Urban Pathways

SCENARIOS OF POTENTIAL REDUCTION OF EMISSIONS BY DIFFERENT BUS TECHNOLOGIES - CASE STUDIES OF QUITO, ECUADOR AND MONTEVIDEO, URUGUAY

Yutong Buses 2021

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The Urban Pathways project helps delivering on the Paris Agreement and the NDCs in the context of the New Urban Agenda and the Sustainable Development Goals. It has established a facility in close cooperation with other organisations and networks active in this area to support national and local governments to develop action plans and concrete implementation measures to boost low-carbon urban development. This builds on UN-Habitat's role as "a focal point on sustainable urbanisation and human settlements including in the implementation and follow-up and review of the New Urban Agenda". The project develops national action plans and local implementation concepts in key emerging economies with a high mitigation potential. The local implementation concepts are being developed into bankable projects, focusing on the access to urban basic services to create a direct link between climate change mitigation and sustainable development goals.

Project concept

The project follows a structured approach to boost Low Carbon Plans for urban mobility, energy and waste management services that deliver on the Paris Agreement and the New Urban Agenda. The project works on concrete steps towards a maximum impact with regards to the contribution of urban basic services (mobility, energy and waste management) in cities to global climate change mitigation efforts and sustainable and inclusive urban development. This project makes an active contribution to achieve global climate change targets to a 1.5°C stabilisation pathway by unlocking the global emission reduction potential of urban energy, transport and resource sectors. The project will contribute to a direct emission reduction in the pilot and outreach countries, which will trigger a longer term emission reduction with the aim to replicate this regionally and globally to make a substantial contribution to the overall emission reduction potential.

Project aims

This project implements integrated urban services solutions as proposed in the New Urban Agenda providing access to jobs and public services in urban areas, contributing to equality and social coherence and deliver on the Paris Agreement and the Sustainable Development Goals.This is the first dedicated implementation action oriented project, led by UN-Habitat to deliver on inclusive, low-carbon urban services. Securing sustainability and multiplier effect, the project aims to leverage domestic and international funding for the implementation projects that will follow from this initiative

Urban Pathways

Urban Pathways Project and Replication Cities

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Every human action cannot be done without causing any type of adverse effect in the nature. Modern societies' ways of consuming and living have driven our planet to its balance limits. In the last two decades, extreme climate events have occurred around the world with unaccountable human, environmental and economic losses, especially in developing countries. The transport sector is no exception. With a mobility based on fossil fuels, it is a major contributor to global warming and pollution around the world (Gerike and Koszowski, 2017).

Therefore, a variety of international regulatory frameworks and commitments have addressed the need to act and diminish greenhouse gas emissions and protect public health. Accordingly, with the ongoing international agendas for climate change and sustainable development, a public transport system should at least cover the three dimensions of sustainability. Several international bodies have addressed this issue. For example, the European Union Council states that a public transport system to be called sustainable should at least meet the following criteria:

"Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health and promotes equity within and between successive generations.

Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.

Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise" (European Commission, 2001)."

Therefore, the achievement of a sustainable public transport system should be part of the local and national policies as part of their strategies to accomplish with the SDGs and Paris Agreement and to protect people´s health in the cities. This report, as part of the "URBAN PATHWAYS: Supporting Low Carbon Plans for Urban Basic Services in the context of the New Urban Agenda " project, intends to give a general overview about the impact of motorized public transport emissions on public health and the expected savings in greenhouse gases (GHG) and air pollutants if selected public transport corridors in Quito and Montevideo are electrified with battery electric buses (BEBs).

EMISSIONS OF MOTORIZED PUBLIC TRANSPORT AND PUBLIC HEALTH

In the past twenty years it has been largely investigated the short- and long-term impacts of emissions coming from diesel and gasoline powered vehicles on public health and climate change. The most common transport emissions are: carbon dioxide (CO2), carbon monoxide (CO), nitrous oxide (N2O), nitrogen dioxide (NO2), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), SO2 (Sulphur oxides), and particulate matter (PM10, PM2,5) and troposphere ozone (O3) precursors (Dobranskyte-Niskota, 2009). These compounds are classified into greenhouse gases (GHG) directly linked to climate change and air pollutants affecting human health. In the first group are CO2, N2O, and O3. Air pollutants often include CO, NOx, NMVOCs, and particulate matter (Miller, 2016).

Carbon dioxide (CO2)

CO2 is a standard greenhouse gas naturally existing in the atmosphere, accounting for about 75% of emissions in the air human beings breathe. It can live in the atmosphere for thousands of years. Research also shows that the level of carbon dioxide concentration has risen to 355 parts per million (PPM), compared to 270 PPM recorded in the 1700s. Carbon dioxide can affect health negatively. That includes dizziness, headaches, restlessness, difficulty breathing, tiredness, convulsion, elevate blood pressure, and increased heart rate (Brooks, 2021).

Ozone (O3)

Tropospheric ozone can cause coughing and sore or scratchy throat, more difficulty to breathe deeply and vigorously and cause pain when taking a deep breath, inflame and damage the airways, make the lungs more susceptible to infection, aggravate lung diseases such as asthma, emphysema, and chronic bronchitis, and increase the frequency of asthma attacks. People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors, especially outdoor workers (EPA, 2021).

Carbon Monoxide (CO)

Carbon monoxide is a color- and odorless gas which, being a dangerous respiratory poison, can lead to death by suffocation. The first unspecific symptoms of poisoning are nausea, dizziness, or headache. It is only later that heart palpitations, impaired consciousness and muscle weakness occur. These impairments prevent the affected person from leaving the room and getting to safety. Carbon monoxide poisoning does not always necessarily lead to death. However, it is agonizing and can have long-term neuropsychological effects, such as anxiety and movement disorders (BFR, 2020).

Particulate matter (PM10, PM2,5)

Particulate matter is mainly related to diesel and older Euro engine technologies. It has been associated with short term and long term increases in mortality and increases in respiratory symptoms, greater use of drug treatments in people with asthma, reduction in lung function, and admissions to hospital for respiratory and cardiovascular disease. The PM2,5 is particularly harmful since it penetrates deeply into the lung and the blood circulation (Barassa, 2021). No threshold could be identified below which health effects were not found (Ribeiro et al., 2020).

Nitrogen Dioxide (NO2)

Nitrogen Dioxide (NO2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NOx). Other nitrogen oxides include nitrous acid and nitric acid. NO2 is used as the indicator for the larger group of nitrogen oxides. A high concentration of NO2 in the air can irritate airways in the human respiratory system. Short periods exposures can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO2 (EPA, 2021).

SCENARIOS OF POTENTIAL REDUCTION OF EMISSIONS BY DIFFERENT BUS TECHNOLOGIES

Quito case study

Quito is the capital of Ecuador, a South American country located between Peru and Colombia in the pacific coast of the continent. Quito is located at 2.800 meters above sea level and has a population of 3 million inhabitants. The urban structure of the city is particularly a longitudinal form from north to south. Due to topographic, urban and transport development the transversal connections are partial. Therefore, the transport in Quito is characterized by a big public transport demand in both directions (north – south) with a growing demand coming from the eastern valleys to the city center in the last 10 years. The public transport system in Quito's Metropolitan District (DMQ) is called the Integrated Public Transport System (SITP). This system is structured by exclusive BRT corridors running north to south, the feeder lines to BRT corridors, running east to west, and conventional lines that have specific routes and provide urban services, as well as services within and between city districts intra- and interparochial routes. Additionally, a metro line was built parallel to the corridors, but is not operating yet. The Metrobus-Q (Metro-Q) is the trunk feeder system that connects the BRT segregated lanes services (trunk system) and the feeder lines. Metrobus-Q has 3 lines or "corridors": Central or Trolleybus, Oriental (Eastern) or Ecovía, and Occidental (Western). These corridors have several organized routes operated with articulated and bi-articulated buses on more than 71 kms of segregated bus lanes. The purpose of this project is to study the Central North Corridor at a prefeasibility level, inaugurated in 2005 and running from La Ofelia Terminal to Playón de la Marín Terminal. The tariff scheme considers an integrated tariff of USD 0.25 normal value, USD 0.12 reduced tariff and USD 0.10 preferential tariff but with the recently built first line Metro the fare ticket will be USD 0,50 for the integrated system and USD 0,35 for the BRT corridors in the coming months (Logit Engenharía Consultiva Ltda., 2020).

The selected corridor has 36 stations including the 2 main transfers stations (one in the north and one in the south) with a distance between stops ranging from 460 m to almost 2km. The northern transfer station of the Central North Corridor (CCN) starts in La Ofelia sector and runs 14,84 km to the south in the heart of the historical center of Quito.

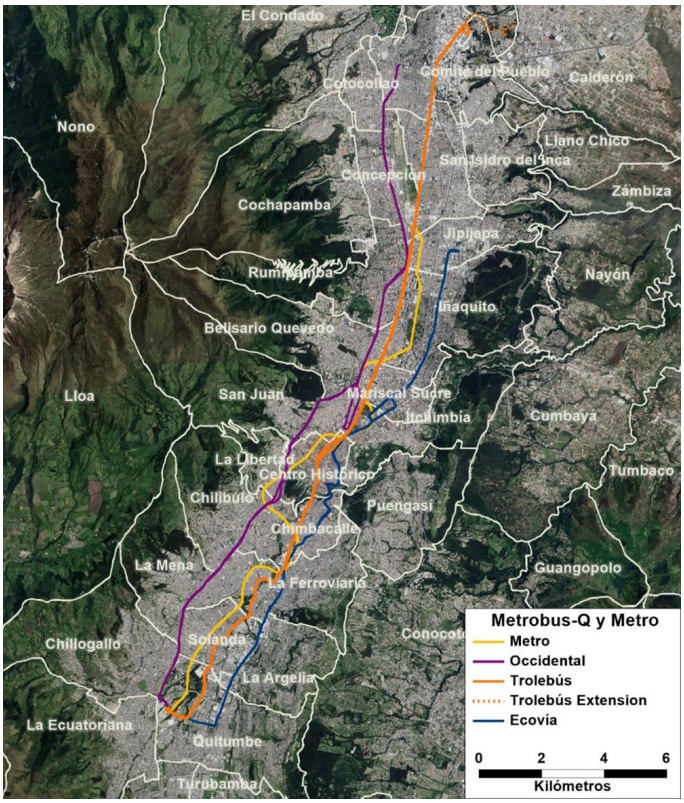

Fig 1. Metrobus-Q BRT Corridor and first Metro line
(Finished but not operative)
Source: (Logit Engenharía Consultiva Ltda., 2020)

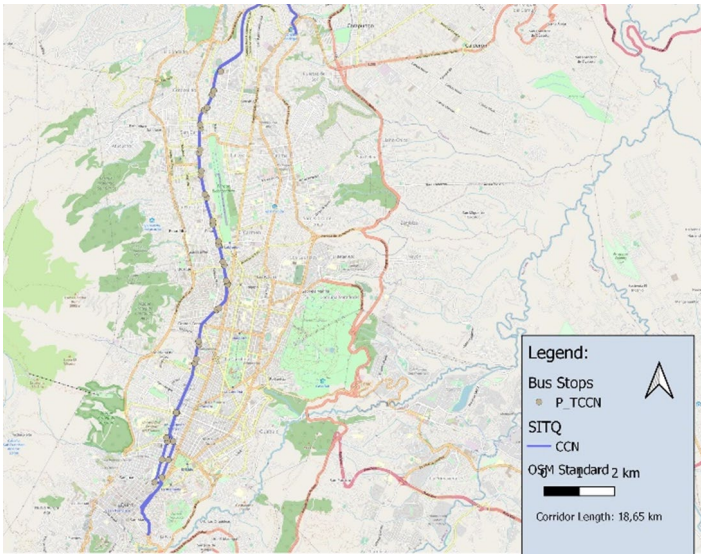

Fig 2. Selected BRT Corridor for case study

Parameters	Length (km)	Bus stops Terminals	Daily Travel Demand (pas-trips)	Distance Service run (km)	Pulling out/in km per veh	Pulling out/in time per veh (min)	IPK
Central North Corridor	14,84	36/2	132.391	29,68	14,84	17,8	4,5
Parameters	**Available periods for charging**	**Service Run Time (min)**	**Yearly mileage per bus (km)**	**Total daily mileage of fleet (km)**	**Current bus fleet (articulated 18m)**	**Commercial speed (km/h)**	**Current bus capacity**
Central North Corridor		98	69.025	12.593,60	64	18	155 p

Table 1. General characteristics of the Central North corridor in Quito

Montevideo Case Study

Montevideo is the capital city of Uruguay, situated on the southern coast of the country, on the northeastern bank of the Río de la Plata. The estimated population for 2022 in the metropolitan area is of 1.76 million inhabitants. It is home to approximately one-third of the country's total population. Montevideo's city proper has a population of 1.3 million inhabitants.

The lines that are analyzed in this report are lines 169 and 143 operated by CUTCSA, a renowned bus operator in Montevideo. Line 169 is 20,8 km long while line 143 was 7,9 km long in 2019. For the line 169 there are three types of services: 1) 169: Ciudad Vieja - Toledo Chica (Direction A: 19,95/Direction B: 23,51 km), 2); 169-2: Aduana – Toledo Chico (A: 21,38/B:21,97 km), and 3) 169 SD: Terminal Ciudadela – Instrucciones (A:16,25/B:16,74 km). Line 143 runs between Ave Battle and Terminal Ciudadela.

The following table shows some general parameters for both lines obtained by the operator and the municipality of Montevideo. The data used for the cost and operational analysis was from year 2019, since they were taken before the pandemic, and it is expected that travel demand and operation conditions return to the former status.

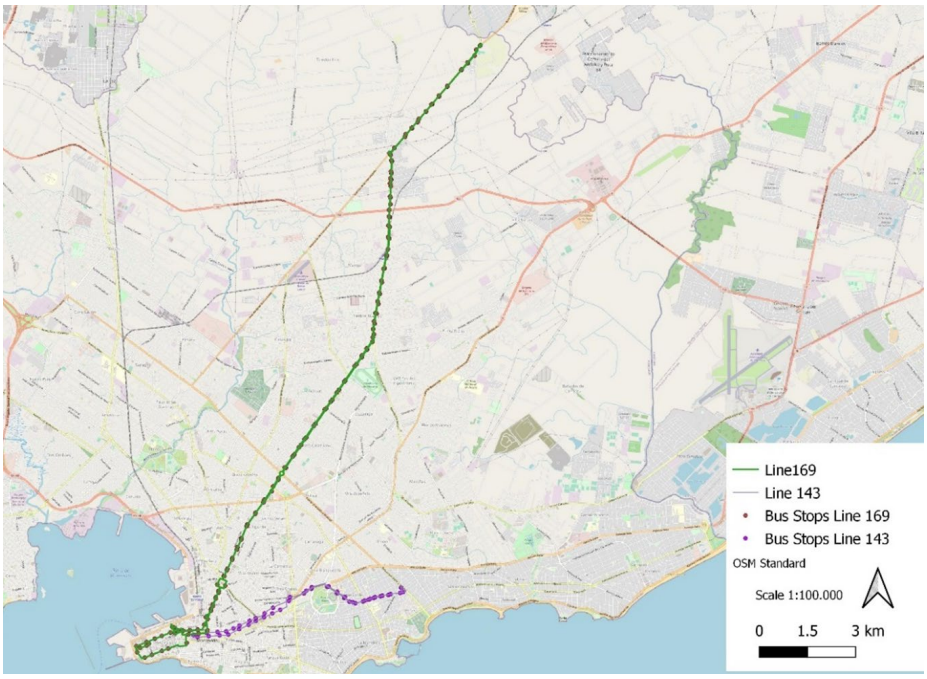

Fig 3. Lines 169 and 143 in Montevideo

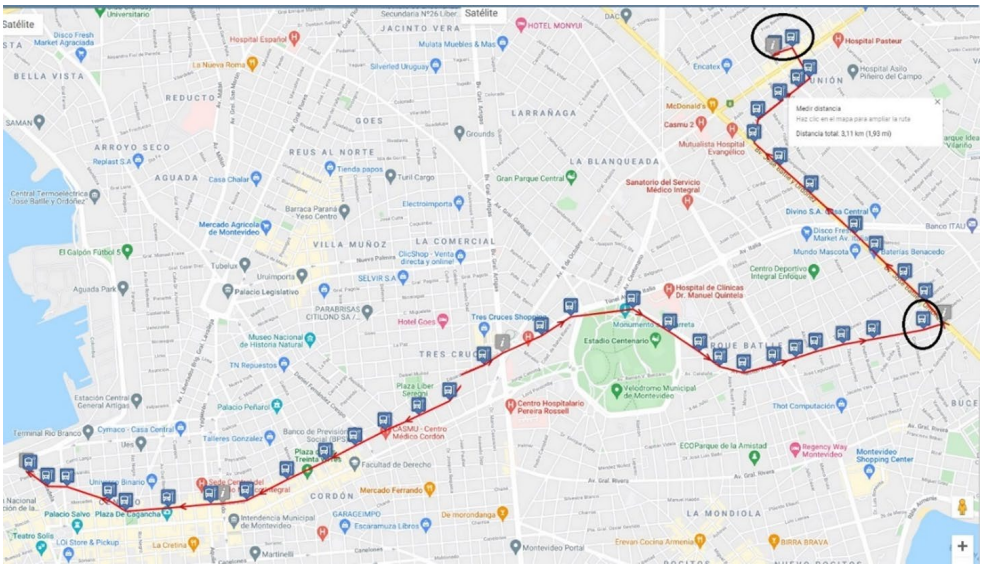

Fig 4. Line 143- 2019

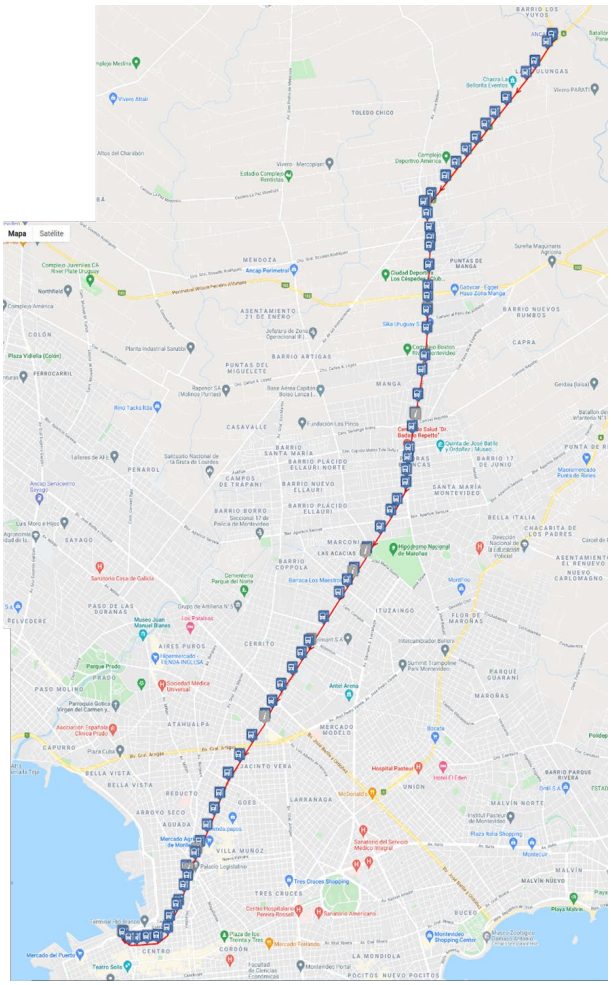

Fig 5. Line 169 - 2019

The following table shows some general parameters for both lines obtained by the operator and the municipality of Montevideo. The data used for the cost and operational analysis was from year 2019, since they were taken before the pandemic, and it is expected that travel demand and operation conditions return to the former status.

Parameters	Length (km)	Bus stops Terminals (both directions)	Yearly Travel Demand (pas-trips)	Service run km	Average occupancy per bus (A/B)*	Max occupancy per bus (A/B)	Current bus fleet (12 m)
Line 169	20,80	73/76	5.172.106	41,01	22,7 (SD:32,5) /21,85 (SD:29)	78/81	29
Line 143	11,01	33/32	1.233.131	22,02	13,6/14,1	57/67	11
Parameters	**Daily mileage of fleet Km**	**Yearly mileage per fleet km**	**Yearly mileage per bus km**	**Daily Mileage per bus km**	**IPK (2018/19/20)**	**Daily average hours-fleet h**	**Commercial speed km/h**
Line 169	4.144,43	1.909.085,32	65.830,53	123,33	3,72/3,76/3,03 (SD: 5,11/5,21/4,7)	261 (max: 304; min: 177,8)	18
Line 143	1.176,44	438.388,89	39.853,54	86,98	3,22	80,41 (max:95,47; min: 23,34)	20

Table 2. Operational parameters of Lines 143 and 169 – Montevideo - 2019
*Direction A: one-way/B: way back; Source: CUTCSA – Intendencia of Montevideo

METHODOLOGY

After the review of different bus technologies for the electrification of BRT corridors and conventional bus lines in Quito and Montevideo, respectively, an analysis of potential emission reduction by different bus technologies will be carried out.

The emissions of diesel buses are based on emission factors defined by every city. The following formula was applied for both cities calculation:

Emissions (ton/year)

=

*FE(g/km)*number of vehicles*yearly mileage (km/(year*veh))*1e^(-6) (ton/g)*

RESULTS

Quito GHG and air pollutants emissions reduction with BEB

Since Quito does not have yet their own emissions factors for diesel buses, we used for CO2 the one calculated by the Diagnosis of Electromobility in Ecuador, sponsored by the Ministry of transport of Ecuador and for other GHG and air pollutants, the recommendation of the Secretary of Environment[1] to use the emission factors of Mexico City. The yearly average mileage applied is 70.393 km/bus.

For articulated diesel buses purchased in 2004, the following emissions factors were applied:

Greenhouse Gases				Air pollutants						
Chemical compounds	CO2	CH4	N2O	COV	CO	NOx	PM10	PM2,5	NH3	SO2
g/km	2580	0,004	0,003	2,744	14,06	12,04	0,936	0,838	0,017	0,005

Table 3. Emissions factors for diesel buses applied in Quito (g/km)
Source: Inventory of Emissions 2012 of Mexico City[2]

If all the 64 articulated diesel buses are replaced by electric buses, the total reduction of greenhouse gases and air pollutants is as follows:

These results show a potential reduction of 5.135,73 ton/y of GHG and 138 ton/y of air pollutants by replacing all the 64 articulated buses with BEBs.

Greenhouse Gases				Air pollutants					
CO2	CH4	N2O	COV	CO	NOx	PM10	PM2,5	NH3	SO2
11397,4	0,018	0,014	12,362	63,342	54,242	4,217	3,775	0,077	0,023

Table 4. Total emissions reduction by electrification of bus fleet in CCN corridor (Ton/year)

Montevideo GHG and air pollutants emissions reduction with BEBs

In the case of Montevideo, the emission factors were taken from the Emissions Inventory 2014[3] published by the Intendencia of Montevideo and are shown in the following table:

CO	HC	NOx	PM10	CO2	SO2
3,59	1,28	13,02	0,53	1067,60	0,03

Table 5. Emission factors for Montevideo (g/km)

1. http://www.quitoambiente.gob.ec/images/Secretaria_Ambiente/red_monitoreo/informacion/inventario_03.pdf
2. http://www.aire.cdmx.gob.mx/descargas/publicaciones/flippingbook/inventario-emisioneszmvm2012/inventario-emisioneszmvm2012.pdf
3. https://montevideo.gub.uy/sites/default/files/biblioteca/inventario2014.pdf

For all type of electric vehicles, the total reduction of emissions is as follows:

	Greenhouse gases		Air pollutants			
	CO2	CO	HC	NOx	PM10	SO2
Emission factors (g/km)	1067,6	3,59	1,28	13,02	0,53	0,03
Emission calculation ton/year (Line 169)	2.038,14	6,85	2,44	24,86	1,01	0,06
Emission calculation ton/year (Line 143)	468,02	1,57	0,56	5,71	0,23	0,01
Total emissions savings (Ton/year)	2.506,16	8,43	3,00	30,56	1,24	0,07

Table 6. Total emissions reduction by electrification of bus fleet in lines 143 and 169 (Ton/year)

The annual avoided emissions of greenhouse gases for Montevideo are 2.257 ton/year, while for air pollutants the final output is 39 ton avoided per year if all bus fleet is replaced in both lines.

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