesel bus contracts must remain at current 7-year terms. This offers a direct procurement incentive without fiscal penalties to national or regional budgets. Alternatively, provincial regulations could be updated to increase BEB contract durations from 10 to 15 years in DKI Jakarta Province.

In the medium- and long-term:

1. Because fuel and energy prices significantly impact TCO, the MEMR should consider removing diesel fuel subsidy prices and retain subsidies for electricity prices for public transit use. This action would erase the TCO gap between conventional and e-bus technology.
2. Extend and strengthen fiscal incentives that favor BEBs. The national government should consider revising the tax code to eliminate all taxes on BEBs imported and assembled in the country for public transit fleets across all provinces. At the same time, taxes should be raised on ICE buses, particularly since diesel and CNG engine emissions incur social costs (which can be monetized), such as respiratory and other health impacts that lower productivity and increase premature mortality. Thus, national budgetary savings from removing fuel subsidies and increased revenue from taxing conventional vehicles (based on their monetized societal impacts) could offset revenue lost from BEB tax exemptions. These national-level fiscal actions fall under the purview of the MoF; local taxes are set by regional governments in coordination with the Ministry of Home Affairs.
3. The national government, led by the MoT and MoF, could provide direct purchase incentives to public transit bus operators. Direct incentives are already being provided for private consumers of passenger cars and motorcycles. This measure could reduce the TCO between BEBs and conventional buses and increase demand for BEBs, supporting the national goal of accelerating EV production and urban adoption. These incentives could be funded through higher taxes on ICEs, elimination of diesel subsidies (repurposing allocated funds for EV acceleration), or carbon taxes in the long term.
4. Adopt Low Emission Zones and create transit restrictions for conventional buses. Traffic restrictions are among the main policy levers local government have to create demand for e-buses. Restricting the operation of polluting ICE vehicles increases the operational activity of BEBs, which also helps reduce TCO for BEBs. These measures can be phased in over several years to allow bus operators to scale up BEB fleets.