Climate and Air Quality Scenarios for E-Bus Deployment:

Deep Dive City Campinas, Brazil

City Characteristics

Campinas is a municipality in the State of Sao Paulo, Brazil. The city has a population of ca. 1.2 million inhabitants in 2021 and an area of 797.6 square km. Campinas presents an urbanisation rate of 98.28%, which is, extremely urbanized[1]. The surrounding Metropolitan Area of Campinas has ca, 3.2 million inhabitants, consists of 20 municipalities and covers an area of ca. 3.800 km with a population density of around 840 people per square km[2].

The Metropolitan Region of Campinas (RMC) was created by Complementary Law no. 870, of June 19th, 2000, to integrate and organize the planning and common interest, such as land use, transportation and regional road system, housing regional road system, housing, basic sanitation, environment, health, education, and public security of its constituent municipalities. The municipality of Campinas is located in a transition area between the Atlantic Plateau, with hills and mountains and a maximum altitude of 990 meters, located in the eastern part of the municipality. The western part is located in the Peripheral Depression, formed by a relief of hills, with altitudes ranging between 600 and 700 meters[3].

Campinas is located in a transition area between tropical and subtropical climates. The average annual rainfall is 1.900 mm/year, with the average temperature around 21°C. The rainy period is from October to March and the dry period is between April and September. Main climate-related risks include extreme temperature, river floods, urban floods, droughts, and land fires.

The City of Campinas is one of the richest in Brazil. The Metropolitan Region of Campinas (MRC) is considered an economic, industrial, scientific and technological centre of the State of São Paulo. The diversified economy and the qualification of the workforce are some of the major reasons for the stage of technological maturity reached by the municipality. The Gross Domestic Product (GDP) of Campinas is the largest in the Metropolitan Region of Campinas at USD 12.8 billion. The Human Development Index (HDI) of Campinas in 2010 was 0.805, the 28th in Brazil (out of 5,565)[4]

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[1] Prefeitura Municipal de Campinas, Secretaria de Transportes, 'Concessão Do Transporte Público. Apêndice 01 – Informações Gerais Do Município'.

[2] Governo do Estado de Sao Paulo, 'Região Metropolitana de Campinas (RMC)'.

[3] Prefeitura Municipal de Campinas, Secretaria de Transportes, 'Concessão Do Transporte Público. Apêndice 01 – Informações Gerais Do Município', 8–9.

[4] United Nations Development Programme, 'IDHM Municípios 2010'.

Transport system

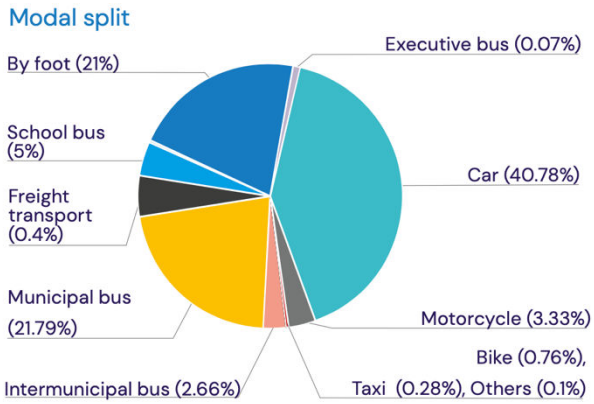


Figure 1: Modal Split. Source: TUMI E-Bus Mission (2022)

Residents of Campinas made an average of 1.81 trips per person and day[5]. The transport system mostly relies on private motorised mobility (car: 40.78%, motorcycle (3.33% of modal split) and bus use (ca. 30% of modal split). Walking accounts for 21% of all trips, while less than 1% of trips are done by bike and taxi. Surveys carried out in the municipality indicate that 53% of cyclists in the municipality use the bicycle as a means of transportation and not only as a leisure mode.

The current Public Transportation System of Campinas, InterCamp, is operated by buses from the public transportation concessionaires. It was created from the proposal of making public transportation induce changes in the conditions of mobility and circulation of people, redefining the concept of the network of lines, the hierarchy of services and establishing and establishing a model of connection and articulation.

In November 2022, the bus network comprised 203 lines and 890 vehicles. More than 60% of the bus fleet consisted of standard and padron buses, 17% were midi buses, 5% were minibuses, and 16% articulated. In 2019, 528,635 passengers were carried per day[6].

Empresa Municipal de Desenvolvimento de Campinas EMDEC is the public transport authority in Campinas. It inter alia supports the operational planning of the public transport network and manages contracts with transport operators[7] which own and operate public buses. Service provision is organized via tendered contracts between the city and transport operators[8]. Tenders are specified in a public participation process City Hall of Campinas[9].

In 2022, Campinas launched new tenders for the concession of the municipal bus services. The tenders require operators to deploy new, more comfortable zero-emission buses in their

[5] Prefeitura Municipal de Campinas, 'Prefeitura Abre Licitação Para Concessão Do Transporte Público'.
[6] C40 Cities, Zebra, and TUMI E-Bus Mission, 'Investment Guide for Zero-Emission Buses in Brazil.'; Prefeitura Municipal de Campinas, 'Prefeitura Abre Licitação Para Concessão Do Transporte Público'; TUMI E-Bus Mission, 'Factsheet - Campinas'.
[7] C40 Cities, Zebra, and TUMI E-Bus Mission, 'Investment Guide for Zero-Emission Buses in Brazil.', 34.
[8] NDC partnership, 'Charging Ahead: The Growth of Electric Bus Markets in Latin American Cities'.
[9] Prefeitura Municipal de Campinas, 'Prefeitura Abre Licitação Para Concessão Do Transporte Público'.

fleets[10]. Concessions are awarded for 15 years, with options to extend for another five years[11]. This prologued contracting period facilitates the recovery of capital costs for new e-buses over [12].

Campinas plan to electrify 20% of their public transit buses through a concessions scheme[13] with private companies. It is estimated that fleet electrification in Campinas will reduce around 20% of GHG emissions by 2030 compared to the 2017 baseline scenario[14].

Climate and air pollution targets

The city of Campinas aims to reduce air pollutants and greenhouse gases, according to Law No. 16.022, of November 5, 2020[15].

Reduction of air pollutants, compared to 2016 levels		Reduction of greenhouse gas emissions, compared to 2016 levels	
2025	5%	**2025**	5%
2030	8%	**2030**	8%
2040	15%	**2040**	16%
2060	31%	**2060**	32%

Law No. 16.022 further mentions "prioritising non-motorized modes, micro-mobility solutions, sharing and circulating public transport powered by clean energy over individual transport in ordering the road system in Campinas"; "norms for urban planning and land use [...] about infrastructure and equipment, transport and the environment, aiming at the mitigation of greenhouse gases and pollutants"; and stresses "the effective prevention and control of atmospheric pollution, considering its fixed and mobile emission sources".

The city of Campinas plans to start elaborating its Climate Action Plan in 2023, besides updating its Greenhouse Gas (GHG) Emissions Inventory. The mayor of Campinas signed in September 2022, the "Commitment to Compliance with Environmental Agreements on Climate, Resilience and Biodiversity". The document brings guidelines for the elaboration of an intersectoral action plan, with municipal actions aligned with initiatives from the State of São Paulo. Among the environmental agreements contemplated are Race To Zero (Global Campaign of the United Nations – UN); Race To Resilience (Campaign Supported by the UN); São Paulo Environmental Agreement (of the State of São Paulo). Also, part of the Charter is

[10] C40 Cities, Zebra, and TUMI E-Bus Mission, 'Investment Guide for Zero-Emission Buses in Brazil.', 16.

[11] Prefeitura Municipal de Campinas, 'Prefeitura Abre Licitação Para Concessão Do Transporte Público'.

[12] C40 Cities, Zebra, and TUMI E-Bus Mission, 'Investment Guide for Zero-Emission Buses in Brazil.', 34.

[13] . ICCT, 'New Concession Bidding Process Could Help Soot-Free and Zero-Emission Buses in Campinas'.

[14] ICCT.

[15] Prefeitura Municipal de Campinas, 'LEI Nº 16.022, DE 5 DE NOVEMBRO DE 2020, Institui a Política Municipal de Enfrentamento Dos Impactos Da Mudança Do Clima e Da Poluição Atmosférica de Campinas.'

the Edinburgh Declaration (positioning document of the subnational governments in contribution to the New Global Framework for Biodiversity Post-2020).

Targets and policies related to the procurement of e-buses

The Urban Mobility Development Fund – UMFD, established by Decree nº 21.821, 07/12/2021, aims to enable the implementation of the Urban Mobility Plan and the Campinas Road Plan. The UMFD is linked to the budget of the Municipal Transportation Secretary, which will establish guidelines and premises for the management of urban mobility and the transportation and traffic systems of the Municipality. The resources of the Fund may come from budget appropriations, from resources transferred by the Union or State Government agencies, from revenues from agreements with public or private entities, among other sources. The UMFD Board of Directors will be chaired by the Municipal Transportation Secretary, who will also have a representative from EMDEC, which will manage the Fund, as well as representatives of the Secretaries of Finance and Legal Affairs.

Campinas has a short-term target to achieve 309 e-buses by 2026. There are no targets defined for the period after 2030. In 2022, 15 E-buses were operating in the city of Campinas. The city plans to have more than 200 electric buses until the end of the current concession period, with a staggered growth of vehicles between the first and fifth years. Over the next five years, Campinas has planned for the inclusion of an average of 51 ZE buses per year, reaching 25% of its fleet[16].

The current tender seeks to adapt the system to the challenges of the 21st century, such as the post-pandemic drop in passenger demand; the competition from other modes, e.g., transportation by apps; and the adoption of remote working by several companies. Other points considered in the current process are the economic, social, and environmental balance of the system and the operation of the BRT (Bus Rapid Transit) corridors. Among the premises are also the cost reduction in the face of the high fuel prices in the transportation sector; the incentive to the adoption of a clean and environmentally sustainable fleet; and the optimization of the lines to fit the city's road plan.

Besides the use of tenders (as mentioned above), Campinas is planning to introduce zones in which only electric buses are allowed to operate to speed up the diffusion of e-buses[17].

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,

[16] C40 Cities, Zebra, and TUMI E-Bus Mission, 'Investment Guide for Zero-Emission Buses in Brazil.', 32; Prefeitura Municipal de Campinas, 'Prefeitura Abre Licitação Para Concessão Do Transporte Público'.

[17] NDC partnership, 'Charging Ahead: The Growth of Electric Bus Markets in Latin American Cities'.

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	240	0	390	1.090
T&D Losses	18%	18%	16%	9%
% of Renewable Energy	85%	85%	85%	85%

In the **base scenario**, we have considered both short-term and long-term targets set by the city (i.e., 309 e-buses by 2026). 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 85% and constant transmission & distribution losses of 18%.

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. In this scenario, the fleet size will be 1.090 buses. This would mean that the city will have to procure 2.330 buses between 2023 and 2050, considering the fleet retirements. In addition, we assumed that the future electricity mix has a higher share of clean energy and

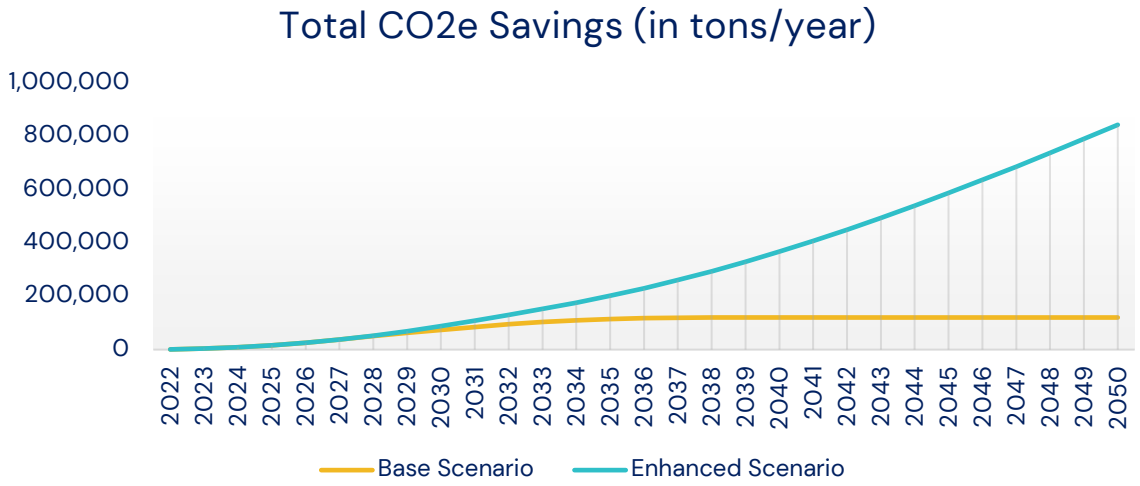
that projected transmission and distribution losses will be halved by 2050 compared to 2023. For Brazil, we have assumed that the share of electricity generated from renewable sources will increase to 85%, and the T&D losses will be halved to 9% up to 2050.

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:

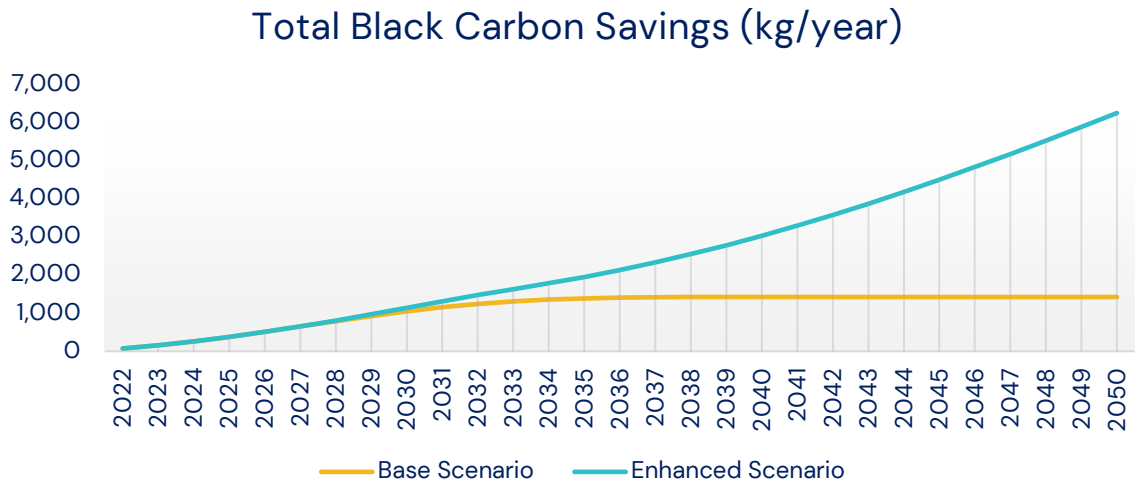
Category (unit)	Base Scenario		Enhanced Scenario	
	Up to 2030	*Up to 2050*	*Up to 2030*	*Up to 2050*
BC (tons)	1	1	1	6
CH_4 (tons)	3	4	3	29
CO (tons)	27	39	30	209
CO_2 (kilo tons)	74	120	88	840
CO_2e (kilo tons)	74	120	88	841
N_2O (tons)	0	1	1	6
NMVOC (tons)	3	4	3	29
NO_x (tons)	61	84	67	356
PM_{10} (tons)	8	13	10	90
$PM2_{.5}$ (tons)	4	7	5	46
SO_x (tons)	0	0	0	0
TSP (tons)	12	20	15	137
Energy consumption (MWh)	110.000	190.000	140.000	1.450.000
Energy consumption (TOE)	10.000	20.000	10.000	120.000

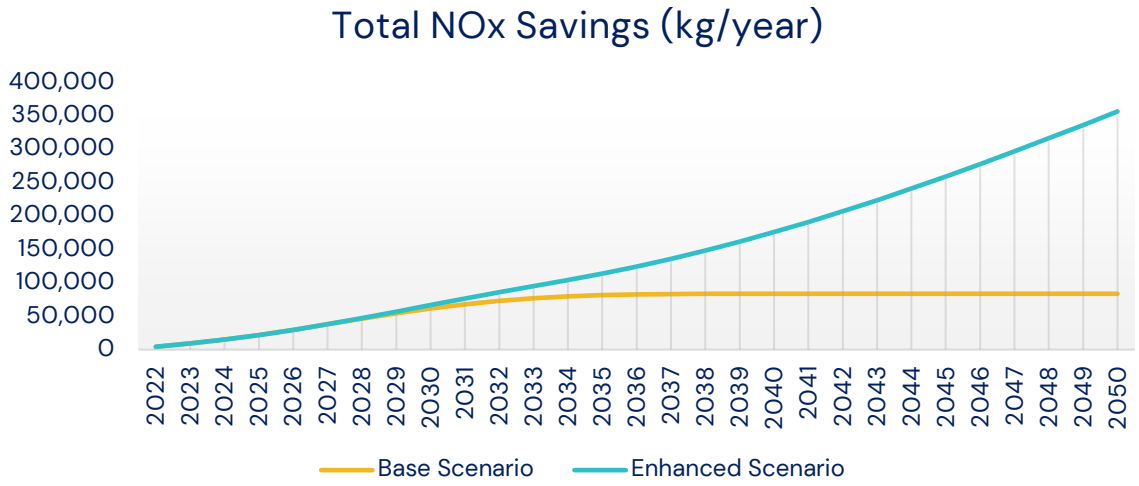
In the base scenario, by shifting to e-buses, the city can reduce emissions to a magnitude of up to 74 $ktCO_2e$ until 2030, provided the envisaged 309 electric buses replace the conventional vehicles. The total emissions saved will be about 120 $ktCO_2e$ until 2050.

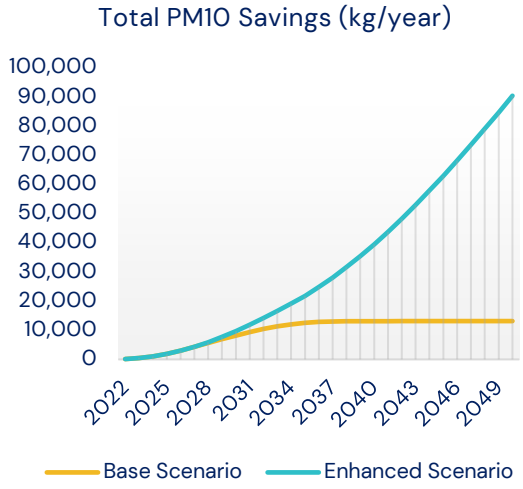
In the enhanced scenario, the city will reduce 88 $ktCO_2e$ until 2030 and 841 $ktCO_2e$ up to 2050. As over 80% of the Brazilian energy mix originates from hydropower and other renewable energy sources, the improvement in the grid makes a minor difference in the emissions. The high magnitude of savings in GHG emissions is primarily due to the large number of e-buses replacing conventional buses.

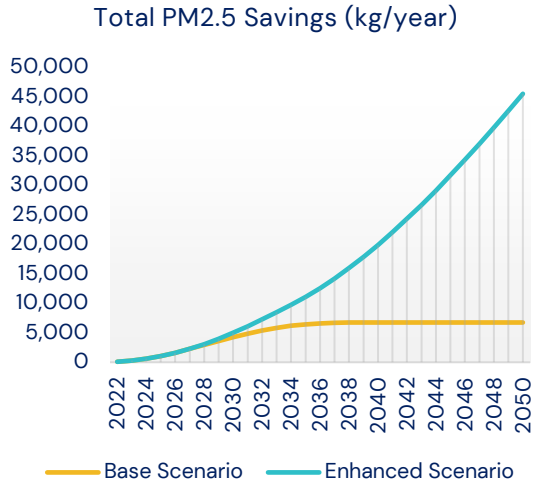


Electric buses decrease greenhouse gas emissions and improve air quality in the local area. The transition towards e-buses is expected to save the city 1 ton of black carbon in 2030 and 2050 for the base scenario. Furthermore, the base scenario also predicts a significant reduction of about 84 tons of NOx and 20 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 6 tons, 356 tons and 136 tons, respectively. The black carbon and particulate matter savings from the enhanced scenario are more than six times compared to the base scenario, while the NOx savings from the enhanced scenario is around four times larger 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.









Emission reduction potential at a national level

Through the NDC update in 2022, Brazil targeted 50% emissions below 2005 levels by 2030 and aims to be climate neutral by 2050[18]. In 2020, IEA reported that 182.5 Mt of CO_2 were emitted by the transportation sector in Brazil, of which 92% were emitted from road transportation[19].

On a national level, E-BEAT estimates that the average annual CO_2 savings per bus in Brazil for the enhanced scenario are 60 tonnes and 61 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 37 Mt in 2030 and 53 Mt in 2050. To put into context, the number is then compared to the 2020 road

[18] Climate Action Tracker, 'Brazil'.

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

transport emission level. It shows that by shifting the ICE buses into e-buses, Brazil will reduce 22% and 32% of their road transport emission in 2030 and 2050, respectively.

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