Climate and Air Quality Scenarios for E-Bus Deployment:

Deep Dive City Barranquilla, Colombia

City Characteristics

Located on the Magdalena River's western bank, Barranquilla is the main economic centre of the Caribbean region of Colombia. The maritime and river ports connected the country with Caribbean Coast, enabling trade with the United States, Europe, and Asia[1]. Barranquilla's GDP is estimated at around 7.899 million USD with industry and commerce being the most important economic sectors.

With a population of 1.3 million, Barranquilla is the fourth most populated city in Colombia[2]. Barranquilla covers 154 km^2 of area and is the core of the Barranquilla Metropolitan Area, which also includes Soledad, Galapa, Malambo, and Puerto Colombia.

Barranquilla has a tropical climate with an average temperature of 27 ^{0}C. Climate risks that are threatening Barranquilla include extreme temperature and flooding, particularly due to the coastal flood.

Transport system

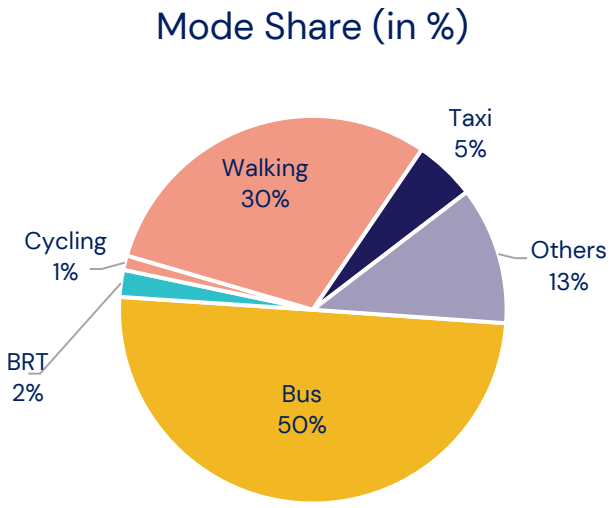


Figure 1 Modal Split in Barranquilla (Source: TUMI E-Bus, 2022)

Public transport is a dominant mode of transport in Barranquilla. Over 50% of urban trips are made on public transport, followed by 31% of trips made by non-motorised modes, chiefly walking. Less than 20% of urban trips are performed by private motor vehicles.

The public transport system consists of 3.240 buses, of which 260 buses serve on 12 trunk routes of the 13.3 km BRT (Bus Rapid Transit) system (TransMetro), and the remaining 2,980 buses operate as regular service.

[1] US Commercial Service Colombia, 'Barranquilla Profile'.

[2] Statista, 'Most Populated Cities in Colombia'; TUMI E-Bus Mission, 'Factsheet – Baranquilla'.

Before the COVID-19 pandemic, the public transport system's daily ridership was about 1,000,000 passengers of which the BRT's share was 139,000 passengers.

Climate and air pollution targets

Though the city of Barranquilla has no climate or sustainable mobility-related targets, at a national level, Colombia pledges to reduce greenhouse gas emissions by 51% by 2030 and to achieve carbon neutrality by 2050[3]. The National Law 2169/2021 promoting low-carbon development aims to have 600,000 electric vehicles in the country by 2030[4]. The law stresses the optimal use of urban land on the principles of Transport-Oriented Development.

Targets and policies related to the procurement of e-buses

The Development Plan "*Soy Barranquilla 2020 - 2023*" prioritises the integration of transport modes in the district and the Metropolitan Area through the "*Red integrada de transporte metropolitan"* project. The plan also aims to renew the public transport fleet for a more environmentally friendly one. Moreover, the plan aims to increase the accessibility around BRT stations to up to 500m in 60% of the district territories. This is achieved by shifting to a more environmentally friendly vehicle fleet connecting to the BRT system[5].

By 2034, the city will have an e-bus fleet of 1,150 vehicles, about 50% of the current conventional bus fleet and in the short term, by 2030, the city aims to introduce about 300 e-buses.

The national law 1964/2019 promoting the use of electric vehicles mandates Colombian cities with a Mass Transit System to implement policies and actions to increase the share of electric or zero-emission vehicles in public transport. The law sets obligations for purchasing new zero-emission vehicles:

Year	Minimum share of zero-emission vehicles in new purchases	Year	Minimum share of zero-emission vehicles in new purchases
2025	10%	2031	60%
2027	20%	2033	80%
2029	40%	2050	100%

[3] Gobierno de Colombia, 'Actualización de La Contribución Determinada a Nivel Nacional de Colombia (NDC)'.
[4] Globalfleet, 'Colombia'.
[5] Alcaladia de Barranquilla, 'Soy Barranquilla. Development Plan 2020-2023'.

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:

Parameters	Base Scenario		Enhanced Scenario	
	2030	2050	2030	2050
Fleet Stock	1.050	0	1.050	4.530
T&D Losses	12%	12%	10%	6%
% of Renewable Energy	73%	79%	73%	79%

In the **base scenario**, we have considered both short-term and long-term targets set by the city (i.e., 300 e-buses by 2023) 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 79% and constant transmission & distribution losses of 12%.

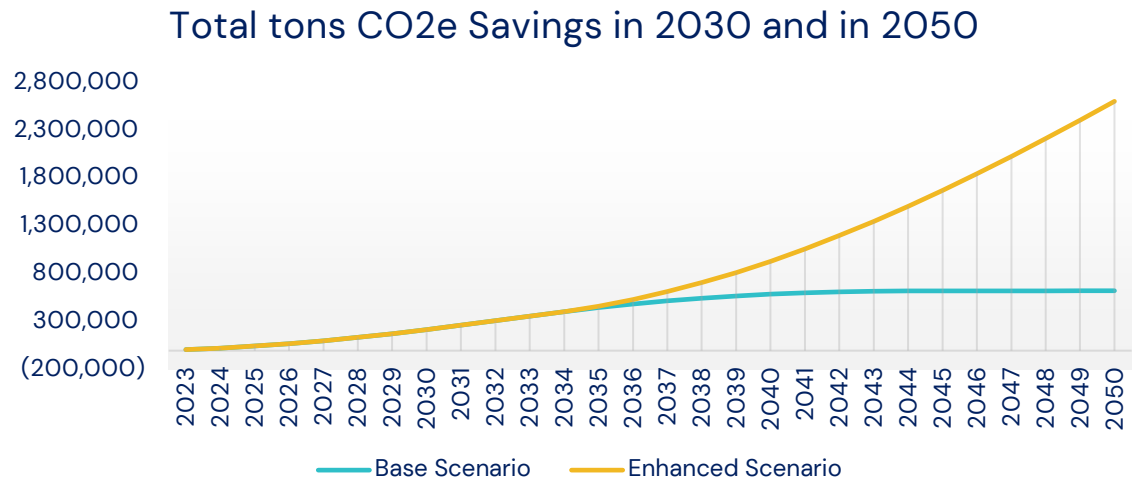
In the **enhanced scenario**, a key assumption was that the entire bus fleet is electrified by 2050 unless the city defined an earlier target for full electrification. Unless that city had no specific target, we estimated the fleet up to 2050 based on the population growth in the city. We assumed the fleet availability per 1000 inhabitants would remain unchanged until

2050. This will lead to an approximate fleet size of 4.530 vehicles in 2050, and the city needs to procure 8.650 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 79% and that transmission and distribution losses will gradually be reduced to 6% 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:

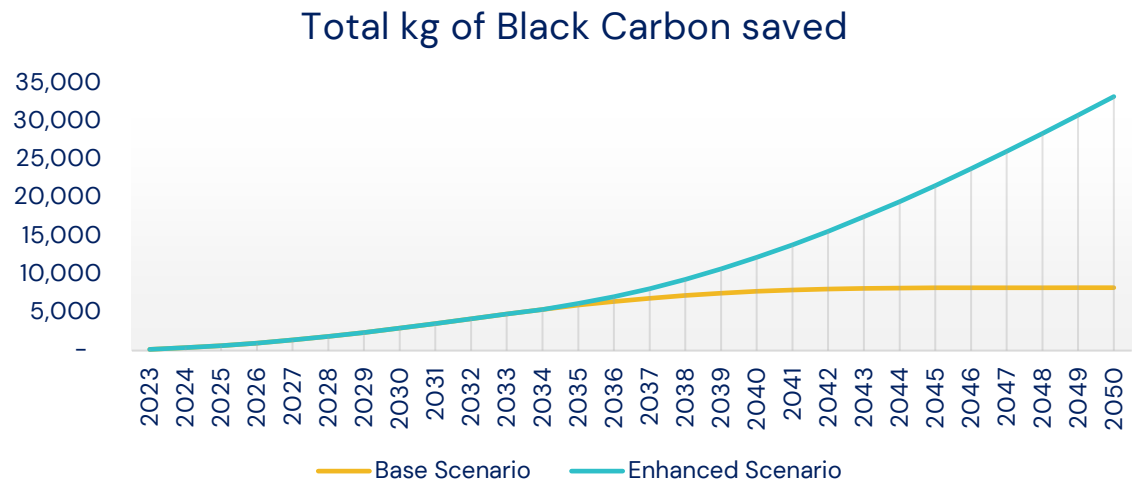
Category (unit)	Base Scenario		Enhanced Scenario	
	Up to 2030	*Up to 2050*	*Up to 2030*	*Up to 2050*
BC (tons)	3	7	3	30
CH_4 (tons)	9	26	9	104
CO (tons)	54	153	54	642
CO_2 (kilo tons)	220	624	220	2.617
CO_2e (kilo tons)	220	625	220	2.621
N_2O (tons)	2	5	2	19
NMVOC (tons)	3	10	3	55
NO_x (tons)	71	206	71	930
PM_{10} (tons)	30	85	30	347
$PM2_{.5}$ (tons)	16	45	16	183
SO_x (tons)	-2	-5	-2	-15
TSP (tons)	45	128	45	521
Energy consumption (MWh)	430.000	1.230.000	440.000	5.360.000
Energy consumption (TOE)	40.000	110.000	40.000	460.000

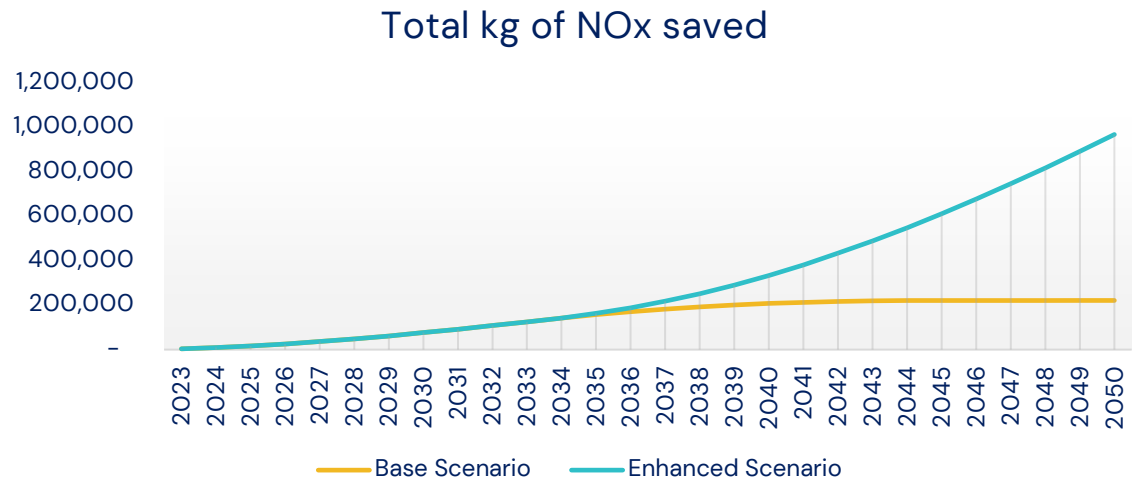
As Barranquilla has set a target for 2030, the savings in the enhanced scenario and the base scenario follow the same path until 2030. By shifting to e-buses, the base scenario shows a reduction of 220 $ktCO_2e$ emissions by 2030. In the long-term, until 2050, the reduction amounts to about 625 $ktCO_2e$. The amount of CO_2e reduced for the enhanced scenario by 2030 remains the same as the base scenario, however, by 2050 the saving increases twelve times more than the base scenario by 2.621 $ktCO_2e$.

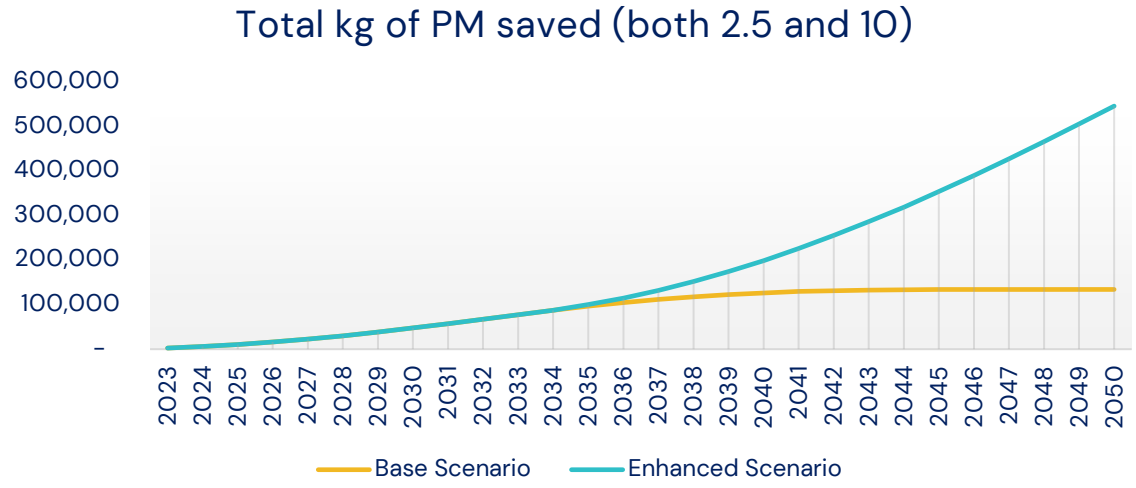


Electric buses decrease greenhouse gas emissions and improve air quality in the local area. The transition towards e-buses is expected to save the city a significant amount of black carbon, with an estimated 3 tons in 2030 and 7 tons by 2050 in the base scenario. Furthermore, the base scenario also predicts a significant reduction of about 206 tons of NOx and 130 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, NOx and particulate matter by 2050 are 30 tons, 930 tons and 530 tons, respectively. The savings from the enhanced scenario are around four times of 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.







Emission reduction potential at a national level

Through the NDC update in 2020 and 2021, Colombia targeted 51% emissions below 2005 levels by 2030 and aims to be climate neutral by 2050[6]. In 2020, IEA reported that 27 Mt of CO_2 were emitted by the transportation sector in Colombia, of which 98% were emitted from road transportation[7].

On a national level, E-BEAT estimates that the average annual CO_2 savings per bus in Colombia for the enhanced scenario are 49 tonnes and 53 tonnes in 2030 and 2050, respectively. 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 9 Mt in 2030 and 12 Mt in 2050. To put into context, the number is then compared to the 2020 road

[6] Climate Action Tracker, 'Colombia'.

[7] IEA, 'Greenhouse Gas Emissions from Energy'.

transport emission level. It shows that by shifting the ICE buses into e-buses, Colombia will reduce 33% and 44% of its road transport emission in 2030 and 2050, respectively.

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