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Mainstreaming Electric Mobility: the Benefits, Barriers, and Business Case for Electric Buses in Indonesia

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EXECUTIVE SUMMARY

The transportation sector is locked in to a carbon-intensive pathway with heavy-duty vehicles responsible for substantial GHG emissions, air pollution, and road congestion. Bus fleet electrification presents a combination of technological readiness, environmental impact, and commercial viability to inspire deployment and set the stage for EV growth. This paper identifies 14 barriers to local e-bus adoption in Jakarta, Indonesia from the perspectives of technology, environment, economics, and policy. Chapter 1 establishes the links between urban transport, air quality, health, and energy within Jakarta's context. Chapter 2 reviews global e-bus market trends and technology options. The lack of domestic experience with e-bus and charging technology prevents initial deployment. Chapter 3 calculates the emissions, pollution, energy consumption, and subsidies related to ICE and e-buses. The results showcase the air quality improvement potential but highlight that grid emissions intensity restricts mitigation gains from the electric transition. Chapter 4 demonstrates how e-buses disrupt traditional bus transport economics. Uncertainties related to acquisition and operational costs as well as secondary market value hamper e-bus TCO and risk estimation. Chapter 5 examines the transport and EV policy framework, identifying limitations in existing regulation governing permits, processes, and incentives for e-buses. Based on in-person meetings, scholarly literature and case studies related to e-bus pilots around the world, the paper recommends 27 actions for stakeholders looking to address the 14 barriers to e-bus adoption in Jakarta. The research also supported the efforts of the Tropical Landscape Finance Facility and UN Environment in accelerating e-bus adoption in Jakarta. This analysis hopes to be pertinent for Jakarta and other metropolises across the world facing similar challenges of mainstreaming electric mobility.

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GLOSSARY OF ABBREVIATIONS

Term	Full form or description
ADB	Asian Development Bank
BNEF	Bloomberg New Energy Finance
BRT	Bus Rapid Transit
BYD	Build Your Dreams (a Chinese EV manufacturer)
C40	C40 Cities Climate Leadership Group
CNG	Compressed Natural Gas
CO_2	carbon dioxide
DKI Jakarta	Daerah Khusus Ibukota or Special Capital Region of Jakarta
EV	electric vehicles
GHG	greenhouse gas
ICE	internal combustion engine
IDR	Indonesian Rupiah
IEA	International Energy Agency
KPBB	Committee for the Phasing Out of Leaded Fuel (Indonesian NGO)
MAB	Mobil Anak Bangsa (Indonesian e-bus manufacturer)
MEMR	Ministry of Energy and Mineral Resources, Indonesia
MOU	Memorandum of Understanding
NDC	Nationally Determined Contribution
NOx	nitrous oxide pollutants
PLN	Perusahaan Listrik Negara (Indonesia's state-owned electricity company)
PM	particulate matter
PM2.5	particulate matter less than 2.5 micrometers in width
PPnBM	Luxury Vehicle Sales Tax
Presidential decree	The Presidential Decree on Acceleration of Battery-Based Electric Vehicles
SO_2	Sulphur dioxide
TCO	Total Cost of Operations
TTW	Tank-to-Wheel
WTT	Well-to-Tank
WTW	Well-to-Wheel

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CHAPTER 1: INTRODUCTION

MOTIVATION

The proliferation of fossil fuel-based public and private vehicles has made transportation the fastest growing source of CO_2 emissions and fossil fuel demand worldwide (Sclar et al, 2019). In 2015, vehicular emissions accounted for 7.5 billion tonnes of CO_2 representing 18% of all man-made emissions with IEA projecting up to 50% higher emissions from this sector by 2060 (Grütter & Kim, 2019). Switching the main power source of vehicles from fossil fuels to batteries is touted as a key innovation and megatrend aligned with decarbonizing transportation. While popular attention has focused on private electric vehicle (EV) adoption, the mitigation potential of electrifying public transport vehicles presents a major opportunity.

Representing just 11% of the global fleet, heavy-duty vehicles contribute almost half of CO_2 emissions and over two-thirds of PM emissions from vehicles (Kodjak, 2015). Urban buses alone account for 25% of black carbon emissions from road transport despite representing just 1% of the global fleet (Miller et al, 2017). There is rapid technological advancement in battery technology, charging infrastructure, and resource efficiency of e-buses, improving feasibility and affordability. Cities around the world are preparing roadmaps for future mobility transitions with e-bus deployment. However, e-bus implementation involves different commercial models, stakeholder interests, and institutional structures. It may also face impediments related to costs, infrastructure, and policies.

This paper will review the technology, evaluate the environmental impact, dissect the economics, and examine the policy framework influencing e-bus adoption in Jakarta. Each chapter probes the major barriers facing local stakeholders and suggests recommendations based on primary and secondary research. Primary information was collected over eight in-person meetings with senior leaders from TransJakarta, operators, and an NGO, in addition to mobility team representatives from the DKI Jakarta Governor's Office, UN Environment Programme, and UNDP from June to August 2019. Secondary information is from scholarly literature on e-mobility innovation and case studies. This analysis hopes to be pertinent for Jakarta and for other metropolises across the world facing similar challenges of mainstreaming electric mobility.

INDONESIA & JAKARTA

Indonesia is one of the world's ten largest GHG emitters, making it critical to global mitigation efforts. Road transport accounted for 25% of national emissions in 2017 producing nearly 125 million tonnes of CO_2 (IEA Global EV Outlook, 2019). Jakarta, the nation's capital of 10 million people, accounts for over 40% of national auto sales (Cochrane, 2015). Like in other mega-cities, urban livability and public space is scarce, leading to notorious road congestion, with a recent claim that Jakarta has the world's worst traffic (van Mead, 2016). This has contributed to Jakarta being declared one of the most polluted cities in the world and the most polluted city in Southeast Asia (Greenpeace International, 2019). Road transportation is responsible for over 70% of the city's air pollution with 58% of all illnesses among the city's residents related to air pollution (Cochrane, 2015). With worsening traffic, pollution, and health problems, clean mobility solutions are central to achieving sustainable growth in Jakarta.

THE TRANSJAKARTA SYSTEM

Jakarta is home to the world's largest public bus system, with 800,000 commuters using the TransJakarta Bus Rapid Transit (BRT) per day (ITDP, 2019). Launched in 2004 as Southeast Asia's first BRT system, it is now the world's longest, covering over 244 kilometers. As of 2019, the 3,334-strong fleet comprised 1,849 diesel buses, 1,145 gasoline buses, and 340 CNG buses of all sizes. Jakarta's BRT system has been hailed for successes in creating dedicated busways, integrating with paratransit, and maintaining an affordable fixed fare of IDR 3,500 (US$0.25) per ride since 2004. It remains an important symbol of the city's growth, with a 23% increase in passengers over the last three years (Andapita, 2019).

RECENT DEVELOPMENTS

There are indications that Indonesia is moving to support electric mobility to improve air quality, reduce GHG emissions, and grow automotive manufacturing. The government unveiled the Presidential Decree on Acceleration of Battery-Electric Vehicles in August 2019. Multiple auto manufacturers like Hyundai and Toyota have announced investments in EV manufacturing. Indonesian companies MAB and Gesits have unveiled locally manufactured prototypes of e-buses and e-motorcycles respectively. Several pilots are being conducted to test EV operations and costs with BlueBird taxis, Go-Jek motorbikes, and TransJakarta buses in Jakarta's public transport ecosystem.

The nascent EV industry would benefit from technical guidance, environmental impact evaluation, improved financing, and policy support to accelerate EV deployment.

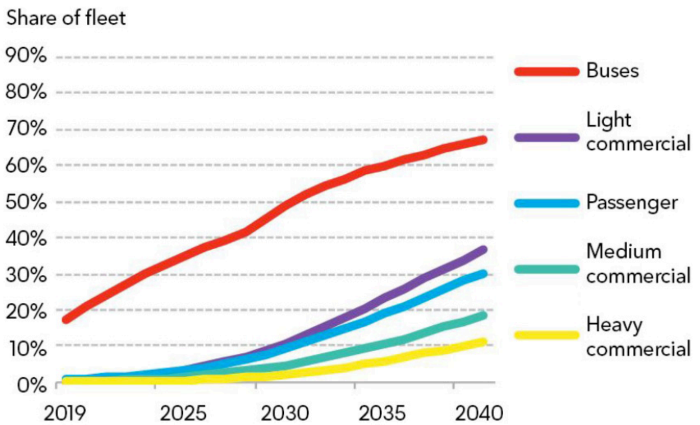
CHAPTER 2: TECHNOLOGY

MARKET LANDSCAPE

The global e-bus market grew 32% in 2018 to reach 425,000 vehicles. Over 99% of these are in China, with dozens of other countries conducting e-bus pilots. There are over 50 e-bus models, primarily single and medium size, from at least 23 manufacturers in the global market. Chinese manufacturers BYD and Yutong have large domestic and international market shares. European, North American, and Indian e-bus-makers are active in limited geographies.

Bus transit has several characteristics which make it impactful to electrify in metropolises: fixed operations, high mileage, high energy consumption, and the lock-in nature of public transport investment. Buses are predicted to be the fastest vehicle to transition to electric powertrains — over 70% of all buses will be electric by 2040 (BNEF, 2019). Three-quarters of all e-buses are likely to be in Asia-Pacific, with China and India taking the lion's share (Mahmoud et al, 2016).

Figure 1: % share of global vehicle type which will be EVs



(Source: BNEF, 2019)

VEHICLE BATTERY

Fully electric buses are powered solely by electricity stored in an on-board battery, rather than internal combustion of fossil fuels.[1] Most e-buses use lithium-ion batteries, a technology making rapid improvements in battery range, cost, and energy efficiency. Commercial models advertise ranges between 100 to 400 kilometers per charge depending on size and battery type. In contrast to ICE buses, e-buses do not produce any local tailpipe emissions and emit significantly less noise at all speeds.

BARRIER 1: Lack of awareness of e-bus technology and benefits

With scant global literature on operational performance or large-scale implementation, TransJakarta, operators, and government officials face knowledge limitations and harbor doubts about battery technology. Many single-size e-bus models claim a range of 250km per charge. This may be theoretically sufficient for overnight charging models as TransJakarta's buses, which cover 200 to 237 kilometers per day, but will not allow for a buffer battery charge of 20%. Stakeholders have range anxiety and are wary that battery range will reduce as e-buses age. Government representatives acknowledged in an interview that there is very little public awareness about the technology and impact of e-buses versus ICE buses.

RECOMMENDATIONS

- **Conduct operational trial:** A comprehensive operational trial of e-buses in Jakarta will reduce uncertainty by generating data on battery and vehicle performance in local conditions. TransJakarta should develop clear metrics and evaluation processes for this trial. Bogotá's trials revealed design compatibility issues which required additional maintenance and customization for local deployment (Sclar et al, 2019).
- **Access global data and best practices:** Manufacturers can share evidence of e-bus performance, operational impact, and warranties from other countries to assuage doubts of local stakeholders. Jakarta must also engage groups like C40 to contribute to and gain from e-bus implementation learnings. At this early stage, cities should emulate successful programs, avoid repeating mistakes, and gain efficiencies from collaboration.
- **Run awareness campaigns:** The benefits and limitations of e-buses should be publicized regularly, targeting influential sections of society like government officials, operators, NGOs, and commuters. Increasing awareness of e-bus technology can allay stakeholder apprehensions, generate global partner interest, and accelerate pilot programs.

CHARGING INFRASTRUCTURE

Slow chargers can be deployed at bus depots, as they take 3–6 hours to fully charge e-bus batteries, depending on model and size. Fast chargers can generate charge in a few minutes en route or at depots but require higher capacity electricity connections at bus stops. TransJakarta needs to collaborate with PLN, the state-owned electricity distribution monopoly, to plan charger deployment.

1This paper will focus on fully-electric buses, referred to as electric buses or e-buses, and will not consider hybrid buses or trolleybuses in the analysis.

BARRIER 2: Lack of standards on charging technology

There are no regulations governing technical standards or usage of charging infrastructure in Indonesia. Parties expressed concern that the absence of regulation will lead stakeholders to develop isolated standards lacking interoperability. Preliminary meetings have revealed differences in compatibility, cost, and availability across commercial offerings. Operators are hesitant to invest or purchase vehicles that may result in technology lock-in. Manufacturers are wary of regulations favoring one standard over another.

RECOMMENDATION

- **Conduct technology study on EV charging standards:** Stakeholders within and outside government can undertake a comprehensive review of charging technology. The Agency for the Assessment and Application of Technology (BPPT) is said to be initiating this effort. This study should assess scope for optimization amongst providers and compatibility between different types of EVs for public infrastructure. Following this review, the government should clarify regulation to reduce uncertainty, promote investment, and enable collaboration between stakeholders to deploy charging infrastructure.

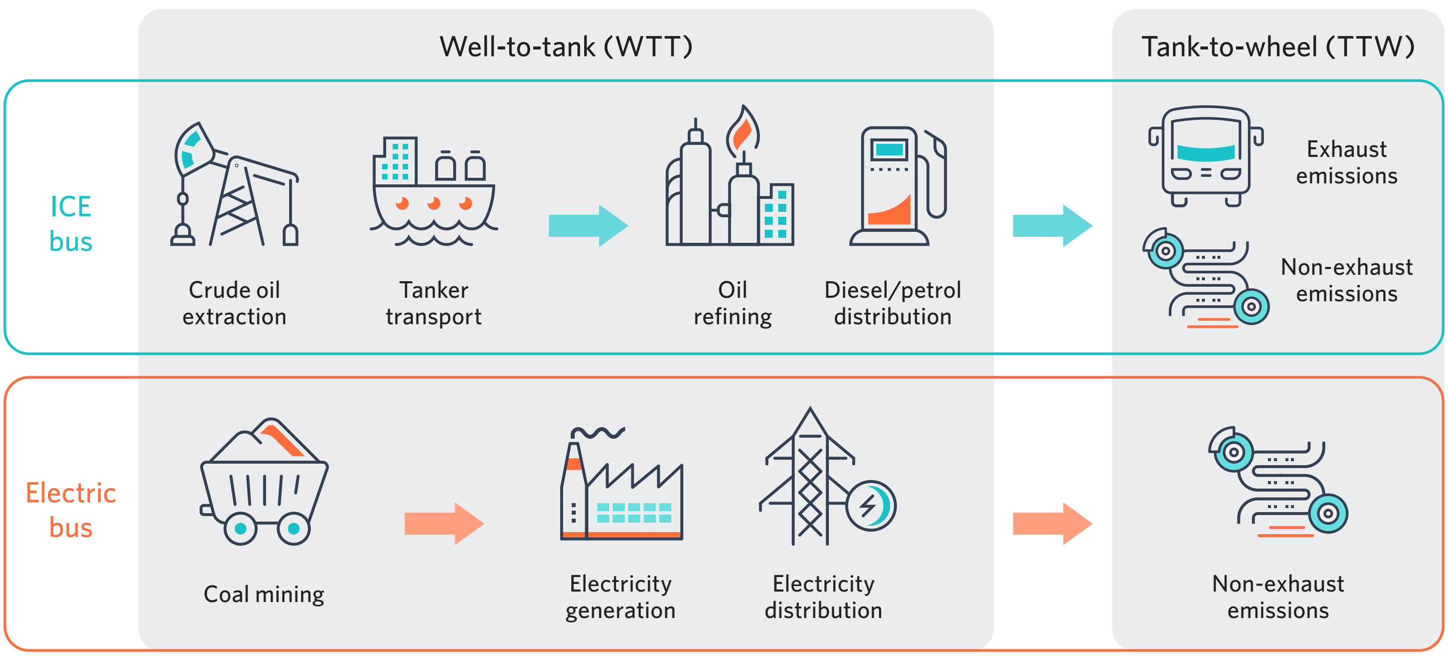
CHAPTER 3: ENVIRONMENT

This chapter calculates the CO_2, NO_x, PM, and SO_2 emissions from TransJakarta's bus fleet of 3000+ buses and BYD e-buses. The emissions analysis uses a micro-level approach with TransJakarta operational data and local assumptions on fuel and electricity. The data is extrapolated to estimate fuel demand changes and subsidy savings from e-bus deployment.

METHODOLOGY

Transportation sector emissions consist of GHGs emitted in the fuel lifecycle from fossil fuel wells to tailpipe, typically referred to as Well-to-Wheel (WTW) emissions. This can be broken down into two sub-ranges. Traditionally, Well-to-Tank (WTT) includes emissions caused by refining and distribution processes for diesel, gasoline, and CNG, whereas the Tank-to-Wheel (TTW) incorporates combustion emissions from exhaust pipes as well as non-exhaust emissions from vehicle operations. For EVs, WTT comprises emissions from electricity generation and distribution, whereas TTW includes only non-exhaust emissions as there are zero exhaust emissions (Dallmann et al, 2017).

Figure 2: Well-to-Wheel emissions lifecycle for bus transport



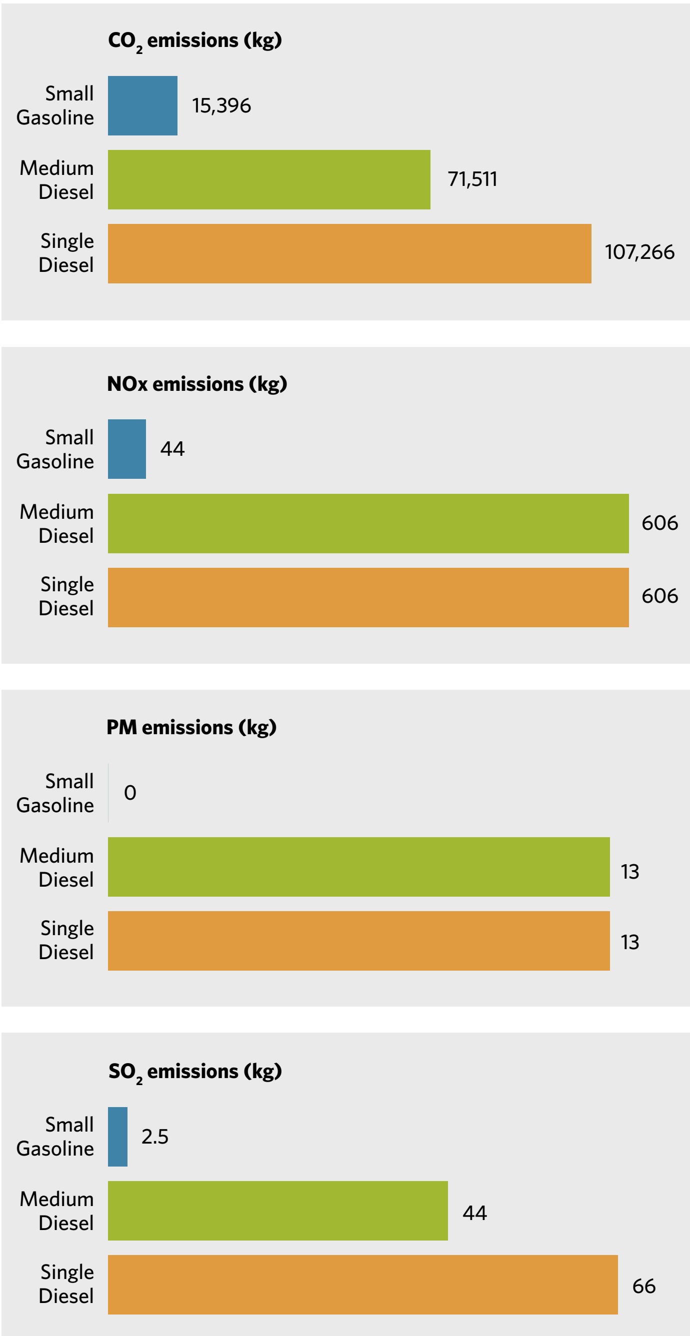
In this paper, GHG emissions from bus transport are estimated using the Activity-Structure-Intensity-Fuel (ASIF) approach (Schipper & Marie-Lilliu, 1999). The assumptions are listed in the Appendix.

- Level of travel activity (A): annual kilometers travelled per bus
- Bus fleet structure (S): bus vehicle population disaggregated by size and fuel type
- Fuel intensity (I): average fuel consumption disaggregated by size and fuel type
- Carbon content of the fuel or emission factor (F): CO_2, NO_x, SO_2, and PM emissions factors of diesel, CNG and gasoline fuels as well as grid electricity and heat production

RESULTS

Urban air pollution and health impact

Figure 3: Annual local exhaust emissions per ICE bus in Jakarta (scale varies by emission type)



This paper estimate that each single diesel bus emits 107 tonnes CO2, 606kg NOx, 13kg PM, and 66kg SO2 per year. TransJakarta's single, medium, and small fleet annually emits 187,000 tonnes CO2, 1,051 tonnes NOx, 21 tonnes PM, and 97 tonnes SO2 through exhaust pipes. Combustion emissions would decrease to zero with e-buses, making a compelling case for adoption from an urban air quality perspective.

This paper does not attempt to estimate value of health costs or hypothetical savings, though Miller et al (2017) estimate US$93 in health savings per ton of CO2 mitigated. Grütter & Kim (2019) categorize the pollution costs faced by Indonesia under the moderate category which entails \$630-\$3,000/ton of sulphur, \$130-\$640/ton of NOx, and \$18,000-\$80,000/ton of PM2.5 emissions. These figures illustrate the magnitude of health benefits Jakarta stands to gain from e-bus deployment by reducing urban exhaust emissions to zero.

Emissions impact

Table 1: Annual well-to-wheel emissions savings of switching buses from ICE to electric powertrain

PER TRANSJAKARTA BUS

	Unit	Single diesel	Single CNG	Medium diesel	Small diesel	Small gasoline
Bus	count	1	1	1	1	1
CO_2	tonnes	38	126	39	8.2	8.6
	kg/km	0.44	1.46	0.45	0.11	0.12
NOx	kg	275	275	434	37	8
PM	kg	-82	-88	-37	-5	-10
SO_2	kg	-651	-717	-330	-69	-75

TRANSJAKARTA BUS FLEET

	Unit	Single size	Medium size	Small size	Total
Bus	count	1242	410	1145	2797
CO_2	tonnes	55,544	15,792	9,855	81,190
NOx	tonnes	342	178	10	530
PM	tonnes	-103	-15	-12	-130
SO_2	tonnes	-815	-135	-86	-1,036

Each single e-bus deployed instead of a diesel bus would annually displace 38 tonnes of CO2 and 275kg of NOx but increase emissions of PM by 82kg and SO2 by 651kg as diesel fuel is replaced with Indonesia's fossil fuel-powered grid. Assuming a 12-year vehicle life, this amounts to 455 tonnes CO2 and 3.3 tonnes NOx reductions but an additional 1tonne PM and 7.8 tonnes SO2. Electrifying the entire TransJakarta single, medium, and small fleet would decrease 81,000 tonnes CO2 and 530 tonnes NOx but add 130 tonnes PM and over 1,000 tonnes SO2 emissions per year. The pollution would shift from dense urban areas with high health impact to areas surrounding power plants. These results demonstrate that e-buses have the potential to substantially reduce CO_2 emissions, urban air pollution, and health costs, but have mixed impacts on non-CO_2 emissions.

The emissions reduction potential of e-buses has been studied in various pilot programs, but the local assumptions behind each study vary widely, limiting direct comparisons. Each e-bus annually displaces 356 tonnes of CO_2, 28kg NOx, and 26kg PM emissions in Shanghai, 64 tonnes of CO_2 in Shenzhen and 140 tonnes of CO_2 in the USA (Aldama, 2019; Li et al, 2019; Persichini, 2018). Analyses in fossil fuel-dependent countries like India, Mexico, and South Africa show GHG emission reductions of 48 tons, 76 tons, and 400 tonnes of CO_2 respectively per year per e-bus. ICCT estimates that over a vehicle's life, e-buses can eliminate 500 tonnes of CO_2e in regions with high carbon intensity grids like Indonesia (Dallmann et al, 2017).

Energy consumption and subsidy impact

Table 2: Annual energy consumption and subsidies of TransJakarta bus fleet

PER TRANSJAKARTA BUS

	Unit	Single diesel	Medium diesel	Small diesel
CNG bus	Lge	96,117	N/A	N/A
Gasoline bus	Lge	N/A	N/A	6,636
Diesel bus	liters	40,160	26,773	5,648
Diesel subsidy @ IDR 2000/liter	Total (million IDR)	80.3	53.5	11.3
	Total (US$)[a]	5,751	3,834	809
e-bus	kWh	112,110	58,391	12,167

TRANSJAKARTA BUS FLEET

	Unit	Single diesel	Medium diesel	Small diesel	Total
CNG bus	Count	96	N/A	N/A	96
	Lge (millions)	9.2	N/A	N/A	9.2
Gasoline bus	Count	N/A	N/A	1,103	1,103
	Lge (millions)	N/A	N/A	7.3	7.3
Diesel bus	Count	1,146	410	42	1,598
	liters (millions)	46.0	11.0	0.24	57.2
Diesel subsidy @ IDR 2000/liter	Total (IDR billions)	92.0	22.0	0.47	114.5
	Total (US$ millions)[a]	6.6	1.6	0.03	8.2
e-bus	Count	1,242	410	1,145	2,797
	MWh	139,241	23,940	13,931	177,112

a US$ 1 = IDR 13,966.5 (Bloomberg, 2019)

Every single-size e-bus would displace over 40,000 liters of diesel consumption per year, with corresponding figures around 27,000 liters per medium e-bus and 5,600 thousand per small e-bus. Electrifying the entire TransJakarta fleet would reduce diesel consumption by over 57 million liters and increase electricity consumption by 177 MWh annually.

Indonesia's cetane 48 diesel subsidies of IDR 2000/liter amount to US$5,751 per single bus, US$3,834 per medium bus, and US$809 per small bus annually. There is no direct subsidy for CNG or gasoline fuel. This means over US$8 million is spent annually to subsidize fuel for TransJakarta's diesel fleet. As electricity for EV charging is not subsidized, these fuel subsidies will result in fiscal savings for every e-bus replacing a diesel bus. The national government should account for these savings while determining potential subsidies for e-buses.

DISCUSSION

Unaccounted in the above results are several factors including operating conditions, non-exhaust emissions, upstream manufacturing emissions, fuel composition, and grid emissions intensity. Local variations in these factors influence actual GHG emissions, precluding direct comparisons of results from different studies. The implications of each of these variables are examined below and can help guide TransJakarta e-bus feasibility study design.

Operating conditions

The emerging literature points to significant variation in operational efficiency between actual and lab-test energy efficiency figures due to traffic conditions, passenger load factor, weather, air-conditioner usage, and vehicle age. Regenerative braking technology helps e-buses reduce energy consumption in traffic (Gao et al, 2017). Passenger loads determine energy consumption in all buses and tailpipe emissions in ICE buses. Jakarta's temperate climate precludes any impact of colder weather, though heat, humidity, and rain could impact battery performance, while air-conditioning usage increases energy consumption (He et al, 2018). Finally, ICE and e-buses become less energy efficient over time, and the age-mix of TransJakarta's existing fleet is not clear. These conditions will directly impact e-bus energy consumption and WTT emissions.

Non-exhaust PM emissions

This paper calculates combustion-related TTW emissions of ICE buses, ignoring non-exhaust PM emissions from abrasion of brake, tire, and suspension components during operations. Jakarta's traffic and road conditions will determine the magnitude of such emissions. Electric bus batteries may have higher tire and road wear-related PM emissions due to increased weight, though regenerative braking may reduce brake-related emissions in e-buses relative to ICE buses.

Grütter & Kim (2019) acknowledge the lack of data but posit that EVs may have lower non-exhaust emissions than ICE vehicles in Asia due to the large impact of regenerative braking technology.

Upstream manufacturing emissions

Outside the well-to-wheel cycle, vehicle manufacturing also results in GHG emissions, particularly as Indonesia aspires to become a regional EV manufacturing hub exploiting domestic deposits of nickel laterite ore, a key ingredient of lithium-ion batteries. Overall, upstream manufacturing emissions may account for only 5–10% of total GHG emissions of e-buses, depending on the grid emissions factor (Grütter & Kim, 2019). Second-life battery usage reduces the environmental damage associated with the vehicle lifecycle, but also highlights the importance of establishing secondary markets for e-bus batteries to reduce waste, environmental damage, and GHG emissions. Accounting for manufacturing emissions and second-life battery usage, e-buses will continue to have lower GHG emissions compared to ICE buses (Grütter & Kim, 2019).

Fuel composition

Indonesia's cetane 48 diesel has 2500ppm sulphur content, well above the Euro 2 standard of 500ppm. Increased sulphur can increase PM and NOx emissions, resulting in possible underestimation of these two pollutants (Wagner & Rutherford, 2013). The government's commitments for 500ppm fuel SO_2 content from 2021 and 50ppm from 2025 would reduce SO_2 emissions from diesel transport (Transport Policy, 2018). Diesel is mandated to contain 20% palm biodiesel blend, with plans to increase to 30% in 2020, though there have been concerns on compatibility with the current fleet (Searle & Bitnere, 2018). This paper uses pure diesel emission assumptions and does not account for biodiesel blend due to the lack of available emissions data. There is evidence that palm biodiesel blends increase NOx and PM pollutants but reduce sulphur and carbon monoxide emissions relative to diesel fuel (Searle & Bitnere, 2018).

Grid emissions intensity

The WTW mitigation potential of e-buses varies dramatically across countries as the gains from eliminating exhaust emissions needs to offset the increase in electricity generation emissions. Wu & Zhang (2017) suggest that WTW CO_2 emissions and energy consumption of EVs in China are much higher than those in Japan. They also find that EVs increase SO_2 emissions in China, India, USA, and Japan – similar to the results in this paper. However, several studies corroborate that e-bus deployment can reduce CO_2 emissions despite high carbon intensity grids. The estimated emissions reductions of e-buses relative to diesel buses range from 25–35% in high-carbon intensity grids to 50–85% in low-carbon intensity grids (Dallmann et al, 2017).

BARRIER 3: Grid emissions reduce e-bus mitigation gains

Indonesia's electricity generation sector, powered by coal (56%), gas (25%), and oil (8%), is a major barrier to realizing higher mitigation potential of e-buses (Purwanto, 2019). This analysis assumes a carbon intensity of 0.81 $kgCO_2/kWh$ in Indonesia (Grütter & Kim, 2019). Indonesia's coal plants operate subcritical technology with high non-CO_2 emissions, explaining the substantial increase in PM and SO_2 emissions with e-bus deployment in Table 1. Table 3 underscores that emissions standards for coal-fired power plants remain several times worse than even other coal-dependent developing countries like India and China.

Table 3: Selected countries' emission standards for coal plants

Country	PM (µg/m3)	SOx (µg/m3)	NOx (µg/m3)
Indonesia	100	750	750
Japan	50	200	200
India	30	100	100
China (hourly)	10	35	50
US (daily)	12.3	136	95.3
EU (continuously)	10	150	150

Source: OECD, 2019

RECOMMENDATIONS

- **Increase renewable energy share of grid production:** Indonesia has ambitious plans to obtain 23% of national energy from renewable sources by 2025, though OECD (2019) finds that it is not on track to meet this target. Purwanto (2019) simulates that by achieving its 2025 target, Indonesia's grid carbon intensity would come down to 0.54 $kgCO_2/kWh$, bolstering the environmental case for e-buses by decreasing WTW emissions substantially. The Jakarta Governor's 2019 directive to promote rooftop solar in schools and public institutions can serve as precedent to evaluate the feasibility of renewable energy microgrids near depots for e-bus charging.
- **Stricter controls on non-CO_2 grid emissions:** The slow pace of grid decarbonization will adversely impact CO_2 mitigation potential of EVs in the near-term. Controlling PM, SO_2, and NOx pollution before, during, and after coal combustion is critical to prepare for EV deployment. Indonesia can update emissions standards for coal plants. It can also implement gasification, flue gas desulphurization, low-NOx burners, electrostatic precipitators, fabric filters, and carbon capture and storage technologies, which reduce various air pollutants from coal plants. These have to be strictly enforced to show measurable impact.

CHAPTER 4: ECONOMICS & FINANCING

BUS ECONOMICS

Electric buses have higher acquisition costs, but lower operational and maintenance costs than ICE buses. Multiple studies present evidence of lower e-bus total cost of operations (TCO) relative to CNG and diesel counterparts in countries as diverse as India and Italy (Conti et al, 2017; Mohamed et al, 2018; Saini & Sarkar, 2018).

In Jakarta, all bus costs are borne by operators, who get reimbursed a fee per kilometer by TransJakarta. The fee, meant to cover costs plus provide a margin, is reset every year to account for inflation and fuel prices for the duration of the contract. With a fixed passenger fare of IDR 3,500 (US$0.25) per ride limiting revenue, regional government subsidies are thought to generate up to 75% of TransJakarta's budget. The role of new stakeholders like utilities, financiers, and manufacturers, along with the changes in fuel and technology, mean that the business model of e-bus operations will differ from traditional models. This brings substantial barriers related to economics and financing of e-buses in Jakarta. The profitability and cash flow of each stakeholder needs to be scrutinized to make a clean-tech transition financially and operationally viable.

ACQUISITION COSTS

Electric bus acquisition costs can be broken down to its battery (40-50%), electric powertrain (20%), and other vehicle components (30-40%) (Grütter & Kim, 2019). Electric buses of all sizes are currently more expensive to purchase than diesel, CNG, or gasoline counterparts.

BARRIER 4: Acquisition costs are high with several uncertainties

TransJakarta has not released e-bus technical specifications such as vehicle dimensions, battery size, floor height, and other characteristics, which may significantly impact e-bus acquisition costs. Regardless of specifications or taxes, e-buses are costlier to purchase than ICE buses. This is the most cited barrier for potential customers in multiple cities (Grütter & Kim, 2019; Kraweic et al, 2016; GGGI & STEP, 2016). In Jakarta, acquisition cost estimates for a single-size e-bus ranged from IDR 3.5 billion to IDR 5.5 billion (US$250,000-US$400,000) depending on the manufacturer and specifications, compared to approximately IDR 2 billion (US$140,000) for a single-size diesel bus. Manufacturers and TransJakarta are aware that these cost ranges make it difficult for operators to purchase e-buses without innovative financing mechanisms.

Finally, e-bus prices are projected to rapidly fall every year due to advancements in battery capacity, density, range, efficiency, and manufacturing costs, causing further uncertainty (Grütter & Kim, 2019). Operators around the world are delaying e-bus purchases in the hope that acquisition costs reduce to improve their economics versus diesel buses. Battery costs may plunge to just 8% of the total e-bus price, enabling e-buses to reach upfront cost parity with diesel buses by 2030 (BNEF, 2019)

RECOMMENDATIONS

- **Clarify e-bus technical specifications:** The Ministry of Transportation and TransJakarta should release technical specifications for public transport operations of e-buses as soon as possible. This will reduce uncertainty around product requirements, enabling manufacturers to approach the market with specific models. Fiscal incentives can then be determined based on the e-bus models required, giving further price clarity to operators, financiers, and manufacturers.
- **Subsidize acquisition costs:** Most e-buses in operation globally were purchased with national or local grant support. Chinese cities have relied on subsidies to make e-buses more affordable. Recent policies in the U.K. and India also use this tool to incentivize the transition. Manufacturers and operators in Jakarta request allocations to be set in the government budget to subsidize e-bus manufacturing and purchase.

BARRIER 5: Dearth of upfront financing mechanisms

Miller et al (2017) posit that financial institutions can accelerate the e-bus transition by considering the operational lifecycle of the income-generating asset, rather than the traditional approach of assessing ability to repay capex amount. Government authorities and manufacturers also play a role in developing evidence and mitigating financial concerns. The lack of innovative long-term financing restrained Madrid's transit agency from scaling a series of e-bus pilots (Sclar et al, 2019). In Jakarta, banks are unable to conduct appropriate risk assessment without evidence of cost savings and without confidence in technology operations. Manufacturers claim more operational data and regulatory clarity is required to showcase how lower operational and maintenance costs reduce TCO in Jakarta. Operators are unable to proceed with further purchases without adequate low-cost financing.

RECOMMENDATIONS

- **Government guarantees on loans:** Full or partial government guarantees or take-over clauses on operator e-bus loans can lower the credit risk to financing companies (Miller et al, 2017). One manufacturer suggested that national or regional governments can incentivize lower interest rates from state-owned banks by issuing guarantees.
- **Access international development finance:** Grants, concessional loans and guarantees can help run feasibility studies to develop evidence and boost investor confidence. In Bogotá, a concessional loan for e-buses was leveraged to crowd-in commercial co-financing. Chile is looking to structure financing alongside the GCF with the ambition of converting 25% of Santiago's bus fleet to electric (Miller et al, 2017). After feasibility studies address the uncertainties and risks, Indonesia can consider approaching the World Bank and ADB for development loans to facilitate the clean-tech transition.
- **Design lease-based financing mechanism:** Lease financing can reduce operational and technology risk, distribute financial costs over time, present investment opportunities for capital providers and shift end-of-life battery risk to manufacturers, who can arrange for secondary use.

  Manufacturers could work directly with operators to design lease contracts, including service or maintenance clauses to generate additional revenue and improve performance. Park City negotiated a model with Proterra with fixed payment commitments to lease batteries over a 12-year contract period, lowering battery performance risk (BNEF, 2018). Bogotá opted to lease e-bus batteries from suppliers based on distance travelled to reduce technology risk.

  Manufacturers could also partner financial institutions to offer specialized financial products. BYD and China Development Bank partnered to launch the 'Zero Vehicle Purchase Price' program whereby bus operators can choose to replace upfront payments with installment payments through a financial lease, operational lease or buyer's credit (Krivevski, 2012). Mitsui and Arup Group's lease model increased confidence for all parties, protecting the operators from loss, while moving the commercial risk and profits to the enabling company (Miles & Potter, 2014).

OPERATIONAL COSTS

Electric bus operational costs vary globally, but are touted to be significantly lower than those of ICE buses. ICE buses incur fuel and maintenance costs during their lifetime, whereas e-buses incur electricity tariffs, maintenance, as well as expenses associated with charging station setup and operations. Saini & Sarkar (2018) suggest that e-bus operational costs per kilometer are 9% lower than for ICE buses in India. BNEF (2018) asserts that cost competitiveness of e-buses relative to diesel buses dramatically improves when annual mileage crosses 80,000 kilometers. TransJakarta's high mileage operations offer potential gains to cost competitiveness, though domestic prices, markets, and other local factors will determine actual operational costs.

BARRIER 6: Operational and maintenance costs are uncertain

Electricity prices are heavily regulated in Indonesia, segmented by category. EV charging falls under a bracket priced at IDR 1,467 (US$0.10) per kWh. The presidential decree hints at preferential rates for EVs, but no new rate has been announced. Manufacturers in Indonesia are unable to share warranty periods or local maintenance costs, causing uncertainty for TransJakarta and operators on the lifespan of the battery and vehicle. Electric bus batteries are expected to last seven years, though this would depend on operating conditions (BNEF, 2018). Electric buses require the purchase of a replacement battery during their commercial lifetime. This investment is the second-most important financial parameter in determining the TCO, though it remains uncertain how much used or new batteries will cost in the mid-2020s (GGGI & STEP, 2016). TransJakarta, manufacturers, and operators are unable to calculate e-bus TCO because of these gaps in knowledge of operational and maintenance costs.

RECOMMENDATIONS

- **Set preferential electricity tariffs for public transport EVs:** The Ministry of Energy & Mineral Resources (MEMR) and PLN can set preferential tariffs for public transport buses and taxis, accounting for fossil fuel subsidy savings as well as health and air quality benefits. Existing tariff discounts provided during off-peak hours of 10pm–4am will further incentivize overnight charging of e-buses like in China (Aldama, 2019).
- **Clarify local maintenance costs:** Manufacturers and international organizations should provide estimates of e-bus maintenance costs. The automobile association Gaikindo and the government can organize a visit to Shenzhen, China for TransJakarta, operators, and city authorities to learn from their counterparts' experience. Running a comprehensive feasibility study will also help determine energy consumption, efficiency, and maintenance costs of the vehicles.

- **Allow advertising on e-buses as a secondary revenue stream:** Miller et al (2017) highlight that bus advertising enhances the e-bus value proposition and revenue for operators. However, few buses in Jakarta's busways display advertisements. There appear to be contractual delays in permitting this as a secondary revenue stream, despite operator contracts specifying advertising revenue-sharing with TransJakarta. With 800,000 passengers per day in the city, TransJakarta bus advertising can be lucrative for private companies, while generating additional income to improve e-bus economics.

BARRIER 7: Costs of charging infrastructure setup and operations are uncertain

Electric bus operations bring added costs of installing and operating charging stations. Installations may require permits as the regional government owns the land assets on which TransJakarta operates. Shenzhen had to postpone e-bus scaling plans because of delays in urban land acquisition for charging infrastructure (Sclar et al, 2019). The costs of purchasing and installing new sub-stations with high-tension cables and activating new electricity connections mean additional upfront financing requirements to deploy e-buses even before operations commence. Philadelphia's transit agency found that procurement and installation of pilot charging stations totaled over US$1 million, leading the agency to reduce the size of its pilot from 25 to 10 e-buses (Sclar et al, 2019).

RECOMMENDATION

- **Clarify costs associated with charging stations:** TransJakarta should initiate engagement with PLN on behalf of the industry to clarify each line item of installation and operational costs. In addition to optimizing charging station setup, location, and staff training, PLN should co-invest or subsidize costs as the e-mobility industry has the potential to increase power demand significantly in the medium-term (BNEF, 2018). There appears to be some movement in this direction with PLN allocating investment budget to support 22 EV charging stations in major cities (Harsono, 2019).

LIFECYCLE COSTS

Besides acquisition and operational costs, two other items impact e-bus economics: procurement and contracting practices as well as resale value in secondary markets.

BARRIER 8: Procurement and contracting practices do not favor e-bus technology

In Indonesia, manufacturers place bids with bus models based on operators' requirements in the government-managed online procurement portal. While several technical specifications and quality criteria are assessed, the financial evaluation compares only acquisition costs. This least-cost bid mechanism biases the selection process against e-bus technology, whose costs are loaded upfront with greater savings over a 10–15-year service life. This presents a major challenge to acquiring e-buses versus ICE buses around the world (BNEF, 2018).

TransJakarta commits to pay operators a fee per kilometer for at least seven years of operation (usually ten years), in return for operators agreeing to run a minimum number of kilometers per day on specific routes. This contractual income guarantee for 7–10 years helps operators access financing from banks for vehicle purchases. The technical service life of vehicles may be significantly longer with battery replacement after 5–8 years. Operators and TransJakarta are unable to estimate e-bus lifespan, maintenance costs, and battery replacement cost to determine modifications to contractual arrangements. Similarly, in Belo Horizonte, Brazil, operator contracts terms did not provide any incentives to deal with the high acquisition costs, risk, and learnings curves associated with e-buses (Sclar et al, 2019).

RECOMMENDATIONS

- **Assess TCO and emissions during procurement process:** The government can give weight to low-emission models as well as maintenance and operational costs while evaluating competitive bids. This would shift existing assumptions of a capital acquisition model to a services acquisition model to eliminate a major financial barrier to e-bus adoption (Miller et al, 2017). While acquisition costs should be assessed and minimized, the potential net savings over lifetime operations should encourage new business models and financing mechanisms in favor of e-buses. In an interview, the Jakarta Governor's office gave assurances that as long as the process is transparent and accountable, these rules can be modified in the future to accommodate new technologies like e-buses.
- **Adapt operator contracts for e-buses:** There are several contractual variations that TransJakarta can consider, after further data is available on the technology and operations.

The duration can be extended to match the warranty lifetime of the e-bus battery and include a renewal option after battery replacement. Such extensions will allow operators to show guaranteed income for a longer duration, enabling access to cheaper bank financing.

BARRIER 9: Absence of a secondary market for e-bus vehicles and batteries hampers valuation and financing

Operators sell ICE buses or auto parts in the secondary market for tourist and airport services after 10 years of usage in public transport routes. However, there is significant uncertainty on the residual value, lifespan, secondary market, and second-life use cases of e-bus vehicles and batteries (BNEF, 2018). Manufacturers, operators, TransJakarta, and the Governor's office expressed that the absence of these data points prevents adoption, valuation, and access to finance. Manufacturers note that even in China, e-buses have been in operation for only five years, precluding robust evidence for lifespan or second-life uses. Finally, as battery prices are expected to drop, there are concerns that the future value of second-life batteries may be low.

RECOMMENDATIONS

- **Encourage research on e-bus battery second-life uses:** Academic and industrial partners should ascertain the use cases, buyers, energy potential, and residual value of EV batteries. Manufacturers claim potential for applications in trains, solar energy cells, household energy storage, street lighting, and smaller vehicles like forklifts for up to 20 years. BNEF (2018) highlights pertinent examples including China Tower's agreement to replace lead-acid batteries with second-life batteries to store backup power for telecom towers as well as BYD's attempt to use second-life batteries for energy storage in China. Further research will increase market confidence in battery depreciation and valuation.
- **Prepare to regulate second-life uses of e-bus batteries:** The presidential decree states the need for EV battery waste management regulation to protect the environment. Effective policy can also define second-life uses, set manufacturer warranties, and clarify safety standards and responsibilities for manufacturers and dealers. These will create an ecosystem and inspire the confidence necessary for stakeholders to value batteries. IEA Global EV Outlook (2019) recommends such regulation to limit risks and adverse impacts. In 2018, Shanghai mandated an independent supervision system whereby manufacturers must prove used battery handling capacity along with local sales (BNEF, 2018).

CHAPTER 5: POLICY

Institutions, infrastructure, processes, and policies have historically been designed to boost ICE vehicle growth, locking the transportation sector into a high-carbon pathway. The nascent EV industry requires regulatory direction and incentives to gain acceptance in the market.

EMISSIONS & TARGETS

While there are several regulations on public transport and emissions, none are tied to e-mobility.

BARRIER 10: No specific targets for electric vehicle or e-bus deployment

The lack of long-term or specific e-bus targets makes it difficult to plan deployment and investment, as acknowledged by operators, TransJakarta, and KPBB. Sclar et al (2019) find that the lack of an overarching e-mobility vision poses a barrier for transit agencies to plan e-bus deployment in Cape Town, Addis Ababa, Mexico City, and Quito. They state that "even when guiding documents were available, the absence of specific targets... render these documents ineffective."

RECOMMENDATION

- **Set long-term bus fleet electrification targets:** IEA Global EV Outlook (2019) notes that "EV uptake typically starts with the establishment of a set of targets... to stimulate demand." Cities and national governments in Canada, India, China, USA, France, and the Netherlands have set targets or progressive purchasing mandates for zero-emission vehicles over the next two decades. Indonesia's national government should set medium and long-term e-mobility targets in the form of a specific number of e-buses or a percentage share of fleet. This will stimulate demand and set the stage for regional targets, enabling policies and investment in Indonesia's e-mobility sector.

VEHICLES

BARRIER 11: Technical requirements for bus permits are not inclusive towards e-buses

To receive a permit to operate, a bus model needs to meet dimensions, tonnage, and motor requirements laid out in Government Regulation No. 55/2012. Electric bus models currently do not have any separate specification requirements, precluding certain models from obtaining the necessary permits. For example, BYD's e-bus model does not meet the 2.5 meter width requirement of single buses by mere centimeters.

RECOMMENDATION

- **Modify technical requirements to accommodate e-bus models:** The Ministry of Transportation should review the market landscape and consult stakeholders to modify technical requirements to be inclusive of clean technology bus models, which may have variations in dimensions or tonnage.

BARRIER 12: Fiscal incentives are uncertain

Financing and cost uncertainty were the two most cited barriers to e-bus adoption in interviews. Vehicles in Indonesia are subject to Value-Added Tax (VAT), Luxury Vehicle Tax (PPnBM), Title Transfer Fee (BBN-KB), import tariffs, as well as testing and service fees. Article 19 of the presidential decree tasks national ministries and regional governments with announcing fiscal incentives for EV adoption and manufacturing, including import duty allowances, PPnBM cuts, export financing incentives, and investment support for charging infrastructure.

RECOMMENDATIONS

- **Subsidize public transport EVs:** The national government could budget funds to provide subsidies for purchasing public transport e-buses as well as charging infrastructure. This should account for the fuel subsidies saved annually from replacing each diesel bus, which amounts US$5,751 per year for single buses, or an expenditure of nearly US$70,000 over a 12-year vehicle lifespan. Most e-bus programs around the world are supported by public finance. Examples include Chinese local government subsidies for e-bus manufacturing and the UK's US$40 million fund to subsidize low-emission bus purchases (BNEF, 2018). India ties EV purchase cost subsidies to battery capacity, incentivizing larger vehicle electrification (Government of India, 2019). However, evidence suggests some caution against policy disrupting economics to the extent that EV programs become dependent on subsidies. China witnessed a slowdown in e-bus sales in 2017 after the government reduced subsidies (Perkowski, 2018).
- **Provide tax and import duty incentives for public transport EVs:** Indonesia can reduce technical testing fees, title transfer fees, and raw material import duties to decrease e-bus acquisition costs and account for air quality benefits. Aligning vehicle taxes to parameters like fuel efficiency, emissions, and public transport usage could increase state revenue by 0.64% of GDP and encourage a low-carbon pathway (OECD, 2019). Norway eliminated purchase and import taxes for EVs, while reducing fees for EV registration, resulting in among the highest national shares of low-emission vehicles. India slashed the goods and services tax on EVs from 12% to 5% and on EV chargers from 18% to 5% to promote e-mobility (Prasad, 2019).

MANUFACTURING

The principal focus of the presidential decree is accelerating domestic manufacturing of EVs and batteries given long-term global growth prospects and domestic nickel laterite ore resources. However, the decree fails to provide any grant, outlay, or incentive for public or private stakeholders. Article 8 obliges manufacturers of electric four-or-more wheelers to use at least 35% local components until 2021, 40% until 2023, 60% until 2029, and 80% thereafter.

BARRIER 13: Domestic content requirements discourage near-term e-bus investment and adoption

Given negligible domestic expertise or supply chain for EV manufacturing in Indonesia, these conditions may discourage or delay investment until the feasibility and economics of adherence are evaluated. These may inhibit e-bus investment more than electric car investment, as the latter has a much larger domestic and export market to target. Electric buses also require specialized components and manufacturing processes for heavy-duty batteries. BYD-Bakrie Indonesia claims it will be "difficult to fulfill localization requirements such as to produce the battery locally" for e-buses (Bakrie Autoparts, 2019). The presidential decree allows for full vehicle imports, but only under a certain quantity for a certain period after EV factory construction has commenced. There remains uncertainty on what this period would be, discouraging any immediate plans for e-bus imports.

RECOMMENDATIONS

- **Relax e-bus local content requirements and clarify calculation:** The details on how domestic content conditions will be calculated should be clarified immediately to aid development of a business case for manufacturers and distributors. Relaxing these requirements can encourage foreign bus manufacturers to set up assembly plants or component manufacturing facilities, rather than be limited to larger investments. This may even spur local investment.

- **Increase e-bus import allowance period:** TransJakarta and operators argue for a reasonable import allowance period. As capital expenditure is much higher for buses, relative to smaller vehicles, the Ministry of Industry should provide adequate time to conduct feasibility studies and analyze uncertainties related to technology and operations with imported e-buses.

ENERGY

Coal will dominate electricity generation, though Presidential Regulation No. 22/2017 on General National Energy Planning (RUEN) and Indonesia's NDC targets 23% renewable energy share of national energy by 2025, and 31% by 2050 (Republic of Indonesia, 2016). If Indonesia rapidly increases its renewable energy share, the emissions mitigation potential of e-buses can be substantially increased.

The presidential decree allowed for tariff reduction at EV charging stations but does not specify any rate. There have been suggestions that the government may offer up to a 30% discount on this price for EVs (Akbar, 2019). Such regulation will positively impact e-bus economics by reducing operational costs and offsetting high upfront costs.

BARRIER 14: Collaboration between PLN and transit stakeholders

All stakeholders interviewed in July 2019 agreed that communication with PLN is not sufficient, but that TransJakarta and government authorities have to lead the negotiations with the utility. It was reported that PLN signed MOUs with TransJakarta, Grab, Go-Jek and 17 other companies to discuss technical and business requirements for EV charging stations (Harsono, 2019). This is a positive first step, which will require long-term planning and business model development. Similarly, after facing increased costs and procurement delays for charging infrastructure in its e-bus pilot, Philadelphia's transit agency collaborated with the utility company to project grid investment and electricity generation requirements (Sclar et al, 2019).

RECOMMENDATIONS

- **Roadmap grid infrastructure and planning:** PLN should lead discussions with MEMR, the Ministry of Transportation, manufacturers, operators, and transit agencies around grid planning and charging infrastructure as EV uptake over the next decade can have considerable impact on grid demand and peak load times. PLN would have to draw up a plan for electricity infrastructure upgrades in urban areas, understanding dynamic factors in coordination with the local government and EV operators. The absence of planning and forecasting could lead to potential technical barriers.
- **Optimize charging station costs:** PLN can clarify charging infrastructure setup and operational costs to TransJakarta and operators as well as determine preferential electricity tariffs for e-buses. Manufacturers, bus operators, and private charging operators may have differing viewpoints on setup, operations, and business models. As the nodal stakeholder with vast experience in the electricity space, PLN is best placed to optimize charging infrastructure, negotiate new business models, anticipate problems, and effect proactive reforms.

CHAPTER 6: CONCLUSION

Based on scholarly literature and case studies related to e-bus pilots around the world, this paper recommends 27 actions for stakeholders looking to accelerate e-bus adoption in Jakarta (summarized in Table 4 below). In the next year, manufacturers and international agencies can lead knowledge sharing on vehicle and battery performance, second-life uses, and cost estimation. International agencies should enable access to grants for feasibility studies. TransJakarta has plans to conduct a robust passenger trial to ascertain technical, financial, and operational challenges to e-bus implementation. Over the next two years, as the transit agency gets comfortable with the technology, operator contracts need to be adapted to suit battery life, replacement, and e-bus economics, while also allowing for advertising revenue. To scale e-bus deployment, commercial banks, development banks, and government need to design innovative financing mechanisms to overcome economic and business model challenges. Transportation stakeholders will have to collaborate with PLN to plan grid infrastructure, operate charging stations, and set electricity tariffs.

Government authorities are central to addressing almost every identified barrier and ensuring stakeholder coordination. They should support feasibility studies and review charging technology to address technical barriers. Energy policy to decarbonize the grid and control non-CO_2 emissions from coal plants will enhance the environmental case for e-buses. Following the presidential decree, national and regional governments must issue implementing regulation to improve governance, set fleet electrification targets, provide fiscal incentives, ease bureaucratic processes, regulate second-life batteries, and relax domestic content requirements for e-buses. Proactive public policy can facilitate collaboration, incentivize investment and accelerate adoption.

The identified barriers and recommended actions are broadly applicable to cities around the world, particularly those in other developing countries. Heavy-duty vehicles are responsible for substantial GHG emissions, air pollution, and road congestion in many cities. Yet, the sector is locked-in to a carbon-intensive pathway. The adverse impact on health, environment, and productivity can be mitigated by urgent action which will enable the shift to sustainable transportation. Bus fleet electrification presents a combination of technological readiness, environmental impact, and commercial viability to inspire deployment and set the stage for EV growth. However, e-bus deployment disrupts transport technology, economics, energy, and policy. Domestic stakeholders will have to initiate comprehensive and collaborative efforts to overcome barriers and realize environmental and health benefits. The global network of researchers, implementers, and authorities must collaborate to expedite the mainstreaming of electric mobility.

Table 4: Summary of identified barriers and recommendations for stakeholders in Jakarta

	BARRIER	RECOMMENDATION	STAKEHOLDERS RESPONSIBLE FOR NEXT STEPS							
			National gov't	Jakarta gov't	PLN (utility)	Trans Jakarta	Operator	Manufac-turer	Bank	Int'l agencies
TECHNOLOGY	Lack of awareness of e-bus technology and benefits	Conduct operational trial		■		■				
		Access global data & best practices	■	■		■		■		■
		Run awareness campaigns	■	■		■				
	Lack of standards on charging technology	Conduct technology study on EV charging standards	■		■					■
ENVIRONMENT	Indonesia's grid emissions intensity reduces mitigation gains from replacing ICE buses	Increase renewable energy share of grid production	■		■					
		Impose stricter controls on non-CO_2 emissions in power generation	■		■					
ECONOMICS & FINANCING	Acquisition costs are high with several uncertainties	Clarify e-bus technical specifications		■		■				
		Subsidize acquisition costs	■	■						
	Dearth of upfront financing mechanisms	Government guarantees on loans	■	■						
		Access international development finance	■	■						■
		Design lease-based financing mechanism				■	■	■	■	■
	Operational and maintenance costs are uncertain	Set preferential electricity tariffs for public transport EVs	■		■					
		Clarify local maintenance costs				■		■		
		Allow advertising on e-buses as a secondary revenue stream				■	■			
	Costs of charging infrastructure setup and operations are uncertain	Clarify costs associated with charging stations			■	■		■		
	Procurement and contracting practices don't favor e-bus technology	Assess TCO and emissions during procurement process	■	■		■	■	■		
		Adapt operator contracts for e-buses				■	■			
	Absence of a secondary market for e-bus vehicles and batteries	Encourage research on e-bus battery second-life uses	■	■				■		■
		Prepare to regulate second-life uses of e-bus batteries	■					■		
POLICY	No specific targets for EV or e-bus deployment	Set long-term bus fleet electrification targets	■	■						
	Technical requirements for bus permits are not inclusive towards e-buses	Modify technical requirements to accommodate e-bus models	■							
	Fiscal incentives are uncertain	Subsidize public transport EVs	■	■						
		Provide tax and import duty incentives for public transport EVs	■	■						
	Domestic content requirements discourage near-term e-bus investment and adoption	Relax e-bus local content requirements and clarify calculation	■							
		Increase e-bus import allowance period	■							
	Collaboration between PLN and transit stakeholders	Roadmap grid infrastructure and planning	■	■	■	■				
		Optimize charging station costs	■	■	■					

APPENDIX: Data and assumptions for emissions calculations

TransJakarta bus fleet disaggregated by size and fuel type (Structure)

Fuel type	Stock
Diesel ICE	1849
CNG ICE	340
Gasoline ICE	1145
Hybrid	0
Battery electric	0
Total fleet	3,334

Bus type	Stock	Passenger capacity
Articulated bus	244	116
Maxi bus	293	92
Single bus	1242	76
Medium bus	410	36
Small bus	1145	11
Total fleet	3,334	N/A

Source: TransJakarta 2019

Note: Articulated and maxi size e-buses are not commercially available and are not considered in this study.

TransJakarta vehicle operations (Activity and Intensity)

Bus size	Fuel type	Vehicle stock	Daily mileage (km)	Annual mileage (km)	Fuel Consumption (lge/km)	Annual fuel consumption (lge)	Vehicle emissions standard
Single	Diesel	1146	237	86,505	0.50	43,253	Euro 2
	CNG	96	237	86,505	1.11	96,117	Euro 2
Medium	Diesel	410	237	86,505	0.33	28,835	Euro 2
Small	Diesel	42	200	73,000	0.08	6,083	Euro 2
	Gasoline	1103	200	73,000	0.09	6,636	Euro 2

Source: TransJakarta 2019 (figures are averages, but assumed to be closest proxies to actual operations in Jakarta)

Fuel and emission parameters (Fuel factors)

Metric	Unit (unless specified)	Diesel		CNG	Gasoline	Electric
Bus size	Size	Single & medium	small	single	small	all
Fuel quality standard [a]	Euro standard	Euro 2	Euro 2	Euro 2	Euro 2	N/A
Fuel density per liter [b]	(kg/L)	0.84	0.84	0.58	0.75	N/A
Fuel density [b]	(kg/Lge)	0.61	0.61	0.19	0.75	N/A
TTW carbon intensity [b]	(kgCO2/lge)	2.48	2.48	1.88	2.32	0
WTT carbon intensity [b]	(kgCO2/lge)	0.50	0.50	0.38	0.46	N/A
PM stock	(g/km)	0.15 [c]	0.08 [c]	0.08 [c]	0	0.85 g/kWh [e]
NOx stock	(g/km)	7.00 [c]	1.00 [c]	7.00 [c]	0.60 [c]	2.94 g/kWh [e]
Sulphur content	(ppm) = (mg/L)	2500 [c]	2500 [c]	0	500 [c]	6.4 g/kWh [e]
Grid emissions factor	(kgCO2/kWh)	N/A	N/A	N/A	N/A	0.81 [d]

Sources:
a Tempo, 2018
b UN Environment Programme (global figures)
c Transport Policy, 2018
d Grütter & Kim, 2019
e Crippa et al, 2018 and IEA, 2019 (Indonesia-specific figures from 2012 – calculations below)

Non-CO2 emissions from Indonesia's electricity grid in 2012

Metric	Unit	NOx	SO_2	PM
Emissions from electricity production + mining [a]	Gg	589.09	1,279.57	170.18
Electricity production [b]	GWh	200,030	200,030	200,030
Emissions factor (calculated)	(g/kWh)	2.94	6.40	0.85

a Crippa et al, 2018; b IEA, 2019

Electric bus energy estimates used for calculations are of BYD models

Metric	Unit	Single bus	Medium bus	Small bus
	Model	BYD K9	BYD C6	BYD T3
Battery size [a]	kWh	324	135	50
Range [a]	km	250	200	300
Test Fuel Efficiency	kWh/km	1.30	0.68	0.17

Source: a BYD, 2018

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