Climate and Air Quality Scenarios for E-Bus Deployment:

Deep Dive City Ahmedabad, India

City characteristics

Ahmedabad, located in the state of Gujarat, is the fifth-largest city in India and the seventh-largest metropolis area. It is also the largest city in the state. Being the most important centre of trade and commerce in Western India, the population in Ahmedabad is increasing. In 2021, the city´s population reached 8.2 million, an increase of 57.6% compared to 2011. The GDP of Ahmedabad is estimated to be around USD 68 billion in 2021.

The city lies 53 meters above sea level on the banks of the Sabarmati River[1]. The hot semi-arid climate of Ahmedabad results average temperature of 27°C in the city (min 24°C and max 43°C), with an annual rainfall of around 782mm[2]. The climate-related risk includes extreme events such as heat waves, which have become frequent and affected many local populations. In general, the air quality index shows that it is satisfactory compared to other cities in India.

Transport system

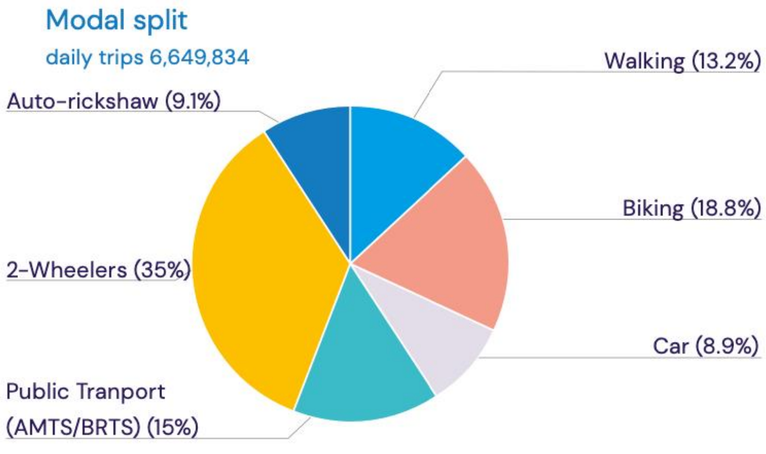

Figure 1: Modal Split. Source: TUMI E-Bus, 2022

Out of 6.3 million daily trips, residents of Ahmedabad use mostly motorised 2-wheelers (35%) while 18.8% of the trips are by bicycle, public transport (15%), walking (13.2%), auto-rickshaw (9.1%) and private car (8.9%). Public transport includes city buses, BRTS, regional buses and railways.

The city buses are operated by the Ahmedabad Municipal Transport Service (AMTS) – a voluntary service managed by Ahmedabad Municipal Corporation under the Bombay Provincial Municipal Corporations Act which operates 204 routes carrying 575,000 passengers daily on average. Regarding city buses, Ahmedabad is also implementing 38 km of metro rail corridor in phase-1, of which 6

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[1] Ministry of Urban Development of India, 'Service Level Benchmark: Ahmedabad'.

[2] Ministry of Urban Development of India.

km of Metrorail is operational[3]. Ahmedabad Municipal Corporation in cooperation with Ahmedabad Janmarg Ltd. (AJL) runs and operates BRTS (Bus Rapid Transit System) with 18 routes carrying 160,000 passengers daily on average. The buses in BRTS are equipped with GPS, GPRS and all stations are equipped with wireless connectivity, real-time vehicle tracking, and a bus monitoring system[4]. The regional/ intercity buses are operated by Gujarat State Road Transport Corporation (GSRTC). On average, the buses travelled 200 km per day with fleet utilisation of around 88% and a fleet age of 5 years.

Ahmedabad has around 1067 ICE buses and 202 e-buses running in 2021. In 2019, 52 AC e-buses of which 40 buses were procured under FAME-I and 10 buses from Additional State VGF by Ashok Leyland. AJL introduced battery swapping technology for 18 e-buses in partnership with Ashok Leyland as Bus OEM and Sun Mobility as the energy service provider. Under FAME II, 150 AC e-buses were added in 2021 of which 90 were by JBM Auto and 60 by TATA Motors. AJL implemented GCC contractual model to manage the bus network and the operator consortium (OEM + bus operators + energy service providers) carrying out the operation and maintenance of the e-buses. The operator consortium receives payment from AJL on passenger km travelled by e-buses.

Climate and air pollution targets

The Climate Change and Environment Action Plan (CCEAP) of Ahmedabad District investigates the current policies and recommends steps that need to be taken in the short-, medium- and long-term to bring about the necessary changes that follow India's climate goals and commitments, including in the transport sector.

The action plan recommends[5]:

(a) promoting e-mobility through awareness, an increase of EVs modal share, the transition of public transport (PT) and intermediate public transport (IPT) to electric-powered or hybrid vehicles, developing widespread charging infrastructure, incentivising e-vehicle owners, etc.;

b) ensuring last-mile connectivity and promoting increased use of PT and IPT;

(c) augmenting non-motorised transport through dedicated cycle lanes; and

(d) improving traffic flow through decongestion and improving road conditions.

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[3] WRI India, 'AMTS Vision Plan: 2035'.

[4] Amdavad Municipal Corporation, 'Bus Rapid Transit System'.

[5] Vasudha Foundation, 'Climate Change and Environment Action Plan of Ahmedabad District'.

In addition, Ahmedabad has Clean and Green Public Transport initiatives from the Government of India through DHI under FAME I and FAME II schemes[6].

Targets and policies related to the procurement of e-buses

Ahmedabad is committed to achieving zero-emission urban mobility. To support this vision, the city has introduced electric buses as a green and sustainable transport solution. The goal is to convert the entire bus fleet to e-vehicles, making Ahmedabad the first Indian city to do so. Additionally, there are plans to increase public transport and active mobility in the coming years. The city plans to procure 150 AC e-buses and 300 (9m) e-buses under FAME II by 2023. The Jamalpur depot is also being developed as a hub for e-buses, with the capacity to accommodate approximately 300-400 e-buses. By 2026, Ahmedabad aims to have 2000 e-buses in operation.

Ahmedabad receives support from the Chief Minister Urban Bus Scheme (CMUBS). Under this, the Gujarat state government and the city authorities each offer a viability gap funding (VGF) of Rs. 12.50/ km towards the operations expenditure of every new city bus (electric or ICE) (TUMI E-bus factsheet Ahmedabad).

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.

[6] TUMI E-Bus Mission, 'Factsheet - Ahmedabad'.

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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:

Parameters	Base Scenario		Enhanced Scenario	
	2030	2050	2030	2050
Fleet Stock	1.840	0	3.840	8.290
T&D Losses	20%	20%	17%	10%
% of Renewable Energy	28%	33%	36%	75%

In the **base scenario**, we have considered both short-term and long-term targets set by the city (i.e., 502 e-buses by 2026) up to 2050. 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 33% and constant transmission & distribution losses of 20%.

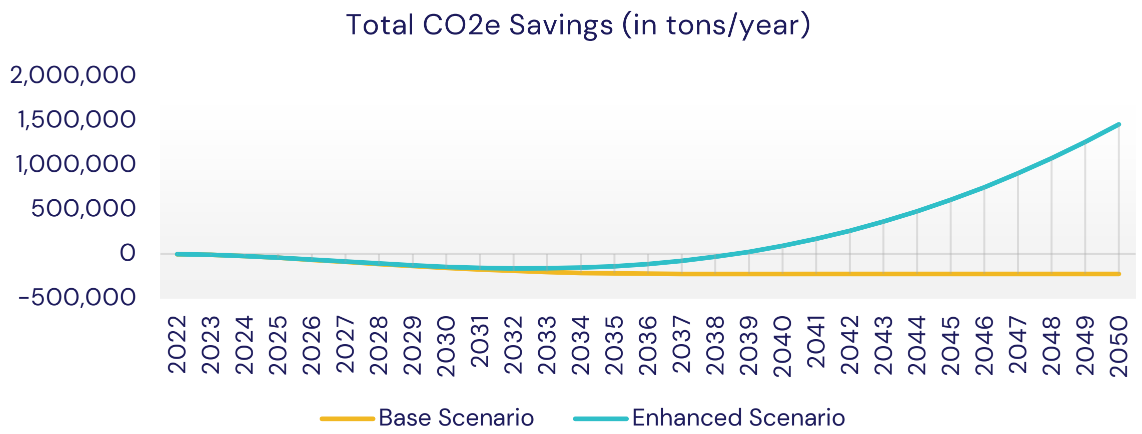
In the **enhanced scenario**, a key assumption was that the entire bus fleet is electrified by 2050 unless the city defined an earlier target for full electrification. Unless that city had no specific target, we estimated the fleet up to 2050 based on the population growth in the city. We assumed the fleet availability per 1000 inhabitants would remain unchanged until 2050. This will lead to an approximate fleet size of 8.290 vehicles in 2050, and the city needs to procure 19.040 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 10% by 2050.

Through the tool, we estimate 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)	5	8	7	66
CH_4 (tons)	13	19	18	162
CO (tons)	90	137	127	1.184
CO_2 (kilo tons)	-155	-225	-144	1.455
CO_2e (kilo tons)	-155	-224	-144	1.460
N_2O (tons)	-1	-1	0	13
NMVOC (tons)	10	16	15	170
NO_x (tons)	-337	-501	-400	-761
PM_{10} (tons)	53	82	76	717
$PM2_{.5}$ (tons)	30	45	42	390
SO_x (tons)	-38	-56	-48	-231
TSP (tons)	82	125	117	1.089
Energy consumption (MWh)	460.000	710.000	670.000	6.480.000
Energy consumption (TOE)	40.000	60.000	60.000	560.000

Due to the high dependence on fossil fuels in electricity generation in India, both the base scenario and the enhanced scenario do not provide savings from shifting to e-buses in terms of tCO_2e. As a major share of Indian electricity is sourced from fossil fuels, the de-carbonisation of the energy system, along with improvements in the grid, is required to reduce greenhouse gas emissions from the electrification of (public) transport.

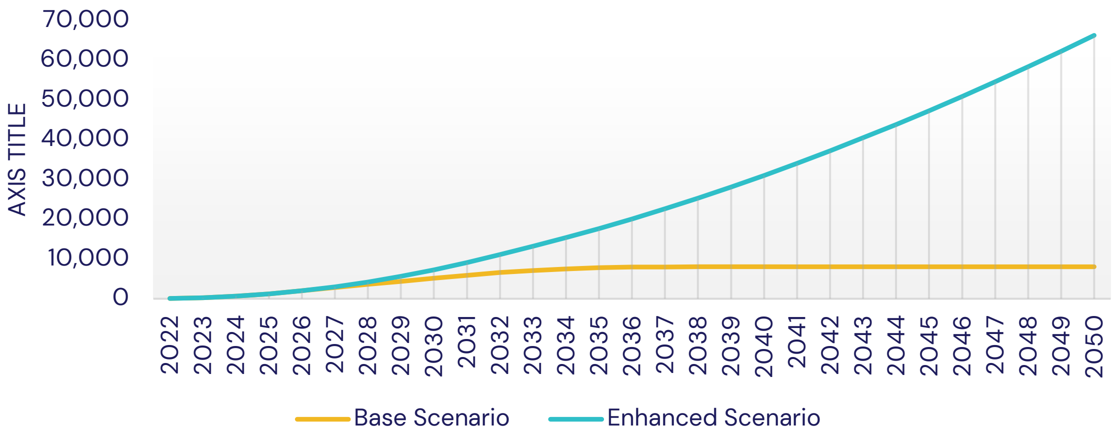
We find that by improving the energy mix and the transmission and distribution losses, the shift to e-buses can give overall GHG savings in 2050, up to 1.460 $ktCO_2e$. Based on the graph, it is evident that there will be a reduction in GHG emissions from 2033 in the enhanced scenario. This scenario involves a shift towards renewable energy sources in the grid mix and an increase in the number of e-buses procured compared to the base scenario.



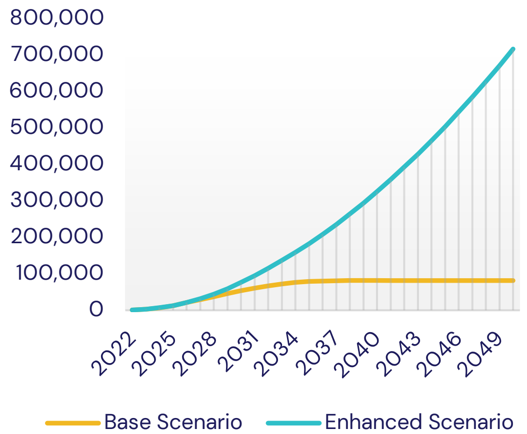
Electric buses decrease greenhouse gas emissions and improve air quality in the local area. The transition towards e-buses is expected to save the city a significant amount of black carbon and particulate matter, with an estimated savings of around 8 tons and 127 tons by 2050 in the base scenario. Furthermore, the enhanced scenario also estimates a significant reduction of 66 tons of black carbon and 1.107 of particulate matter by 2050. The black carbon and particulate matter savings from the enhanced scenario are around eight times compared to 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.

Due to the cumulative reporting of NOx savings, the final cumulative number is negative. Yet, if one sees the annual NOx savings, it can be noticed that in the enhanced scenario cleaning the grid and implementing a large share of e-buses has air quality benefits.

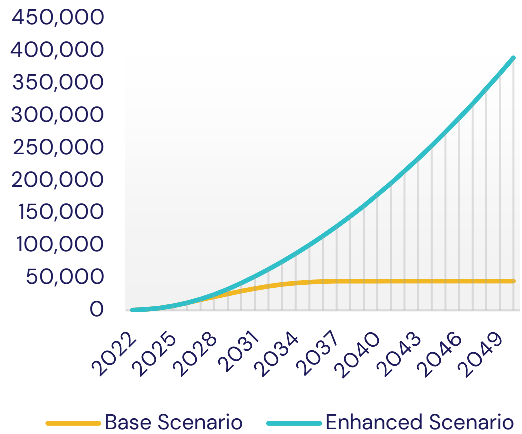
Total Black Carbon Savings (kg/year)

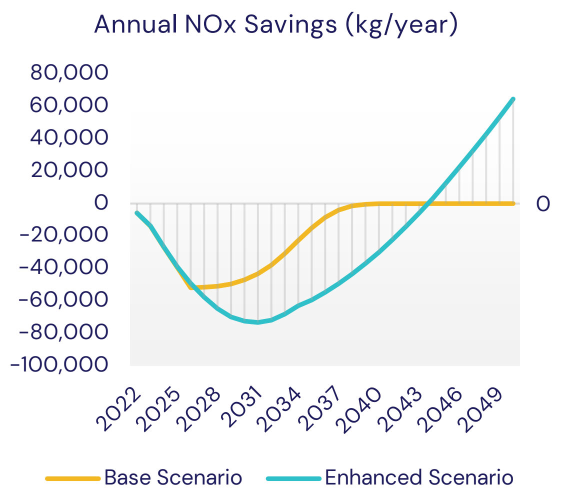


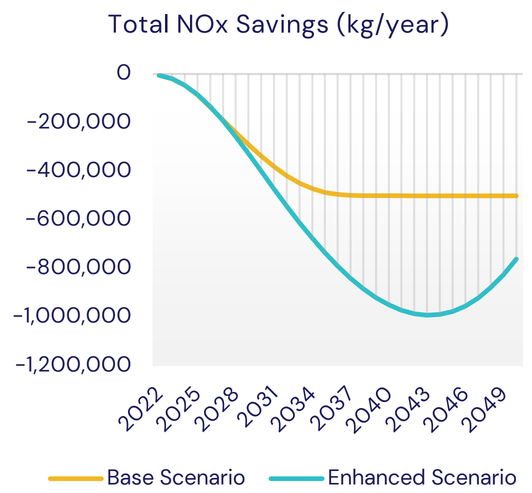
Total PM10 Savings (kg/year)



Total PM2.5 Savings (kg/year)







Emission reduction potential at a national level

According to the updated NDC in 2022, India targeted 45% emissions below 2005 levels by 2030 and aims to be climate neutral by 2070[7]. In 2020, IEA reported that 269 Mt of CO_2 were emitted by the transportation sector in India, of which 94% were emitted from road transportation[8].

On a national level, E-BEAT estimates that the average annual CO_2 savings per bus in India for the enhanced scenario are 3 tonnes and 32 tonnes in 2030 and 2050, respectively. The striking difference between 2030 and 2050 savings is mainly due to India's high dependence on coal for its electricity generation. Currently, coal represents 70% of the country's energy mix, despite the country's plan to reduce it to 50% by 2030[9]. Meanwhile, E-BEAT 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 7 Mt in 2030 and 168 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, India will reduce 3% and 67% of their road transport emission in 2030 and 2050, respectively. Furthermore, the savings percentage can potentially increase to 89% in 2050 by shifting 100% of buses from ICE buses to e-buses.

[7] Climate Action Tracker, 'India'.
[8] IEA, 'Greenhouse Gas Emissions from Energy'.
[9] Climate Action Tracker, 'India'.

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