Climate and Air Quality Scenarios for E-Bus Deployment:

Deep Dive City Jakarta, Indonesia

City Characteristics

Jakarta, the capital city of Indonesia, is the nation's financial epicentre and most populated city, with a GDP estimated to be over USD 321 billion and a population of 10.5 million. Together with Bogor, Depok, Tangerang, and Bekasi, the Jakarta Metropolitan Area stretches along 4,384 km^2 with a population density of 13,000 people per square kilometre[1]. With a tropical monsoon climate, Jakarta's predominant climate is hot and humid with an average temperature around 27 °C.

Despite Jakarta's progressive improvement in its infrastructure over the last decade, the city still faces various challenges such as flooding, air pollution, and traffic congestion[2]. The city is particularly vulnerable to flooding from rising sea levels, notably due to the existing low terrain and its significant land subsidence[3]. In 2022, PM2.5 reading in Jakarta is reported to reach 136,9 $\mu g/m^3$, 27 times higher than the WHO guidelines[4]. In response to these challenges, the government has implemented several climate actions in various sectors, ranging from renewable energy, and waste management, to sustainable transportation systems[5].

Transport System

The transportation system in Jakarta is a complex network that covers road, rail, water, and air transport. Private vehicles, notably motorcycles, are dominating the share of transport in Jakarta, followed by cars, shared modes, and public transport[6]. Figure 1 illustrates the distribution of the modal split in Jakarta.

Motorcycle is Jakarta's predominant mode of transport, with more than 17 million vehicles recorded in 2022[7]. Not only utilised for private transportation, but a motorcycle in Jakarta is also essential for ride-sharing, last-mile delivery, and as a motorcycle taxi (*ojek*)[8].

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1 Martinez and Masron, 'Jakarta: A City of Cities'.

2 UNFCCC, 'Jakarta: The Sinking City'; ITDP, 'Jakarta Is What Resiliency Looks Like'.

3 UNFCCC, 'Jakarta: The Sinking City'.

4 Jong, 'As Jakarta Chokes on Toxic Air, Indonesian Government Stalls on Taking Action'.

5 Jakarta Rendah Emisi, 'Actions - Jakarta Rendah Emisi'.

6 TUMI E-Bus Mission, 'Factsheet - Jakarta'.

7 BPS Provinsi DKI Jakarta, 'Jumlah Kendaraan Bermotor Menurut Jenis Kendaraan (Unit) Di Provinsi DKI Jakarta 2020-2022'.

8 Saffan and Rizki, 'Exploring the Role of Online "Ojek" In Public Transport Trips'.

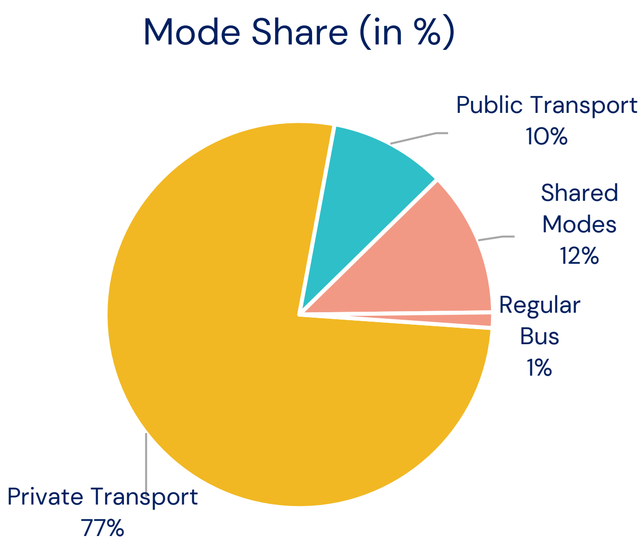

Figure 1 Modal Split in Jakarta (Source: TUMI E-Bus, 2022)

Compared to other cities in Indonesia, Jakarta is leading the public transportation sector through its varied mode of public transit and its extensive routes. Established in 2004, Transjakarta is the first BRT in Southeast Asia and currently holds the record for the longest BRT route in the world by 251.2 km[9]. In 2019, Transjakarta on average served more than 72,000 passengers daily[10]. The rail-based modes of transport in Jakarta are operated by four different entities: Commuterline Jabodetabek for the city train, MRT Jakarta for the mass rapid transit, LRT Jakarta for the light rail transit, and RailLink for the airport train. Commuterline Jabodetabek serves over 700,000 passengers per day, connecting the Greater Jakarta Area[11].

A study conducted in 2020 shows that the transportation sector is the main source of air pollution in Jakarta, notably for NO_x, CO, PM_{10}, and $PM_{2.5}$[12]. The government established various policies to mitigate air pollution in the transportation sector, notably by enhancing the emission test, limiting the vehicle age, and encouraging the use of electric buses[13].

Climate and Air Pollution Targets

The government of Jakarta sets an ambitious target in addressing climate change and reduce air pollution in the city. Through the DKI Jakarta Government's Decree No. 90/2021, Jakarta targeted the GHG emission in 2030 would be 30% below the baseline scenario and established a net zero emission in 2050[14]. It is projected that this scenario will reduce 32.362.000 tCO_2e in 2030[15]. Jakarta also published the Climate Action Plan 2021-2050 that mentioned additional climate targets, such as 42% renewables for the energy mix by 2050, a

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[9] Transjakarta, 'Layanan Bus'.
[10] BPS Provinsi DKI Jakarta, 'Jumlah Penumpang Dan Pendapatan Trans Jakarta Menurut Koridor/Rute 2019-2021'.
[11] KAI Commuter, 'Tentang Kami'.
[12] Jakarta Rendah Emisi, 'Transportation and Processing Industry Become the Biggest Contributor of Air Pollution in Jakarta'.
[13] Jakarta Rendah Emisi.
[14] Government of DKI Jakarta, 'PERGUB Prov. DKI Jakarta No. 90 Tahun 2021 Tentang Rencana Pembangunan Rendah Karbon Daerah Yang Berketahanan Iklim'.
[15] Government of DKI Jakarta.

mode share of public transportation by 38.6% in 2050, and a mode share of active mobility of 10% in 2050[16].

Targets and Policies Related to the Procurement of E-buses

In 2022, the government established the DKI Jakarta Government's Decree No. 1053/2022 to accelerate the implementation of e-buses for Transjakarta fleets. The target mentioned the 10,047 fleets of e-buses by 2030 and also the procurement of its supporting charging infrastructure[17]. The decree also mentioned that 50% of the Transjakarta fleet would be electrified by 2027 and 100% electrification by 2030. Currently, there have been 30 operating e-buses that are run by Transjakarta, with additional 70 buses planned to be added.

The e-Bus Emissions Assessment Tool (eBEAT)

The eBEAT tool is co-developed by TUMI E-Bus Mission and SOLUTIONSplus. It is a bus stock model that integrates the evolution of the bus fleet based on the number of new entrants, considering sizes (for e-buses), fuel split and emission standards, a vehicle survival curve, new vehicle technology improvements, and vehicle degradation. The tool aims at a better understanding of the impact of an accelerated procurement of e-buses in cities in Asia, Africa, and Latin America.

The tool can calculate time-series estimations of emissions based on existing plans and targets for e-bus procurement and on 'what-if' scenarios that consider external factors such as changes in the national energy mix or transmission losses in the electricity grid. The calculator goes beyond greenhouse gas emissions and captures air pollutants and energy consumption.

While the calculator uses city-specific data on procurement plans and targets or vehicle-km, it also provides default values to reduce data requirements. Users can adapt default values for the e-bus and the 'what-if' scenario.

Impact of Accelerated E-bus Procurement on Emissions

High-capacity, efficient, clean, and high-service-quality passenger transport modes such as electric buses (e-buses) play a critical role in accelerating the reduction of emissions from urban transportation.

To analyse the impacts of the accelerated e-bus procurement, we have developed two scenarios, viz., a base scenario and an enhanced scenario. The parameters that are used in each scenario are summarized in the table below:

[16] Government of DKI Jakarta, 'Towards Climate Resilience and Carbon Neutrality: Jakarta Climate Action Plan 2021–2050'.
[17] Government of DKI Jakarta, 'Kepgub DKI Jakarta No. 1053/2022 Tentang Pedoman Percepatan Program Penggunaan Kendaraan Bermotor Listrik Berbasis Baterai Dalam Layanan Angkutan Transjakarta'.

Parameters	Base Scenario		Enhanced Scenario	
	2030	2050	2030	2050
Fleet Stock	12.170	0	12.170	16.300
T&D Losses	9%	9%	7%	4%
% of Renewable Energy	22%	22%	33%	75%

In the **base scenario**, we have considered procurement targets set by the city (i.e. 8,883 e-buses by 2025) and 12,172 e-buses in 2030, and our estimate is slightly higher than the target set by the government. The data was obtained from the TUMI e-bus network website and updated figures from the TUMI partners. Moreover, we assumed a moderate increase in the share of renewable energy sources in the electricity mix to 22% and constant transmission & distribution losses of 9%.

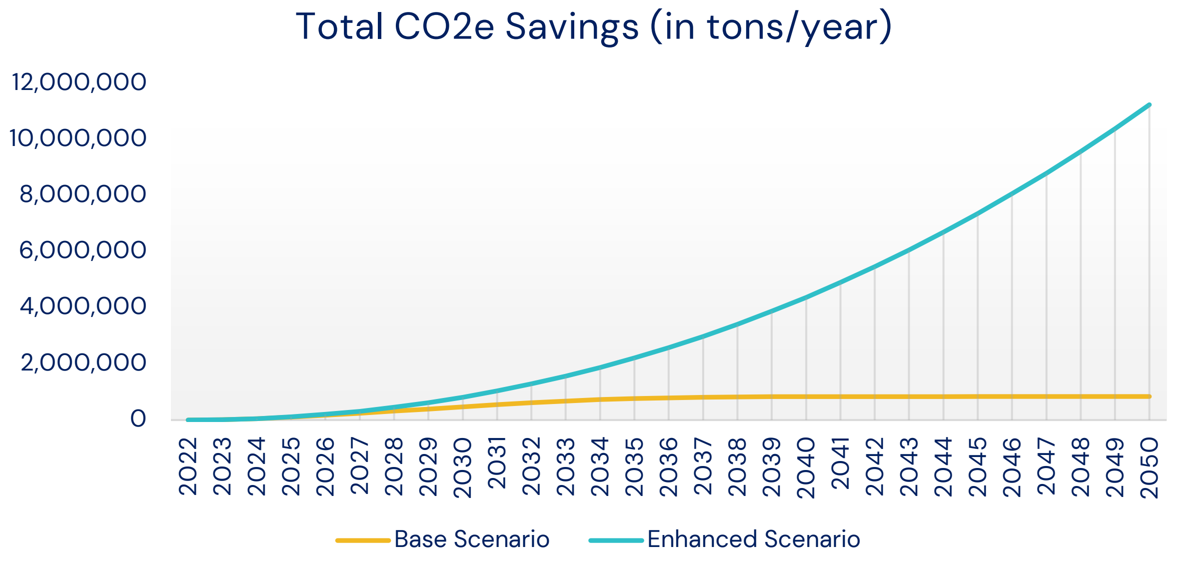
In the **enhanced scenario**, a key assumption was that the entire bus fleet is electrified by 2030, according to DKI Jakarta Government's Decree No. 1053/2022. The fleet size up to 2050 was estimated based on the population growth in the city. We assumed the fleet availability per 1000 inhabitants would remain unchanged until 2050. This will lead to a fleet size of 16,297 vehicles in 2050, this would mean that the city needs to procure 44,752 e-buses until 2050, considering the vehicle retirement up to 2050. In addition, we assumed that the future electricity mix will have a higher share of renewable energy at 75% and that transmission and distribution losses will gradually be reduced to 4% by 2050.

The tool estimates the cumulative savings for emissions and energy consumption by shifting to e-bus. Conventional urban buses are predominantly fuelled by diesel engines, emitting black carbon (BC), a harmful and carcinogenic particle. Other emissions that are analysed are the most crucial air pollutants source that significantly affects human health and environmental quality, such as NO_x and particulate matter (PM). The following table gives a snapshot of the cumulative savings from shifting to e-buses according to the base and enhanced scenarios:

Category (unit)	Base Scenario		Enhanced Scenario	
	Up to 2030	*Up to 2050*	*Up to 2030*	*Up to 2050*
BC (tons)	179	312	180	914
CH_4 (tons)	145	253	147	771
CO (tons)	5.764	10.076	5.787	29.274
CO_2 (kilo tons)	469	831	811	11.218
CO_2e (kilo tons)	474	839	815	11.243
N_2O (tons)	8	14	10	91
NMVOC (tons)	196	350	206	1.260
NO_x (tons)	24.234	42.332	24.565	128.987
PM_{10} (tons)	143	250	156	1.044
$PM2_{.5}$ (tons)	143	251	150	885

SO_x (tons)	-215	-377	-196	-560
TSP (tons)	156	273	175	1.261
Energy consumption (MWh)	8.130.000	14.240.000	8.210.000	43.090.000
Energy consumption (TOE)	700.000	1.220.000	710.000	3.710.000

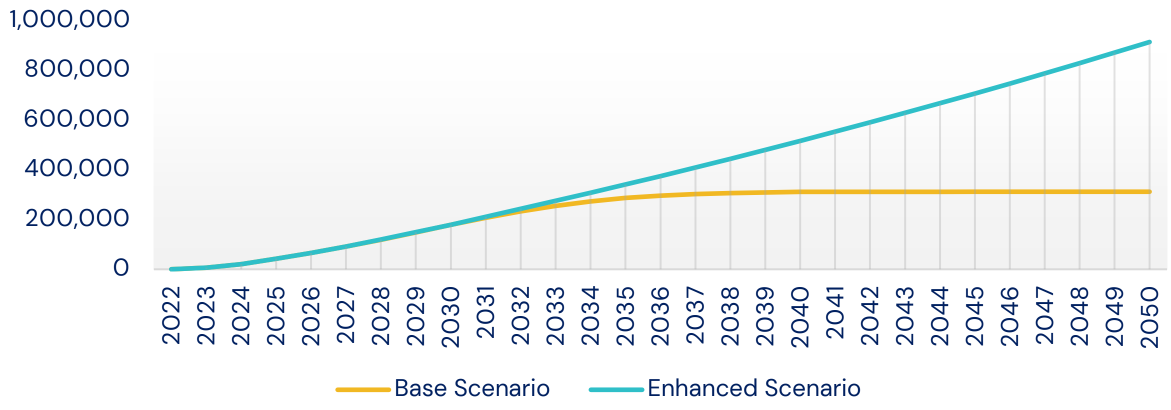
By shifting to e-buses, the base scenario shows a reduction of 474 ktCO_2e emissions by 2030. In the long-term, until 2050, the reduction amounts to about 839 ktCO_2e. Meanwhile, the enhanced scenario shows a reduction of 815 ktCO_2e by 2030 and the number significantly increases to 11.243 ktCO_2e by 2050, or thirteen times more than the base scenario. Thus, improving the current target may potentially reach or even exceed the level of savings that are estimated by the enhanced scenario.



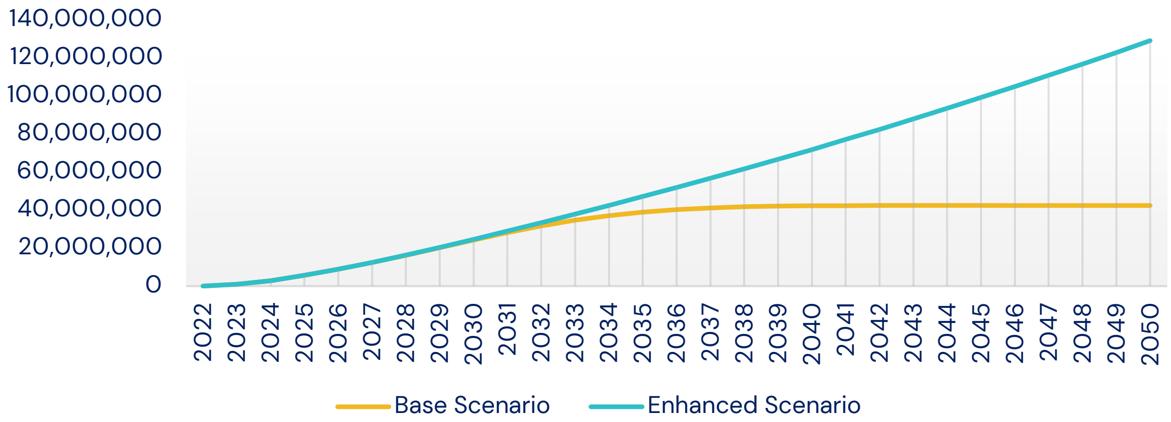
The shifting to e-buses provides a benefit regarding urban air quality. The transition towards e-buses is expected to save the city a significant amount of black carbon, with an estimated 179 tons in 2030 and 312 tons by 2050 in the base scenario. Furthermore, the base scenario also predicts a significant reduction of about 42.332 tons of NO_x and 501 tons of particulate matter saved by 2050. These figures demonstrate the benefits of switching to electric buses to the environment and the local community.

In the enhanced scenario, the reductions in black carbon, NO_x and particulate matter by 2050 are 914 tons, 128.987 tons and 1.929 tons, respectively. The savings from the enhanced scenario are around three-fold to the base scenario.

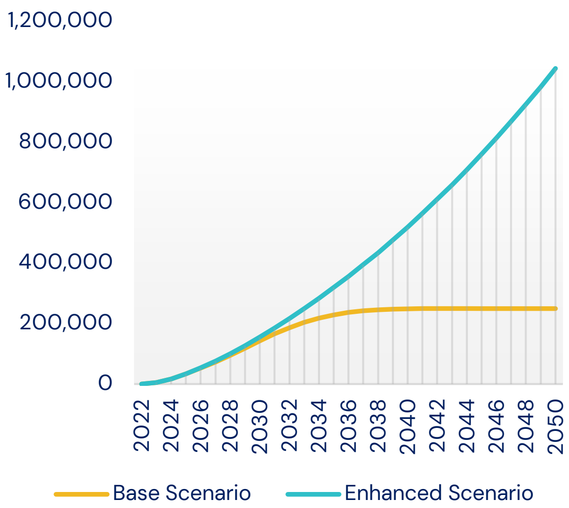
Total Black Carbon Savings (kg/year)



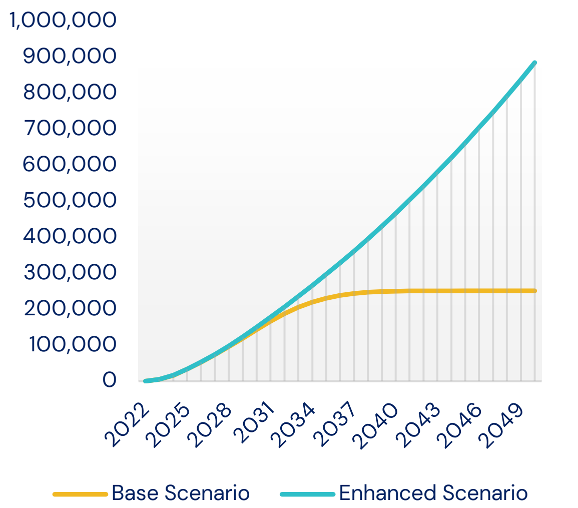
Total NOx Savings (kg/year)



Total PM10 Savings (kg/year)



Total PM2.5 Savings (kg/year)



Emission reduction potential at a national level

As mentioned in the NDC update in 2021 and 2022, Indonesia targeted 32% emissions below BAU by 2030 and aims to be climate neutral by 2060[18]. In 2020, IEA reported that 126 Mt of CO_2 were emitted by the transportation sector in Indonesia, of which 90% was emitted from road transportation[19].

On a national level, E-BEAT estimates that the average annual CO_2 savings per bus in Indonesia for the enhanced scenario are 16 tonnes and 52 tonnes in 2030 and 2050, respectively. The striking difference between 2030 and 2050 savings is mainly due to Indonesia's high dependence on coal for its electricity generation. Currently, coal represents 61% of the country's energy mix, and the country is planning to increase it to 64% in 2030[20]. Meanwhile, E-BEAT's enhanced scenario assumes that 75% of the grid generation will be sourced from renewables.

Assuming the steady growth of bus fleet size to population ratio and a 75% shift from ICE buses to e-buses, it is estimated that the annual CO_2 savings will reach 8 Mt in 2030 and 62 Mt in 2050. To put into context, the number is then compared to the 2020 road transport emission level. It shows that by shifting the ICE buses into e-buses, Indonesia will reduce 7% and 55% of their road transport emission in 2030 and 2050, respectively. Furthermore, the savings percentage can potentially increase to 73% in 2050 by shifting 100% of buses from ICE buses to e-buses.

[18] Climate Action Tracker, 'Indonesia'.
[19] IEA, 'Greenhouse Gas Emissions from Energy'.
[20] Climate Action Tracker, 'Indonesia'.

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