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GREEN YOUR BUS RIDE
Clean Buses in Latin America

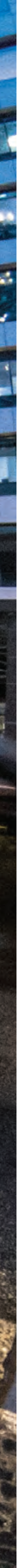
Summary report

January 2019

NDC Support Facility · steer · THE WORLD BANK

Transport is the fastest growing source of greenhouse gas emissions worldwide, responsible for 23% of global CO_2 emissions from fuel combustion. Driven by the unprecedented rate of urbanization and demand for transportation, transport has become the largest contributor of greenhouse gas emissions in Latin America.[1]

1 IEA (2015), IADB (2013).



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Overview

This report presents the findings of a comprehensive study on the drivers and barriers to the uptake of cleaner technologies for public transport in five cities in Latin America: Buenos Aires (Argentina), Mexico City (Mexico), Montevideo (Uruguay), Santiago (Chile) and São Paulo (Brazil). These cities were selected to represent a range of sizes, demographics, economies, transport systems, and governance structures in the Latin America region. Their diverse experience is valuable for informing regional replication efforts on clean bus technologies.

To transform transportation in Latin America for sustainable development, the World Bank has been using a conceptual framework of "Avoid-Shift-Improve": "Avoid" unnecessary motorized trips by creating more compact and productive cities; "Shift" to more efficient and integrated modes such as public transport and non-motorized modes; and "Improve" the environmental and safety performance of vehicles, as well as the operational efficiency of transport systems.

In recent years, a range of clean vehicle technologies have gained increasing appeal in cities due to their multiple benefits derived from converting energy efficiently to vehicle movements, higher compatibility with renewable energy, and lower tailpipe and lifecycle emissions compared with conventional buses. These technologies could improve air quality and public health in cities overall, as well as benefiting climate change globally. They also bring an opportunity to rethinking about how to make public transport more attractive to citizens. The transition to clean buses will thus achieve substantial benefits not only by "improving" actual bus performance, but also by "shifting" people from private vehicles on to public transport - essential for reducing carbon footprints in general, relieving traffic congestion and improving overall urban efficiency.

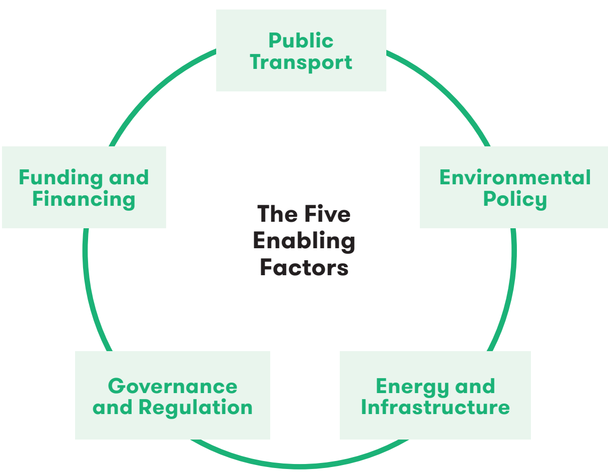
Given the limited information on the barriers and opportunities existing in individual cities

and the region, the World Bank is conducting a programmatic approach aimed at accelerating the transition to clean technology buses. This approach embraces knowledge sharing, strategic planning, capacity building, and financing of projects identification. This promising agenda received funding support from the NDC Support Facility (http://www.worldbank.org/en/programs/ndc-support-facility) as a contribution to the NDC Partnership (http://ndcpartnership.org).

The terms "clean technology bus" or "clean bus" are used interchangeably in this report to refer to a variety of advanced technologies involving lower-emission energy sources, such as clean diesel (Euro VI equivalent), compressed natural gas (CNG), battery-electric (BEB), hybrid diesel-electric (Hybrid or HBD), biofuel and hydrogen-powered buses. The clean bus concept in general entails cities adopting a noncommittal technology-neutral approach while they conduct evidence-based assessments of specific bus technologies tailored to local conditions.

The study includes diagnostics, consultation and recommendations regarding the drivers and barriers to the uptake of cleaner technologies for public transport in five cities in Latin America: Buenos Aires (Argentina), Mexico City (Mexico), Montevideo (Uruguay), Santiago (Chile) and São Paulo (Brazil). These cities were selected to represent a range of sizes, demographics, economies, transport systems, and governance structures. Their experience is valuable for informing regional replication efforts on clean bus technologies.

The data collection methodology included reviewing the latest technical literature and local workshops and interviews with primary stakeholders in all five cities. The stakeholders included key players from government institutions, vehicle manufacturers, financial institutions, bus concessionaires and civil society. Data collection sought to identify the main barriers and opportunities for the uptake of clean buses, by analyzing the five key factors of their enabling environment: Public Transport, Environmental Policy, Energy and Infrastructure, Governance and Regulation, and Funding and Finance.



The work ended with a three-day regional training event in Iguassu Falls, Brazil. The event was attended by Latin American and the Caribbean (LAC) counterparts from ministries of transport, energy, environment, and finance from 12 cities and municipalities in nine countries. Also present were regional stakeholders, including financiers, manufacturers, national transport operators' associations, energy distributors, and partner organizations, consulting firms, and research institutes from the US, China, UK, India and Spain. The discussions and feedback from the event were used to fine-tune the findings and recommendations in this report.

This report first presents an overview of the five cities and a variety of clean bus technologies **(Chapter 1)**, the total costs of ownership of different clean bus technologies in each city **(Chapter 2)**, and an analysis of the cost-effectiveness of emissions reductions in the local contexts **(Chapter 3)**. This is followed by a summary of the diagnostic findings grouped into five key factors that constitute the enabling environment **(Chapter 4)**: A. Public Transport Systems, B. Environmental Policies, C. Energy Sector, D. Governance and Regulation, and E. Funding and Finance. Chapter 4 also includes the self-evaluation results[2] from LAC counterparts.

The report goes on to provide general recommendations for improvements within each of the five factors, categorizing each intervention as essential, desirable or supportive of the level of priority **(Chapter 5)**. The report concludes by recommending specific interventions for each city and displays an implementation roadmap with suggested specific timeframes, priority levels and required stakeholder involvement **(Chapter 6)**.

Clean Bus Technologies

The performance, emissions and costs of clean bus technologies can vary significantly depending on local conditions, including corridor characteristics, energy prices and the market availability of vehicles and parts. The optimal choice of clean bus technology for a particular city or corridor will depend on a variety of factors, including which emissions (e.g. air pollutants or CO_2) are of greatest concern. Feasibility considerations such as upfront costs, availability of finance, ease of operation and maintenance, institutional capacities, and political will, also need to be considered.

2 The self-evaluation exercise, carried out during the Iguassu Falls workshop, involved stakeholders from each country. This is a subjective evaluation that reflects the knowledge of the participants at the workshop but who did not necessarily possess information on all the relevant areas. The evaluation does not represent the view of The World Bank or Steer.

BEBs, with zero greenhouse gas (GHG) and air pollutant emissions at the tailpipe, are the most energy-efficient option among the clean bus technologies, and typically have the lowest lifecycle GHG emissions (grams CO_2 per km) under a well-to-wheels (WTW) analysis. However, the carbon intensity of the electricity grid (grams CO_2 per kWh) and corridor-specific drive cycles (speed, acceleration, deceleration) significantly impact GHG emission rates. Euro VI diesel buses have low air pollutant emission rates, but higher CO_2 emissions than BEBs. CNG buses have low particulate (PM) emissions, but higher CO_2 and smog-precursor emissions (NOx) than Euro VI buses. Net GHG emissions from biofuel buses depend on their energy source and production method, with PM levels similar to Euro VI diesel, but higher NOx emissions.

Total Cost of Ownership

Clean bus technologies have higher upfront capital costs than diesel buses, but these are often offset by lower operational and maintenance costs. Current BEBs generally have higher Total Costs of Ownership (TCO)[3] than diesel buses but, according to Bloomberg, most BEBs are expected to have lower TCO than diesel buses within 2 - 3 years, and the upfront costs for BEBs are projected to be equivalent to diesel buses by 2030[4].

TCO analyses were undertaken for the five Latin American cities using local, national and international data sources, and considering different bus technologies[5] such as: diesel (the baseline for each city), overnight depot and fast "opportunity" charging BEBs, HBD, CNG, and biofuels.

The TCO evaluation revealed that vehicle acquisition costs are different in each city, and that competitive processes (e.g. Santiago)[6] can sometimes lower costs. Moreover, green financing mechanisms can offer significant benefits in countries with high interest rates.

3 Total Costs of Ownership (TCO) include the lifetime costs of vehicle purchase, infrastructure, operations and maintenance, labor, battery overhaul and taxes on vehicles and fuels.
4 Bloomberg New Energy Finance, 2018. Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2.
5 These technologies are not necessarily present today in all cities evaluated. The selection of bus types by city has been determined based on clean bus technologies that the transportation ministry or key institution has set for evaluation, but they have also been validated with the Local WB consultant.
6 BEB prices before applicable taxes in Buenos Aires and Montevideo are 42% and 50% higher than in Santiago (comparing the same vehicle model).

Cost Effectiveness Analysis

The World Bank conducted a cost-effectiveness analysis of the marginal abatement cost (MAC) of reducing a tonne of CO_2 emissions[7] when switching from diesel buses (Euro V)[8] to clean bus technologies. The analysis considered TCO for each technology, as well as the externality costs of air pollution (NOx and PM). Cost-effectiveness analysis is dependent on a set of factors that vary over time (e.g. as technologies evolve), and are subject to local interpretation.[9] Therefore, the results summarized in this report should be taken as a depiction of the current situation at the time of publication, and broader generalizations are not advised.

Diagnostics of Key Barriers and Opportunities

Of the various factors impacting the pace of adoption of clean technologies in urban transport in the five cities, the following issues emerged as key challenges:

- **Public transport system inefficiencies** – such as from informal services offered by small vehicles with high costs of operation, low-quality service and increasing expenditures are of greater concern to both the city authorities and the public than emissions of CO_2 or air pollutants.
- **Small-scale interventions and lack of data on costs and performance.** Lower-emission buses represent about only one percent of all buses in the five cities. While some technologies have been piloted in the five cities, operators express general concerns about the costs, performance, operations, and maintenance of unfamiliar technologies. A lack of data on actual local costs and energy,environmental, and operational performance is also a barrier to comprehensive technology comparisons.
- **High upfront costs** of clean buses, especially for BEBs, pose a significant barrier to short-term uptake, principally in some cities where vehicle prices are still high.
- **Electricity distribution networks under development.** The vast majority of transportation energy use in the five cities is based on oil. However, most of the national governments have set objectives to increase electricity production from renewable sources. New investments will be needed in local electricity distribution networks to support high BEB penetration, including for fast-chargers.
- **Market competition.** High concentration of public transport service delivery by a few companies with strong market power can lead to low levels of service, inefficiencies, and high fares. Limited market competition presents a significant barrier in most cities and current bus operators are resistant to change operating practices and technologies.
- **Understanding and managing the new institutional frameworks.** The need for complex institutional coordination and constraints on competition are emerging as key barriers to the development of the market for cleaner bus technologies. Forthcoming concession tenders in Santiago and São Paulo present potential opportunities for introducing clean buses. Electricity providers can serve as strategic partners in deploying BEBs, and there are opportunities to expand clean bus manufacturing capacity.
- **Lifting financing constraints.** Cities face financial challenges in enhancing the quality, frequency and coverage of public transport systems. The cities face conflicting pressures to keep fares low (i.e. to increase affordability) and to minimize fare subsidies (i.e.to meet budget constraints). The higher upfront costs of clean buses can exacerbate funding and finance challenges, especially since commercial banks and often operators have only minimal knowledge of clean bus technologies and seek to avoid market risks.
- **Procurement processes** tend to focus on reducing upfront costs rather than minimizing TCO.

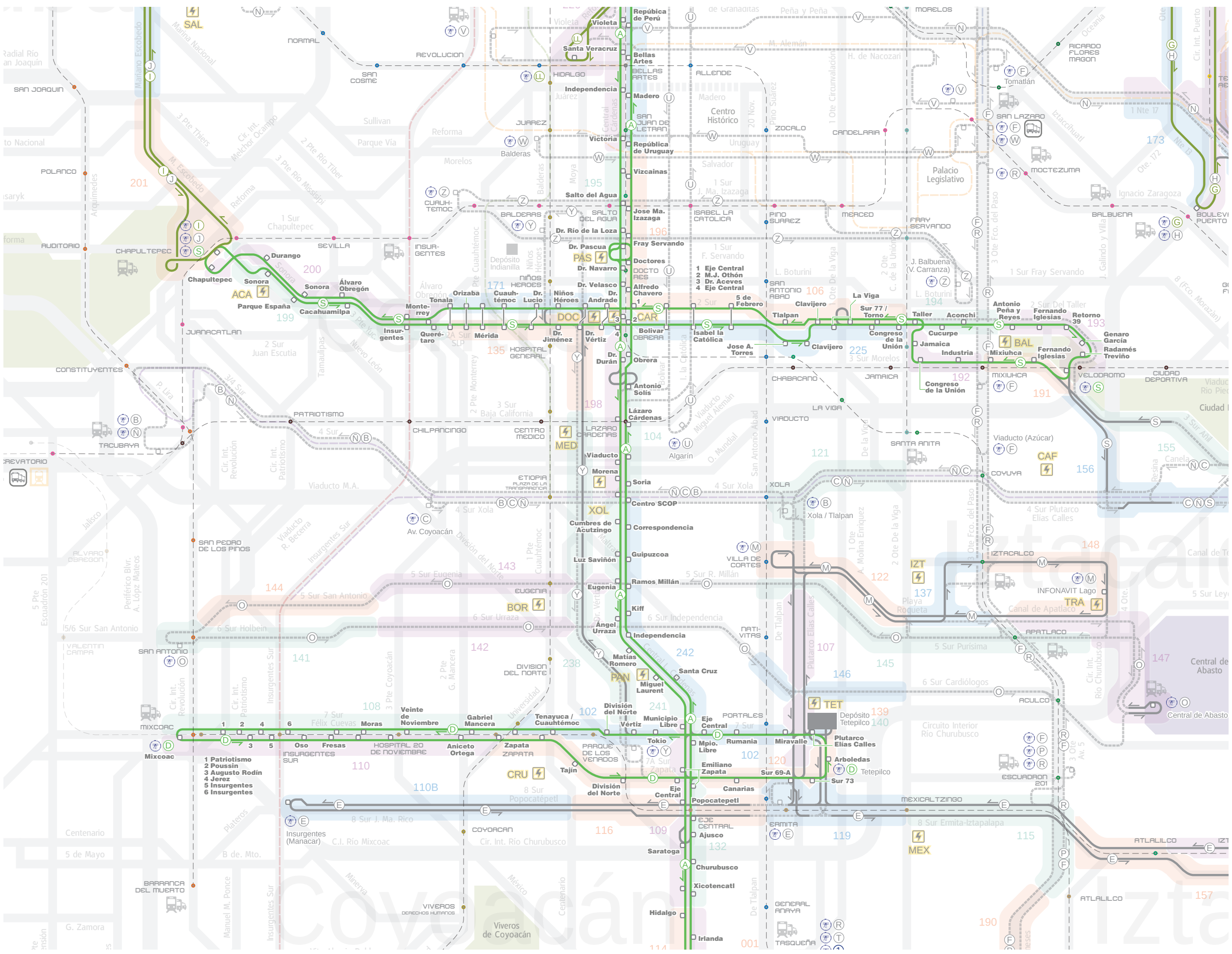
7 Marginal abatement costs are a ratio of incremental cost-effectiveness calculated by taking the difference in costs between clean buses and Euro V diesel buses and dividing that by the difference in CO_2 emissions.
8 We assume a base technology of Euro V for diesel buses for consistency across the five cities. This is a conservative estimate since the buses in the five cities have higher real-world emission performance than what the standards claim.
9 In the presentation of the results below we consider a technology to be "cost effective" if the marginal abatement cost is negative, i.e., generating a net cost savings compared to the base technology. Each city or country may have their own threshold as to what $/tonne level is desirable given other mitigation options and co-benefits considered.

- **Nascent environmental policies for alternative technologies.** All five cities are working to reduce GHG emissions and improve air quality, but often lack data to support and target policy development. Noise pollution is a significant concern but has attracted limited policy attention. The cities lack experience of regulating BEB battery disposal and need policy tools to support battery reuse for energy storage.

General Recommendations

The report includes a number of preliminary recommendations for advancing clean buses. Key points include to:

- The selection of clean bus technology should consider both corridor-specific performance requirements (e.g. distance, speed, capacity, noise) as well as the availability of city-wide infrastructure
- A Total Cost of Ownership (TCO) methodology is recommended to evaluate the financial performance of clean technology buses, particularly BEBs.
- Improving data collection on air and noise pollution is essential in order to capture more fully the benefits of clean vehicle technology
- Public Authorities should provide stakeholders timely and up-to-date information on the capacity of power distribution networks and the adequacy of the charging infrastructure
- City and national governments could join hands with research institutes and academia to share the state-of-the-art battery technology with respect to electric vehicles
- Policies which address market distortions in the operations of conventional vehicles and harmonize emissions standards will do much to improve the economic outcomes arising from private sector involvement in the adoption of clean vehicles
- Improving market competition and concession processes can advance the deployment of clean buses



Introduction

1

Clean buses cover a variety of fuel and vehicle technology combinations. This report considers the following technologies: Euro VI Diesel, Compressed Natural Gas, Biofuel, Hybrid diesel and Battery Electric Buses.

Specific clean bus technologies face a variety advantages and disadvantages in categories such as costs (vehicles, infrastructure, energy, operation and maintenance, secondary market value), feasibility (technology maturity, commercial availability, fuel availability), performance (range, efficiency), and environment: GHGs, air pollution, land use, water use and quality. Table 1.1 below summarizes the key advantages and deterrents of clean bus technologies, which are further discussed below.

Table 1.1.: Advantages of and deterrents to clean bus technologies.

Technology	Advantages	Deterrents
Diesel - Euro VI	• Existing technology • Lowest purchase costs • No need for new infrastructure • Much lower PM than older diesel tech • Known secondary market value	• High GHG emissions • Subject to availability of ultra-low sulfur diesel
Compressed Natural Gas (CNG)	• Readily available from manufacturers • Moderate to low purchase price • Modest price premium compared to other clean bus technologies	• Emission advantages over Euro VI diesel are modest compared to other clean bus technologies • Infrastructure upgrades needed if no existing network
Biofuels	• GHGs can be 40-60% lower than diesel, depending on feedstocks	• Higher NOx emissions than Euro VI diesel • Potential land use concerns: GHGs and competition for food crops • Water use and quality concerns
Hybrid Diesel Electric (HBD)	• 20-30% GHG reduction • Relatively mature technology • Lower operation costs • No new infrastructure needed	• Emission benefits depend strongly on duty cycle and driver efficiency • Higher acquisition cost than diesel
Battery Electric (BEB)	• Zero tailpipe emissions • 50-100% GHG savings (depends on electricity source) • Lower maintenance and operation costs • Starting to become commercially available • Battery costs declining rapidly • BEBs expected to have same upfront cost as diesel by 2030	• Very high bus purchase price • Secondary market value uncertain • Evolving technology with limited commercial application in LAC • Electricity distribution infrastructure upgrades needed for rapid-charging • Range limitations for some BEB
Hydrogen	• Zero tailpipe emissions • 50-100% GHG savings	• Currently in an experimental stage with high vehicle costs • High infrastructure costs

Source: Based on Carnegie Mellon University (2017), Steer (2018), EU (2014), Delucchi (2010) and Bloomberg (2018)

Diesel - Euro VI

Euro VI diesel buses are commercially available and have the lowest purchase costs of the clean bus technologies examined. Existing secondary markets for used diesel buses creates value for fleet owners that is not currently available for newer technologies. Euro VI diesel does not require new transportation infrastructure, but does require market availability of ultra-low sulfur diesel, which may require changes in fuel supply infrastructure (importing, refining, distribution). From an emissions perspective, Euro VI diesel offer only modest GHG benefits, and have significantly lower PM and NOx emissions rates than older diesel technologies, but not as low as BEBs.

CNG

Compressed natural gas buses are readily available from manufacturers at a modest price premium compared to other clean bus technologies. Infrastructure upgrades would be required if there is an inadequate network for CNG distribution. CNG buses emit more CO_2 and NOx than Euro VI diesel buses but have the potential for significant reductions in particulate emissions.

Biofuels

Biofuels from a range of feedstocks can be used to power urban buses including biodiesel and bio-CNG. Greenhouse gas emissions from biofuels can be 40-60% lower than diesel, depending on feedstocks and production techniques, but NOx emissions are much higher than for Euro VI diesels. Biofuel feedstock cultivation can lead to environmental concerns including water use and water quality as well as concerns about land use impacts on GHGs and competition for food crops.

HBD

Hybrid diesel-electric buses are a relatively mature technology with higher upfront costs than diesel and potentially lower operating costs. Hybrids offer low to moderate GHG savings, but GHG benefits depend strongly on drive cycle and driver efficiency.

BEB

Battery electric buses are an evolving technology that is just starting to be commercially available in Latin America. BEBs require high upfront costs for vehicle purchase, but entail lower maintenance and operating costs. Secondary markets for BEBs do not currently exist, thus reducing their full value for fleet owners. With rapidly declining battery costs the TCOs of BEBs are expected to be lower than diesel over the next few years. BEBs may require electricity distribution infrastructure upgrades (such as for rapid-charging). BEBs do not emit local air pollutants and offer potential GHG savings of 50-100% depending on the sources of electricity generation. Some BEBs face range limitations in terms of the number of kilometers that they can drive per charge or per day, so technology selection must be carefully aligned with route requirements.

Hydrogen

Hydrogen buses are currently at an experimental stage and face both high vehicle and infrastructure costs. As with BEBs they have zero tailpipe emissions and have the potential for 50-100% GHG savings, depending on the hydrogen production and transport methods.

Emissions and Noise Pollution from Clean Bus Technologies

Air pollutant and GHG emissions are a function of energy source and vehicle technology.[10] Bus emissions can also vary significantly depending on local and technological conditions such as drive cycle (speeds, acceleration and deceleration) and the condition of emission control devices. Electric buses tend to have the lowest overall emissions rates, CNG buses have low PM_{10}, but relatively high CO_2 emissions, and Euro VI diesel buses perform well for air pollution but not for CO_2.

Thorough GHG analysis should consider full life-cycle emissions, including upstream emissions (e.g. electricity generation, biofuel production, methane leakage from natural gas pipelines), fuel refining processes, and downstream emissions (e.g. vehicle re-use and disposal).

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10 Exposure to particulate matter (PM), especially that smaller than 10 microns, can penetrate deep into the lungs and has been linked to lung and heart ailments (US EPA, a). Nitrogen oxides (NOx) contribute to ground-level ozone pollution, which harms breathing and aggravates lung diseases (US EPA, b).

The life-cycle data in Table 1.2 indicates that low-speed urban operation has higher GHG emissions than medium-speed urban or higher-speed commuter buses.[11] BEBs have the lowest lifecycle GHG emissions, which vary significantly depending on the energy matrix. Biofuel emission rates also vary greatly depending on their feedstock and production method.

Given the significant variation in clean bus performance rates it is essential to measure the actual energy efficiency and emissions rates for clean bus technologies under local driving conditions and energy systems. Pilot testing and ongoing measurement will help inform effective clean bus technology selection and deployment strategies.

11 An average of low and medium speed CO2 values were applied for the cost-effectiveness analysis to reflect typical urban driving conditions in the five cities. The specific emissions factors applied for each bus type and city are displayed in Appendix A.

Each city has its own local character in terms of operation, regulation, stakeholders and environmental conditions, making each of them unique. Moreover, they differ in size, ranging in population from 1.7 to 21.4 million on the metropolitan scale, and from 1.4 to 12.1 million at city level.

Table 1.2: Well-to-wheel GHG emissions (g CO_2e / km).

Technology	Low speed*	Medium speed*	Commuter / suburban
Diesel - Euro VI	2,290	1,840	1,380
CNG - fossil	2,350	1,680	1,200
Hybrid Euro VI	1,800	1,470	1,400
Bio-diesel - plant oils	1,430	1,150	860
Bio-CNG - landfill gas	1,440	1,030	730
BEB - Santiago, Chile	1,070	760	797
BEB - Mexico City	1,050	750	780
BEB - Buenos Aires	860	610	630
BEB - São Paulo	430	310	320

Source: ICCT 2017

*Modeling assumed the Manhattan drive cycle for low-speed routes (average 11 km/h), and the Orange County Transit Authority drive cycle for medium-speed routes (average 19 km/h).

Total Costs of Ownership

2

The choice of optimal bus technology for a particular corridor or city will be informed by a variety of factors, including which pollutants are of highest concern (e.g. GHGs or health impacts of PM), balanced by cost and feasibility considerations, which vary significantly from city to city.

High upfront costs are a major barrier to the uptake of clean bus technologies. Better understanding of the total costs of ownership (TCO), including the costs of vehicle purchase, infrastructure, operation, maintenance and disposal, over the lifetime of the vehicle is essential for informing finance and procurement decisions and for designing effective business models. Similarly, assessing the cost effectiveness of the various bus technologies, such as for service provision and emissions reduction (next chapter), is critical for policy and procurement decisions.

The results of World Bank TCO analyses for each of the five cities are presented in this chapter. These findings are based on data on the current situation, and allow for initial comparisons among bus technologies within each of the five cities, as well as across the five cities. It is important to note that since clean bus technologies and markets are evolving rapidly, current cost estimates and forecasts only represent a snapshot in time that can be expected to change. It is noteworthy that the TCOs of BEBs are decreasing, but the results are highly dependent on local conditions and the battery-charging technology considered. In addition, the acquisition, maintenance and operating costs of clean buses vary significantly across geographies, and information on local costs for non-commercial technologies and maintenance are rarely known with certainty, requiring informed assumptions to support the analysis.

Given the dynamic nature of clean bus technologies and variations in local conditions, these assessments should therefore be considered as a point of departure for deeper, localized analysis and measurement.

World Bank TCO Analysis

The World Bank conducted TCO analyses based on a variety of local, national and international data sources, including technical literature and manufacturer information, exercising professional judgment when city or country-specific data were not available.

The selection of the bus technologies for TCO analysis for each city was based on consultations with local experts, considering implementation potential and the availability of cost data.[12]

Appendix A summarizes the key input data and assumptions used for these analyses. Staff costs refers only to bus operators. Administrative staff costs or common costs to all the technologies, such as tires or fixed costs, are not included.

The TCO estimates for each of the five cities are presented in the following figures.[13]

Buenos Aires TCO Estimates

World Bank TCO Analysis indicates that CNG buses in Buenos Aires have the lowest TCO of the analyzed technologies. Due to higher fuel costs and fuel taxes, TCO for diesel buses is higher, but the fuel cost is subsidized for concessionaires (negative bars). Biofuel buses have TCO 6% higher than CNG, due primarily to higher fuel cost and fuel taxes. Despite lower fuel and maintenance costs, BEBs TCO are higher than the rest of the technologies.

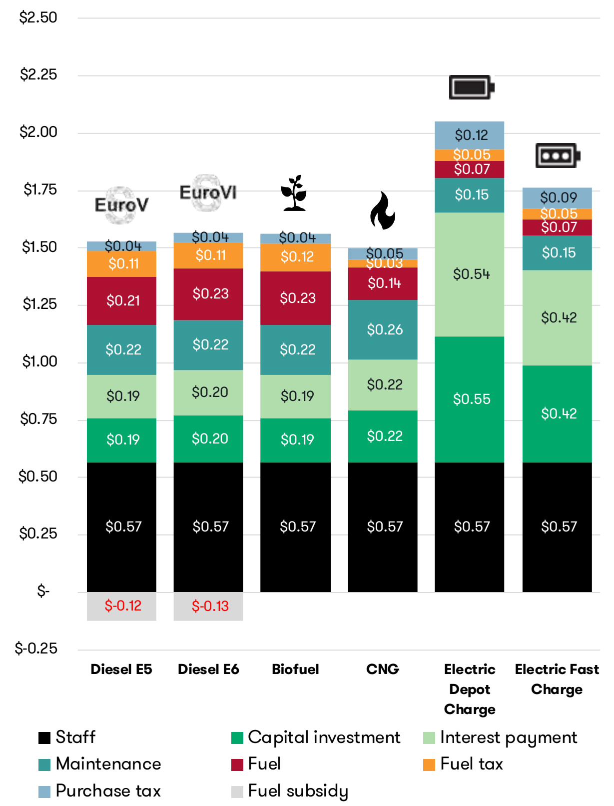
Mexico City TCO Estimates

BEBs in Mexico City have the lowest TCO of the technologies considered to be due primarily to lower fuel and maintenance costs. Hybrid buses have TCO 15% higher than diesel buses, although their fuel cost is lower. Although the TCO for BEBs is lower than the rest of the technologies, no private concessionaires have tested these buses.

12 For example, certain vehicle types or fuels might be excluded from analysis if unavailable in the local market.

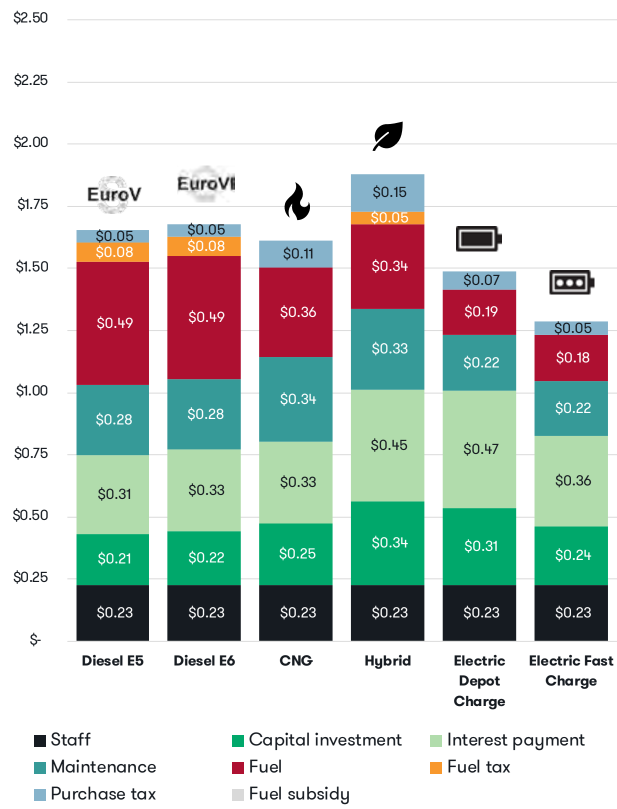
13 Amounts in USD. Note that these TCO graphs do not reflect emission reduction benefits. See the next section on cost effectiveness which addresses emissions.

Figure 2.1: World Bank TCO Buenos Aires estimates ($/km)



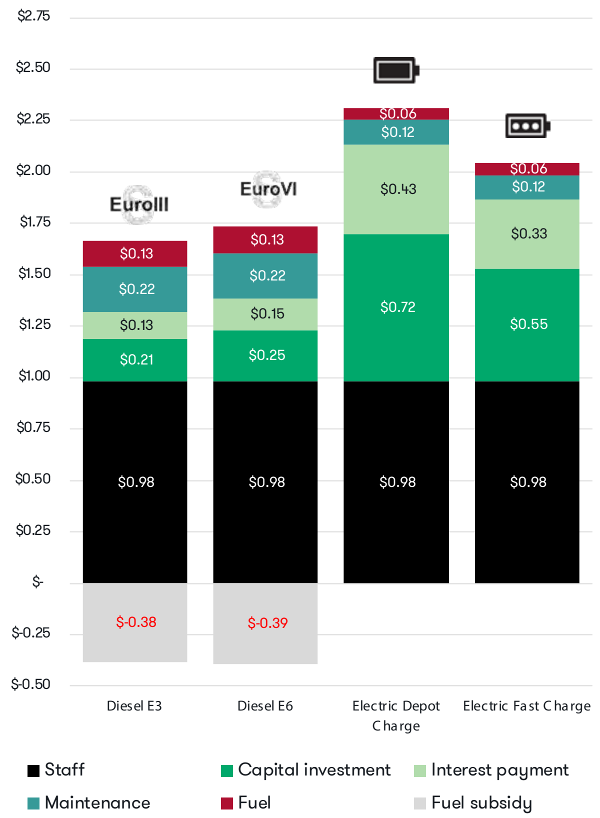
Source: Steer for the World Bank based on various sources summarized in Appendix A.

Figure 2.2: World Bank TCO Mexico City estimates ($/km)



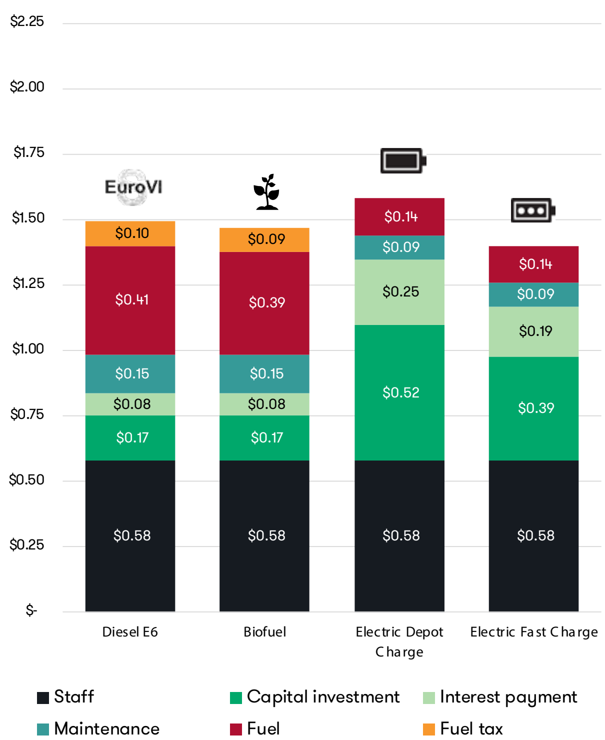
Source: Steer for the World Bank based on various sources summarized in Appendix A.

Figure 2.3: World Bank TCO Montevideo estimates ($/km)



Source: Steer for the World Bank based on various sources summarized in Appendix A.

Figure 2.4: World Bank TCO São Paulo estimates ($/km)



Source: Steer for the World Bank based on various sources summarized in Appendix A.

Montevideo TCO Estimates

TCO for diesel Euro III buses are similar to fast charge BEBs in Montevideo. The current diesel subsidy for bus concessionaires allow diesel technologies to be at least 20% more competitive than any kind of electric bus.

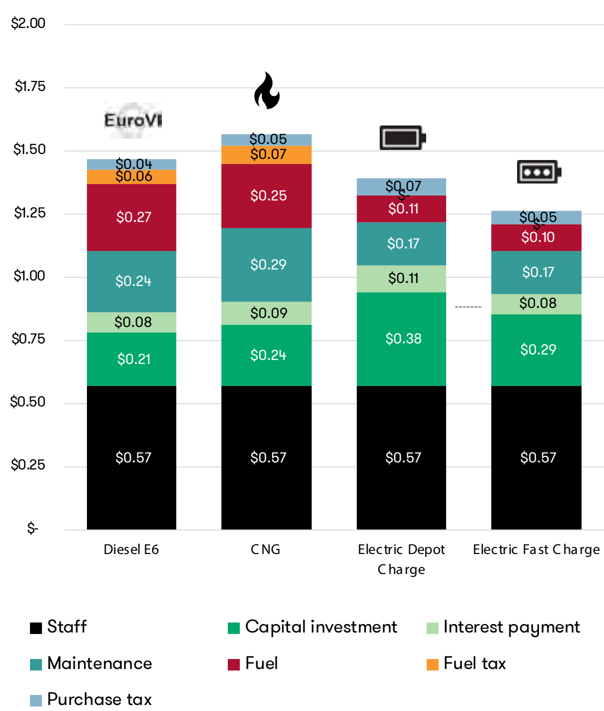
São Paulo TCO Estimates

Biofuel and Euro VI diesel buses in São Paulo have low TCOs due to the vehicle costs and moderate fuel costs. Fast charge BEBs have the lowest costs among the technologies and depot charge BEBs TCO is the higher than the rest of the technologies.

Santiago TCO Estimates

BEBs in Santiago have the lowest TCO of the technologies analyzed, on average, 9% lower than for diesel buses. Despite higher vehicle acquisition costs, the low TCO for BEBs is due primarily to lower fuel costs. CNG buses have TCO 8% higher than BEBs due primarily to higher fuel costs, and diesel buses have TCO 9% higher than BEBs due to higher fuel and maintenance costs.

Figure 2.5: World Bank TCO Santiago estimates ($/km)



Source: Steer for the World Bank based on various sources summarized in Appendix A.

BEB TCO and Range Considerations

There are a variety of BEBs available from manufacturers with different battery sizes, charging configurations (static depot-charging and en-route fast "opportunity" charging – both wireless and overhead contact systems), each with its own associated driving range (e.g. km/day). BEB selection and TCOs are influenced by the daily distance they are required to travel. BEBs with larger batteries can travel greater distances without en-route charging and cost more upfront.

The TCOs of BEBs improve in comparison to diesel as the daily travel distance increases (Figure 2.2). This is true even for buses with smaller (110 kWh) batteries coupled with more expensive wireless charging systems. BEB range can also be impacted by topography (e.g. navigating hilly terrain requires more energy than flat areas) and climate (e.g. air conditioning leads to faster battery discharge). There is no substitute for local measurement of BEB performance in actual driving conditions.

While BEBs currently have higher TCOs than diesel buses, Bloomberg (2018) projects that within 2-3 years most BEB configurations will have lower TCOs than diesel, and that upfront BEB costs will be the same as for diesel buses by around 2030. Growing demand for BEBs could reduce battery prices even faster, resulting in cost parity by the mid-2020s.

Both the World Bank TCO analysis and Bloomberg TCO findings show that in terms of costs, BEB is the best alternative when its lifecycle is considered. However, BEB vehicle purchase prices and financing currently have the greatest effect on the total cost of BEBs, as in the case of Buenos Aires and Montevideo, where BEBs are less competitive with other technologies. In some cases, competitive processes (e.g. Santiago) can lower costs. Therefore, green financing mechanisms offer significant benefit in countries with high interest rates.

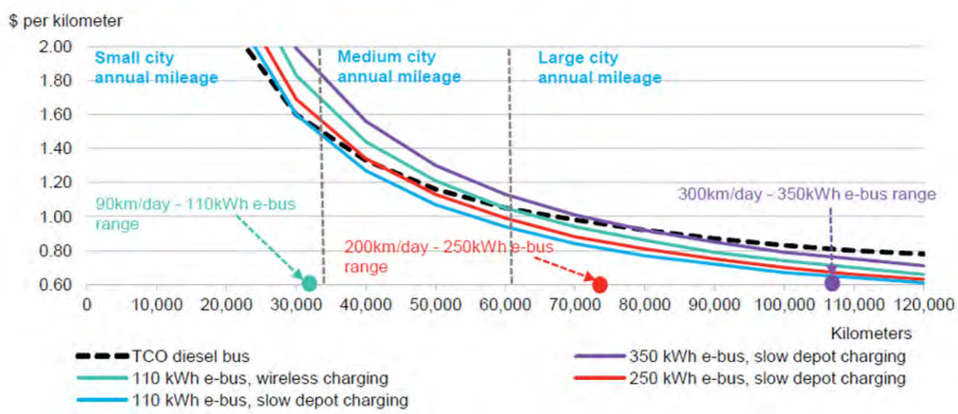
Having presented findings on the total costs of ownership of clean buses, the next chapter explores the cost-effectiveness of various clean bus technologies in reducing CO_2 emissions.

The World Bank conducted a cost-effectiveness analysis of the marginal abatement cost (MAC) of reducing a tonne of CO_2-equivalent (CO_2e) emissions when switching from Euro V diesel buses[14] to clean bus technologies. The analysis considered the TCO for each technology, as well as the externality costs of air pollution (NOx and PM). Cost-effectiveness analysis is dependent on a set of factors that vary over time and context, and is subject to local interpretation.[15] Therefore, the results summarized below should be taken as a depiction of the current situation at the time of publication and broader generalizations are not advised.

14 We assume a base technology of Euro V diesel buses. This is a conservative estimate since the buses in the five cities have higher real-world emission performance than the standards claimed for the European contexts.

15 In the presentation of the results below we consider a technology to be "cost effective" if the marginal abatement cost is negative, i.e., generating a net cost savings compared to the base technology. Each city or country may have its own threshold regarding what $/tonne level is desirable given the other mitigation options and co-benefits considered.

Figure 2.2: Total cost of bus ownership comparison with different annual distance driven.



Source: Bloomberg New Energy Finance, AFLEET, Advanced Clean Transit Notes: Diesel price at $0.66/litre ($2.5/gallon). Electricity price at $0.10 kWh, annual km. traveled - variable. Bus route length will not always correspond.

Cost-effectiveness Analysis

3

Cost-effectiveness analysis of the marginal cost of reducing a tonne of CO_2-equivalent (CO_2e) emissions when switching from diesel buses to clean buses was undertaken based on review of the latest technical literature. The analysis considered TCO and the externality costs of air pollution. Results of the analysis are summarized below.

Marginal Abatement Costs

Marginal abatement costs (MAC) graphs depict the economic costs of CO_2 emission reduction measures relative to a baseline situation. The graphs show the cost of reducing one tonne of CO_2 from a particular emission reduction measure as well as the magnitude of the potential CO_2 savings. The inclusion of multiple emission reduction measures in one graph allows for comparison across CO_2 reduction options.

In the case of clean buses, we are interested in how the various technologies compare to diesel buses (Euro V) in terms of both the cost-effectiveness of emission reduction ($ per tonne CO_2) and the potential CO_2 savings (tonnes of CO_2). Marginal abatement costs are calculated by taking the difference in TCOs between clean buses and diesel buses and dividing it by the difference in CO_2 emissions.

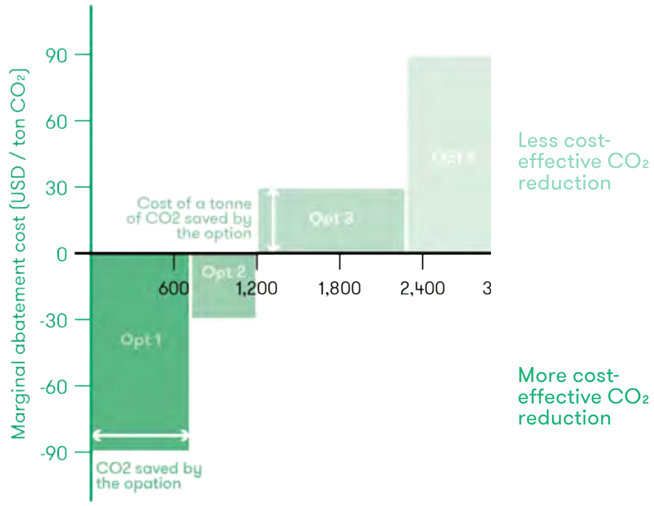
The MAC histograms depict the cost and CO_2 reduction potential of each clean bus technology as follows:

- The vertical height represents the cost to reduce one tonne of CO_2 emissions, with negative values (below the line) indicating net cost savings.[16]
- • The horizontal width of each bar indicates the cumulative CO_2 reduction potential from each bus technology over its lifetime.

The marginal abatement costs for each clean bus technology vary by city, as indicated below. Note that the total height (green) of each bar indicates the marginal abatement costs, while the gray portion indicates the marginal abatement costs with the externalities considered, i.e., the benefits of reduced air pollution. (Figure 3.1)

16 Note that the magnitude of positive values is an indicator of relative cost-effectiveness (e.g., a technology with a MAC of $20/t CO_2 yields greater CO_2 savings per dollar spent than a technology with a MAC of $100/t). However, the magnitude of negative values does not provide any relevant information on relative cost effectiveness. Since all the technologies analysed emit less CO_2 than diesel buses, negative values only indicate that the TCOs of these technologies are lower than for diesel. Neither does the magnitude of the negative value reflect the magnitude of TCO reduction compared to diesel.

Figure 3.1: Interpretation of Marginal Abatement Cost histograms.



Marginal Abatement Costs for the Five Cities

The World Bank calculated marginal abatement costs for clean bus technologies in each of the five cities. The results are as follows:[17]

In **Buenos Aires** (Figure 3.2), opportunity charging BEBs and CNG are cost-effective (negative values). In contrast, depot-charging BEBs pose high net costs for each tonne reduced (positive values), but also high emission reduction potential (wide horizontal bar). The MAC of a depot-charging BEB is $138 per tonne; if environmental externalities are included, the MAC is reduced to $133 per tonne.

In **Mexico City** (Figure 3.3), fast-charging and depot-charging BEBs yield significant cost savings and have high CO_2 mitigation potential. CNG[18] buses are deemed cost effective but offer only minimal CO_2 savings. Hybrid[19] buses pose very high MAC ($283 per tonne) with moderate mitigation potential when compared to other bus options.

17 See Appendix A for details on the inputs and assumptions for the cost-effectiveness analyses.

18 We assume Euro III for CNG buses. This is a conservative estimate since the buses in the five cities have higher real-world emission performance than the standards claimed for European contexts.

19 The analysis assumed the same air pollutant emission factors for hybrid diesel-electric buses as for Euro V diesel buses. This is a conservative assumption based on literature review, showing that hybridization does not automatically guarantee reductions in regulated non-CO_2 pollutants (e.g. NOx) compared to conventional diesel engines, even for buses certified to the same emission standards.

In **Montevideo** (Figure 3.4), hybrid buses are currently the only cost-effective clean bus option, with a moderate CO_2 reduction potential BEBs pose high mitigation costs, due primarily to the upfront costs of BEBs compared to diesel buses. The inclusion of externalities does not significantly reduce the high MACs of BEB ($102 for opportunity-charging and $210 for depot-charging).

In **Santiago** (Figure 3.5), fast-charging BEBs yield net cost savings, while depot-charging BEBs pose moderate costs ($13), and low costs with externalities included ($9). , while offering high CO_2 reduction potential. CNG buses are the least economically viable technology due to high CNG fuel costs in Chile and low CO_2 mitigation potential. HBD buses are not cost-effective in Santiago ($149 per tonne of CO_2 reduced).

In **São Paulo** (Figure 3.6), CNG buses offer net cost savings per tonne of CO_2 reduced, but offer trivial CO_2 mitigation potential. Fast-charging BEBs is a cost-effective option under current assumptions, with substantial CO_2 mitigation potential, while depot-charging BEBs indicate a large CO_2 reduction potential at a moderate cost ($42, or $39 accounting for externalities). Hybrid buses require $31 for per tonne of CO_2 reduced and have a moderate CO_2 reduction potential.

Figure 3.2: Marginal Abatement Costs histogram for Buenos Aires

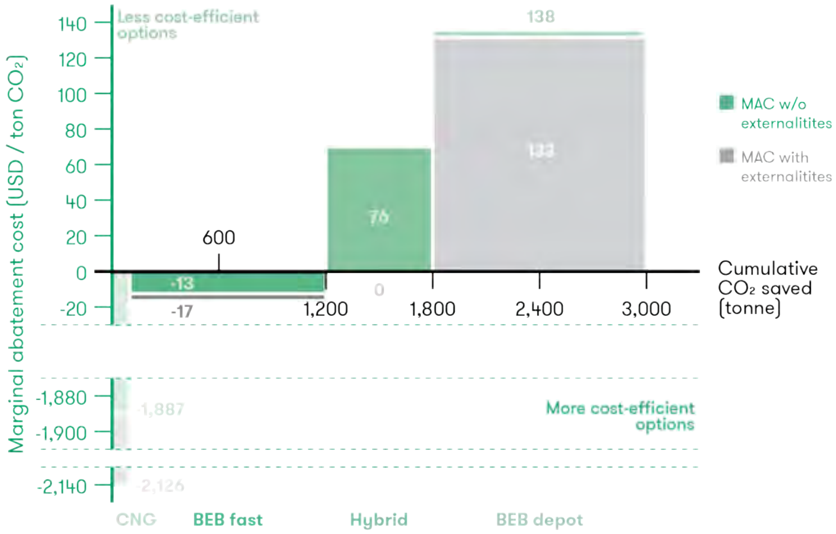


Figure 3.3: Marginal Abatement Costs histogram for Mexico City

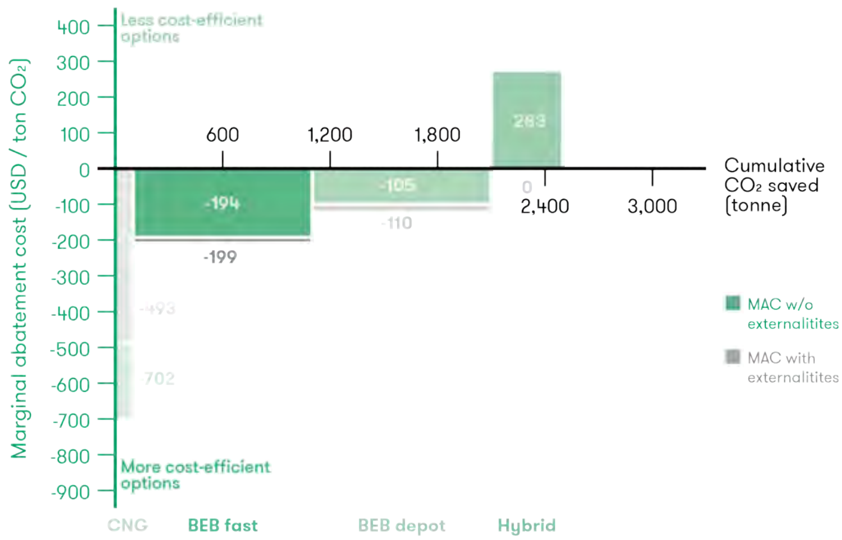


Figure 3.4: Marginal Abatement Costs histogram for Montevideo

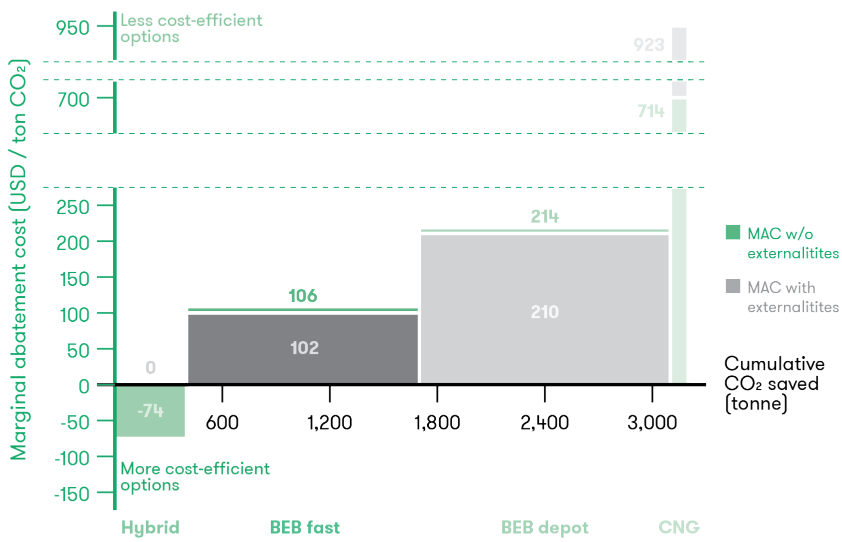


Figure 3.5: Marginal Abatement Costs histogram for Santiago

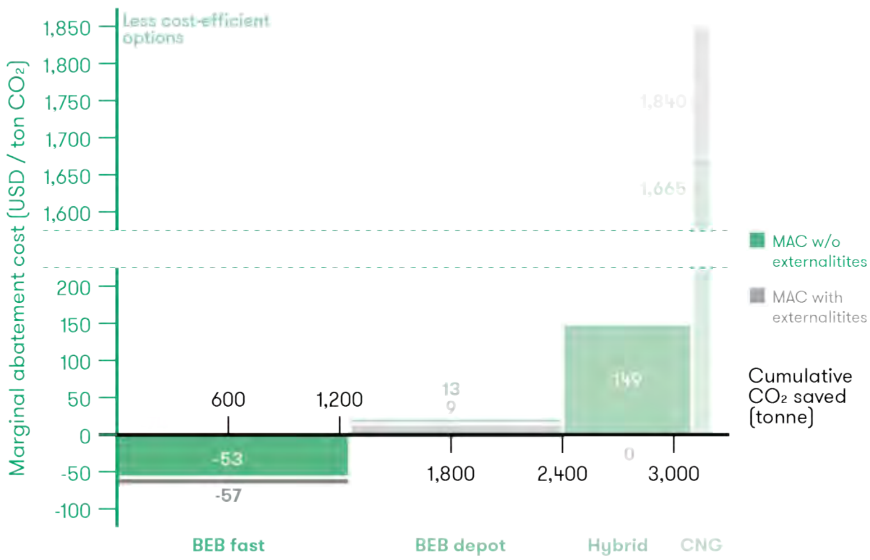
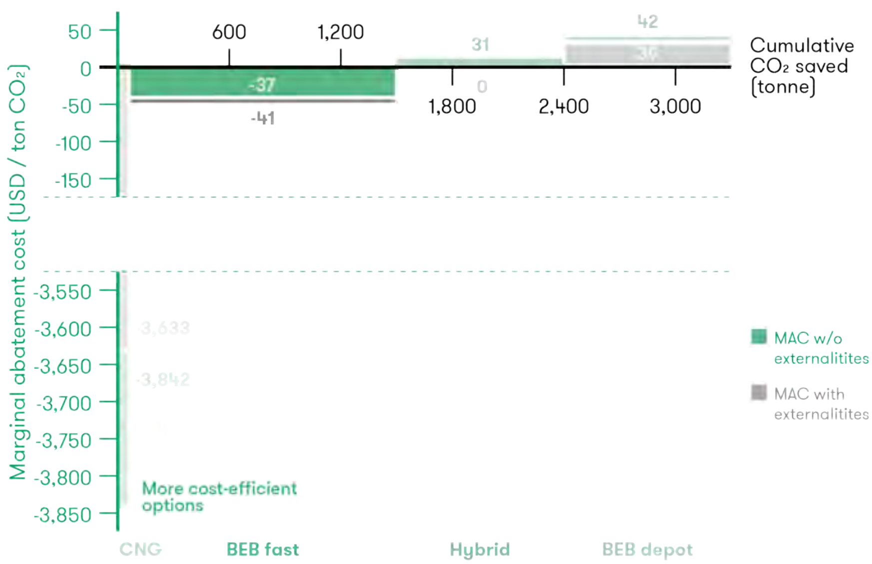


Figure 3.6: Marginal Abatement Costs histogram for São Paulo



Insights from Cost-Effectiveness Analyses

The cost-effectiveness results presented above do not represent definitive findings, but they provide initial input to local decision making with regard to deciding which clean bus technologies may be the most effective and cost effective for reducing CO_2 emissions and reducing the harmful impacts of air pollution.

Compressed Natural Gas Buses

- CNG buses are cost-effective for CO_2 reduction in Mexico, Buenos Aires and São Paulo, but provide very low levels of CO_2 reduction. CNG buses provide significant reductions of PM emissions relative to Euro V or earlier diesel bus technologies, but may increase NOx emissions. On the other hand, Euro VI CNG and Euro VI diesel buses have comparable NOx and PM emissions and result in a considerable improvement relative to older technologies.
- Where not already cost-effective from a CO_2 perspective, the inclusion of air pollution externalities decreases the cost-effectiveness of CNG buses.

Hybrid Buses

- Hybrid buses are cost-effective for CO_2 reduction only in Montevideo, providing moderate CO_2 reductions. In São Paulo, CO_2 abatement costs from hybrid buses are $31 per tonne.
- Where not already cost-effective from a CO_2 perspective, inclusion of air pollution externalities improves the cost-effectiveness of hybrid buses in Mexico City, Santiago and São Paulo to $0 per tonne.

Battery Electric Buses

- BEBs offer the highest levels of CO_2 reduction potential of the clean bus technologies analysed.
- Opportunity-charging BEBs are more cost-effective than depot-charging BEBs due to their lower battery costs and their higher efficiency.
- The cost-effectiveness of BEBs is highly dependent on bus acquisition prices.
- BEBs are more cost-effective in countries with higher diesel prices and lower electricity prices.
- Lower carbon intensity grids can help reduce the MACs of BEBs.
- Under current finance conditions opportunity-charging BEBs are cost-effective in all cities except Montevideo. Depot-charging BEBs are cost-effective in Mexico and require a modest $13 per tonne in Santiago and $42 per tonne in São Paulo.
- Inclusion of externalities diminishes the MAC for BEBs by only a few percent in cities where they are not already cost-effective (except for Santiago, where inclusion of externalities reduces the MAC of depot-charged BEBs from $13 to $4 tonne).

Countries with highly fluctuating bank lending rates can consider other financial instruments, discussed in **Chapters 4 and 5.**[20]

The results of the cost-effectiveness analyses can inform deeper analyses, including by helping to prioritize which technologies to include in pilot testing and performance measurement under actual local conditions. The ultimate decision on clean bus technology selection will include emission reduction cost-effectiveness analysis as well as other performance, cost and feasibility considerations.

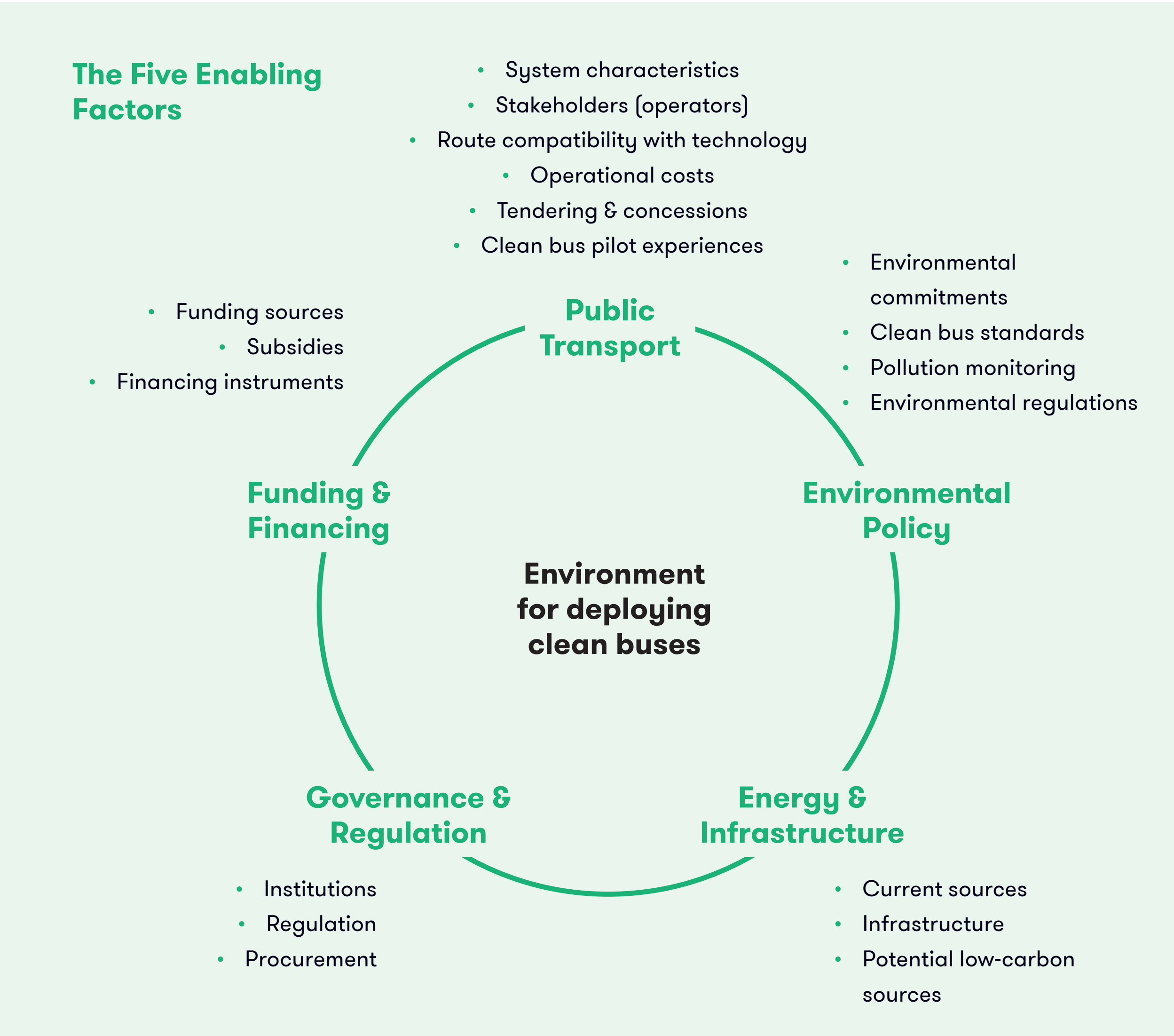
20 Argentina and Brazil have very high lending interest rates. Large operators in these countries could avoid their high regional interest rates by negotiating financial agreements with operators. In São Paulo better financial conditions could decrease the TCO of BEBs by around 10%.

Enabling Environment

4

Effective introduction of clean bus technologies requires evaluation and improvement of five key enabling factors: public transport systems, environmental policies, energy & infrastructure, governance & regulations, and funding & finance. The analysis of those elements provides the framework of deterrents to facilitators for new bus technologies to achieve faster implementation.

Figure 4.1: Main factors that influence the enabling environment for clean buses



Source: Steer

What makes a good enabling environment for the implementation of clean buses?

The identification of the primary challenges to drivers for introducing new clean bus technologies was conducted using a framework of five key enabling factors, as shown in Figure 4.1.

To identify the potential to improve urban public transport services by transforming buses into clean mobility solutions, we need to understand the context of these services in the region. This involves analyzing enabling factors, which include the **public transport system** of each city, in order to evaluate the system and its operational characteristics, such as route compatibility with clean bus technologies and operational costs, tendering and concessions status, and previous experience with clean bus technologies.

Environmental policies are a critical enabling factor, since GHG emissions continue to grow worldwide at a faster pace than populations. Climate change is one of the most important global challenges this century. Given that clean buses can help cities achieve local and national GHG and air pollutants reduction targets, each country's Nationally Determined Contribution (NDC) commitments were identified, together with local laws, where applicable, that set targets for reducing atmospheric emissions. Environmental regulations and clean bus standards, such as specific regulations for battery disposal and re-use options were also analyzed, as well as the existing air quality monitoring network.

Energy and infrastructure are important enabling factors since some clean bus technologies may require infrastructure upgrades, such as electricity distribution for rapid-charging or CNG distribution networks. Energy matrices and currently available fuel sources were analyzed in order to identify barriers that may hinder the uptake of these new technologies.

Furthermore, **governance, regulation and markets** were analyzed in order to characterize the entities responsible for national and local transport policies, and the key characteristics of bus concessionaires and their organizations, fleet conditions and direct or indirect incentives established for fleet renewal. Finally, since clean buses typically have higher upfront costs than diesel buses and therefore strain municipal budgets, the currently available options for **funding and financing** clean bus projects in the five cities were identified.

Figure 4.1: Overview of the Five Cities (data for metropolitan regions, unless otherwise specified).

	Buenos Aires	Mexico City	Montevideo	Santiago	São Paulo
Population City / Region (million)	2.9 / 12.8	8.9 / 20.8	1.4 / 1.7	6.1 / 7.1	12.1 / 21.4
Density (inh/km²)	3,341	2,660	1,010	461	2.692
GDP / capita (2015, USD 2018, country level)	$13,698	$9,920	$15,524 [A]	$13,736	$8,750
Annual budget (mill. USD 2018)	$8,148	$11,477	$600 [B]	n/a [C]	$9,757
Credit rating (Standard & Poors 2018)	raAA	mxAAA	n/a [C]	n/a [C]	brAAA
Vehicles per 1,000 people (Country, 2015)	527	274	578	238	392
Public transport (% of trips)	45%	44%	39%	38%	32%
Transport % of GHGs [D] (city level)	28%	71%	44%	79%	61%
Total fleet / Lower emission buses	18,413 / **8**	~30,600 / **640+**	1,560 / **2**	6,681 / **5**	14,957 / **209**
Bus operators (type, ownership)	**193** private	**2** public; **16** BRT concessions; **27** corridor concessions [E]	**4** private	**7** private	**15** private permissions; **12** private concessions
Minimum daily wage (USD 2018)	$20.4	$5.77	$17.6	$17.2	$10.2
Bus Fare (USD 2018)	$0.30	$0.33	$1.02	$1.11	$1.17
% of fare vs minimum wage	2%	6%	6%	6%	11%

Sources: Steer from: AR: (Presidencia de la Nación, 2017), MX: INEGI, Encuesta Origen - Destino en Hogares de la Zona Metropolitana del Valle de México (EOD) 2017, UY: Montevideo's Municipality (2017). CL: Encuesta Origen-destino, Santiago, 2012. BR: Pesquisa de Mobilidade da Região Metropolitana de São Paulo, 2012

* From C40 GHG emissions interactive dashboard at http://www.c40.org/other/gpc-dashboard. A) at country level. B) based on a five-year budget. C) not available at this level. D) 2017, E) There is no official information of the exact number of private concessions in Mexico City.

A. Public Transport

Public transport is a vital source of mobility for many people in Latin American cities and buses play a very important role in this context due to their flexibility to adapt to urban growth and their ability to provide wide coverage. To identify the potential for improving public transport services in the cities by transforming buses into clean mobility solutions, we need to understand the role played by them in the region.

This section presents an overview of the role the buses play in the five cities addressed by this project. The following section describes the current situation of public transport and the role of the bus system, current public transport tariffs, fare collection mechanisms and operating costs. The processes involved in the development of bus projects are also discussed, and attention is drawn to the clean bus technologies already tested in each city.

Public Transport System Context

In order to understand the enabling environment for clean bus technologies, it is important to consider the current features of the public transport systems in the five cities and the factors that influence them.

The public transport modal share ranges from 32% to 45% in the five cities and includes rail, bus and cycling, with buses responsible for the vast majority of trips (Figure 4.1). The population density varies from 461 to 3,341 people per square kilometer, with no clear relationship with public transport modal share.

Motorization rates range from 238 to 578 vehicles registered per 1,000 people. Cities with higher private vehicle ownership rates tend to have a higher bus mode share. The per-capita GDP in the five cities ranges from around $8,750 to $15,500, with no clear relationship to modal share. Average bus fares are about $0.30 in two cities and more than $1.00 in the other three, representing the existence of a range of subsidy policies for both drivers and passengers. Bus fares range from 2% to 11% of minimum daily wages, with lower ratios tending to correlate with higher bus mode share.

Bus fleet characteristics vary significantly across the five cities, with fleet sizes ranging from about 1,500 to 30,000 vehicles, and the average bus life ranging from 5 to 20 years (Table 4.1). The introduction of clean bus technologies can be challenging in cities with a large number of operators (such as Buenos Aires and Mexico). While annual bus sales data for the cities are not readily available, an estimate can be made from the bus market demand from these cities. Fleets that currently have higher sales rates may be better positioned for faster transformation to clean bus technologies, which could be accelerated via fleet rationalization, route optimization and increased scrappage rates.

The current fleet of cleaner buses operating in the five cities is about 870, which includes 440 trolley buses, 300 CNG buses, 17 BEBs and 14 hybrids.

Table 4.1: Bus fleet characteristics

City	Fleet size	Average age	Operators	Average buses per company	Annual bus sales (estim.)	Sales as % of bus fleet
Buenos Aires	18,412	5	193	95	3,600	20%
Mexico City	30,641	~20[A]	200+[B]	n/a	n/a	n/a
Montevideo	1,560	13	4	390[4]	117	8%
Santiago	6,681	8.4	7	954	800	12%
São Paulo	14,957	5	27	554	3,000	20%

Source: Steer from local sources

A estimated
B two public operators, 16 BRT concessions and 27 corridor concessions, plus an unknown number of individual concessions

Figure 4.2: Lower-emission bus technologies in the region.

	Buenos Aires	Mexico City	Montevideo	Santiago	São Paulo	Total (current)
Ultra-low Sulphur Diesel (ULSD) EuroVI	-	90 2018 >	-	2019 >	-	90
Natural Gas	2008 - 2009	300+ 2014 >	-	-	1990s	300+
Biofuels	-	-	-	-	2	2
Hybrid	-	11* 2015 > (* 9 diesel, 2 CNG)	1	1	1	14
Battery Electric	8 2018 >	2 2018 >	1 2016 >	3	3	17
Trolley-bus	1966 >	240 1951 >	1992 >	1994 >	200	440
Hydrogen	-	-	-	-	3	3
Total (current)	8	643+	2	4	209	870+

Number of buses — No fleet data available

Source: Steer

Summary of Public Transport Barriers and Drivers

- Adoption of stricter bus emissions standards would support the uptake of cleaner technologies. At present, only Mexico City and Santiago mandated Euro VI standards for new buses from 2019 . In the other cities higher emitting buses make up the majority of the fleets,[21] with no immediate plans to introduce Euro VI models.
- However, public transport system inefficiencies caused by, for example, informal services offered by small vehicles with high operating costs, seem to be of greater concern to city authorities and the public than pollution from emissions. The improvement of public transport systems, with a move towards larger buses, could open opportunities for new technologies.
- Most of the cities have already tested a variety of clean bus technologies and electrification appears to be a popular technology solution in all five countries. Operators are however concerned about the costs, performance, operation and maintenance of unfamiliar technologies such as BEBs.
- Cities that place age limits on buses help to accelerate fleet renewal, which can feed secondary markets and create additional value for fleet owners. The lack of secondary markets for new bus technologies can weaken the business model for clean buses.

Most cities have tested new bus technologies, but operators are resistant to change due to concerns about the performance, operations, maintenance and costs of new technologies. Although the capital costs for clean bus technologies are higher than for diesel buses, these can be offset by lower operating maintenance costs for CNG, hybrid and BEBs.

21 For example, 50% of Euro III buses in Buenos Aires and São Paulo, 78% Euro III in Santiago, and a mix of Euro II and III models in Montevideo.

Table 4.2: Country GHG reduction commitments and transportation share of GHGs

	Argentina	Mexico	Uruguay	Chile	Brazil
National NDC GHG mitigation target (by 2030)	-25% vs. BAU baseline	CO_2/GDP: -40% vs. 2013 level	CO_2/GDP: -49% vs. 1990 level	CO_2/GDP: -30% vs. 2007 level	CO_2/GDP: -75% vs. 2005 level
Transportation sector share of total CO_2 emissions	24%	32%	50%	31%	48%

Source: Steer with data from CAIT Climate Data Explorer

B. Environmental Policies

Each country has set nationally-determined contribution (NDC) goals for mitigating GHG emissions (with emissions targets set against a range of different base years).

Air pollution is an important concern in each of the five cities due to its impact on health, quality of life and the economy. Each city has an automatic atmospheric monitoring network that produces historical data used in local environmental planning and strategy development. In Mexico City, São Paulo and Santiago, real-time information produced by these networks is used to identify dangerous air pollutant concentration levels and trigger emergency actions such as rationing the circulation of cars and trucks.

Table 4.3 shows the air quality monitoring stations for each city and the continuously measured pollutants.

Table 4.3: Air pollution monitoring stations per city

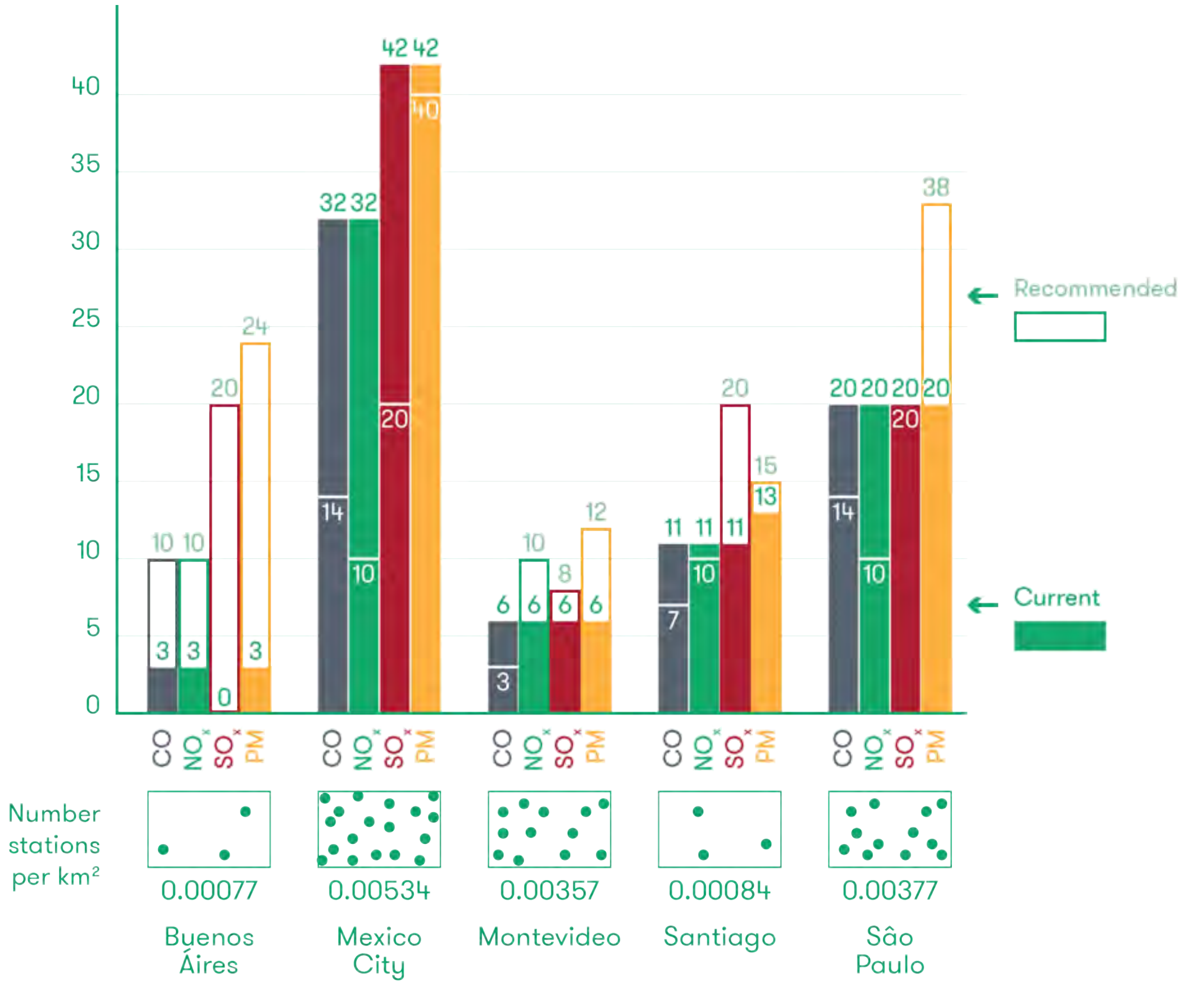
	Buenos Aires Region (AMBA)	Mexico Valley Metropolitan Zone (ZMVM)	Metropolitan Area of Montevideo (AMM)	Santiago Metropolitan Region (RM)	Metropolitan Area of São Paulo (RMSP)
Station	3	42	6	13	30
Average CO value	n/a	0.67 ppm (2016)	0.40 (2015)	0.68 ppm (2017)	1.03 (2017)
Average PM value (µg/m³)	PM_{10}: 27 $PM_{2.5}$: 13 (2016)	PM_{10}: 43 $PM_{2.5\text{-}10}$: 20 $PM_{2.5}$: 23 (2016)	NO_2: 26 PM_{10}: 1 $PM_{2.5}$: 19 (2015)	PM_{10}: 62 $PM_{2.5}$: 27 (2017)	PM_{10}: 29 $PM_{2.5}$: 17 (2017)
Mean O_3 levels	n/a	30 ppb (2015)	n/a	13.4 ppb	40 ppb (2016)

Stations in the city, not metropolitan level like the others. Also, in this case the CO emissions correspond to annual averages of the maximum daily concentrations of CO (average of 8 hours) for the metropolitan region *Ppm: parts per billion.

Source: AR: https://data.buenosaires.gob.ar/dataset/calidad-de-aire y http://apps.who.int/gho/data/view.main.AMBIENTCITY2016?lang=en. MX: http://www.aire.cdmx.gob.mx/descargas/publicaciones/flippingbook/informe_anual_calidad_aire_2016v1/informe_anual_calidad_aire_2016.pdf. UY: Intendencia de Montevideo. CL: https://sinca.mma.gob.cl. BR: https://cetesb.sp.gov.br/ar/wp-content/uploads/sites/28/2013/12/relatorio-ar-2016.pdf

The five cities have particulate matter above the WHO recommendations for PM_{10} (20 micrograms/m²). Only Montevideo, according to the city's records, shows acceptable $PM_{2.5}$ (10 micrograms /m²) levels (although in this case monitoring stations are not located at pedestrian level). The most critical situations found are in Santiago and Mexico City, followed by São Paulo. The cities with slightly better results (Buenos Aires and Montevideo) also have the lowest number of monitoring points in the network. Deficiencies in air quality monitoring – both in terms of the specific pollutants monitored, and the locations and distribution of monitoring stations - limit the ability of cities to effectively identify risks and target their emission reduction strategies.

Figure 4.3: Air quality monitoring systems



Source: Steer. Recommended number of stations per city population-wise: Guidelines for Ambient Air Quality Monitoring (CPCB, 2003)

Each of the five cities has prepared local plans to contribute to achieving national GHG mitigation goals, and reducing local air pollutants. Specific mitigation measures (Table 4.4) that have been proposed in city transport plans are primarily co-benefits of transport management efforts.

Table 4.4: Examples of local environmental policies pertaining to transportation

City	Local policy pertaining to transportation
Buenos Aires	• The 2017 Clean Mobility Plan aims to reduce CO_2 emissions by 14% and NOx and PM emissions by 50% (below 2015 levels by 2035). The plan includes initiatives such as clean bus technologies pilots, low-emissions zones and improvements in air quality measurement.
Mexico City	• A federal program sets strategic actions for reducing pollutant concentrations with a strong focus on vehicles and mobility, including promoting a modal shift from private vehicles to public transport. • Local plans include vehicle-scrapping programs for public transport agencies and technology substitution. The Hoy No Circula program (no-drive days) for private vehicles started in 1989. • Mexico City has pledged to ban diesel buses by 2025 (C40, 2016).
Montevideo	• The 2012 metropolitan climate plan defines three strategic lines of action for transportation: Increase mobility efficiency, Promote active transport, and Introduce clean technologies for the transport system.
Santiago	• The 2016 Atmospheric Decontamination Plan includes several transport sector measures, such as: low-emission cargo zone, restrictions for vehicles older than 10 years and modal change incentives.
São Paulo	• A new regulation establishes emission reduction targets: CO_2 of fossil fuel origin - 100% within 20 years; PM - 95% within 20 years; NOx - 90% within 20 years.

Source: Steer with information from local emissions policies

Some of these cities already had previous legal requirements that were not complied with, as in the case of São Paulo. The previous city law on climate change (2009) required the annual replacement of 10% of the bus fleet and stipulated the end of fossil fuel buses within a decade (2018). However, this target was far from being met, due mainly to the failure to align the law with the terms of bus concession contracts, and the lack of mechanisms for monitoring, controlling and enforcing cases of non-compliance with targets. In 2018, only 1.4% of the fleet (mostly trolley-buses), met the 2009 goals. The new São Paulo law however establishes annual targets for emissions reductions, and failure to meet these targets will result in monthly fines for the operators of each non-complying vehicle. In this way, the city has bolstered the credibility of the regulations and their ability to enforce operators to meet the new targets.

Summary of Environmental Barriers and Drivers

- **Environmental commitments** at national and local levels are important drivers for the introduction of clean buses. The five countries have established NDC targets and strategic climate change actions to reduce GHG emissions. In Mexico, the transport sector accounts for the highest levels of GHG emissions, while in Brazil and Uruguay land use change and agriculture emissions are more significant. In addition to these national goals, each of the five cities possesses environmental plans and targets to reduce local air pollutants.
- **Local air pollutants** above WHO recommended levels. Santiago has the highest PM levels. Air quality monitoring systems, especially in Buenos Aires and Montevideo, need improvement, including expanding the monitoring of other pollutants ($PM_{2.5}$, O_3, SO_2/SH_2), increasing the number of stations and improving their locations.
- **Noise** has been addressed in cities as having a lower priority than air pollution. São Paulo and Buenos Aires are developing strategic noise maps to better understand traffic-related noise, and Buenos Aires is pursuing traffic-calming actions to help reduce levels.
- **Regulations for BEB battery disposal** or reuse have not yet been developed in any of the cities. This potential for secondary use of BEB batteries for energy storage should be explored jointly with electricity suppliers. Improper disposal of batteries can lead to heavy metal contamination of soil and water. The benefits of battery re-use and the costs of disposal should be included in full cost analyses.

The cities are committed to reducing GHG and local pollutants, although improvements are needed in their air quality monitoring systems to provide a better understanding of emissions sources. Noise is a significant concern but has not been treated with the same priority as atmospheric emissions. There is a lack of regulations for BEB battery disposal and a need for analysis on options for BEB re-use for energy storage.

C. Energy

Given that the existing energy matrix and energy distribution infrastructure of cities impact urban bus emissions, the success of clean bus deployment efforts will depend upon an appropriate supply of, and easy access to, low-emission fuels and energy sources.

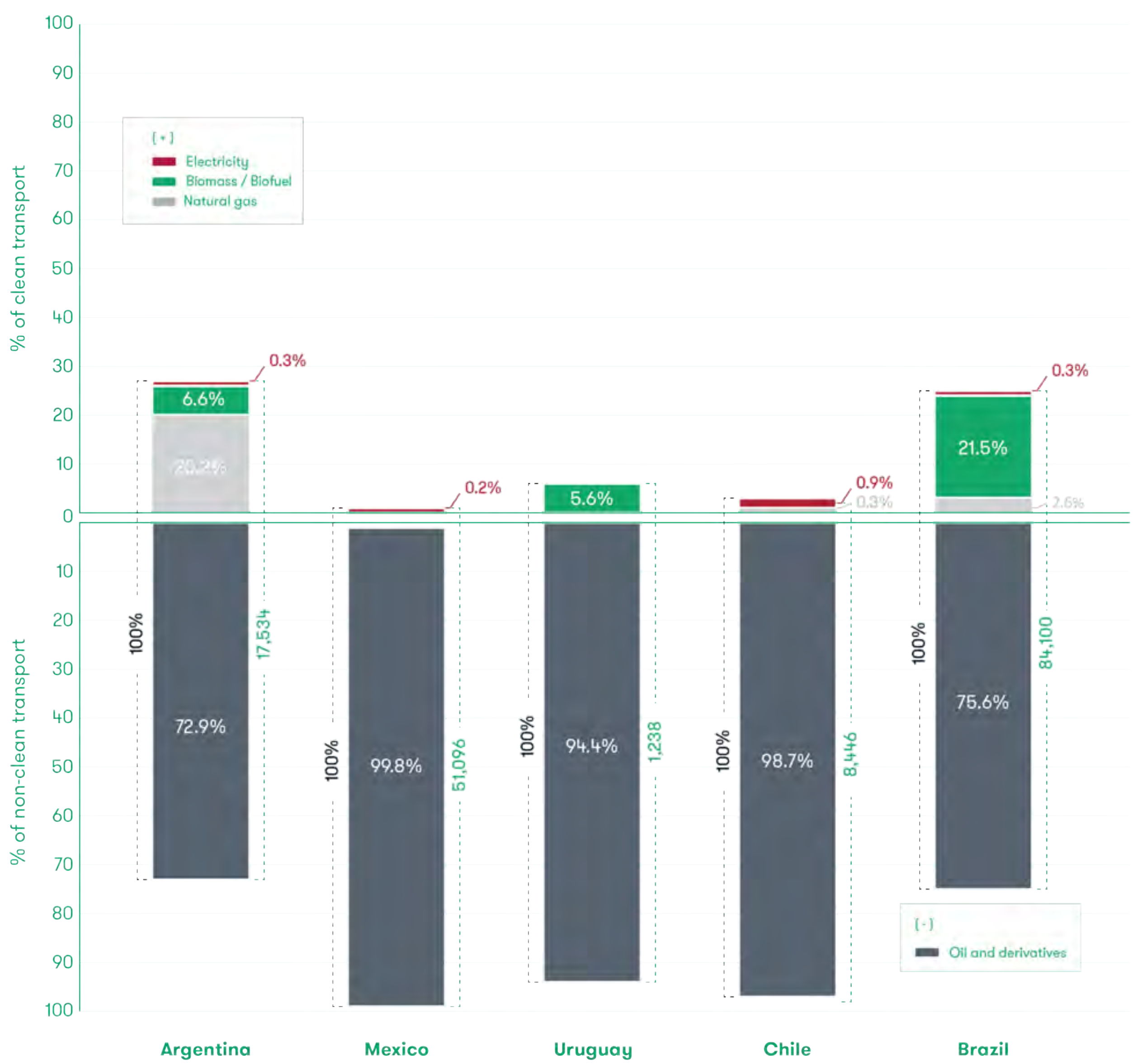
The vast majority of transportation energy in the five countries is currently oil-based. The two exceptions are Brazil (approximately 20% biofuel use), and Argentina (20% natural gas) (Figure 4.4).

An assessment of the current availability of fuels for clean buses reveals that ultra-low sulfur diesel for use with Euro V, Euro VI and hybrid buses, is commercially available in all the cities except Montevideo. Compressed natural gas is available in all the cities, although Mexico City has a limited distribution network. While the mandatory share of biodiesel in the diesel mix is expected to increase in Brazil, Argentina and Uruguay, biofuels are not available to fuel buses in Mexico City or Santiago.

The mitigation of GHG arising from the use of BEBs depends on the availability of electricity generated from low-carbon sources. Most of the five countries have set targets for increasing electricity production from renewable sources. Figure 4.5 shows the electricity energy matrix for each country and their goals for different time horizons. The electricity providers consulted in the five cities claimed that there is sufficient capacity on their networks to launch electric bus operations, but upgrades may be required for high penetration levels and the construction of a fast-charging infrastructure.

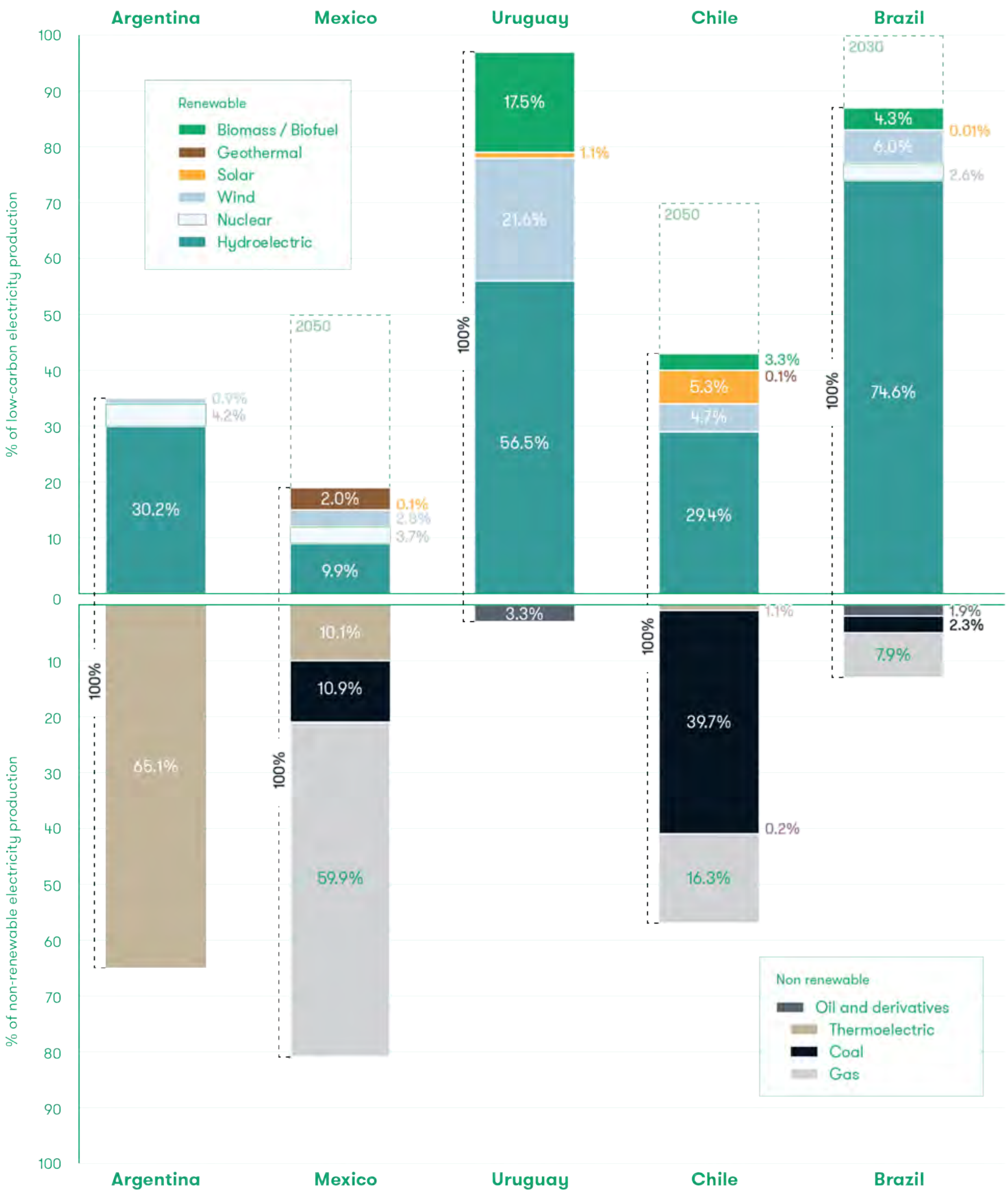
The transport sector is primarily dependent on oil-based fuels, but the availability of alternative fuels, renewable sources of energy and distribution infrastructure are opening opportunities for technology transitions. New investments will be needed in electricity distribution networks to support high BEB penetration, with costs depending on local conditions.

Figure 4.4: Energy sources for the transportation sector



Source: Steer with data from the International Energy Agency. Absolute numbers represents thousands of tons of oil equivalent (ktoe)

Figure 4.5: Energy matrix for electricity generation



Source: Steer, with information from: AR: Informe anual (CAMMESA, 2017). MX: Programa de Desarrollo del Sistema Eléctrico Nacional (Secretaría de Energía, 2017), CL: Boletín del Mercado Eléctrico, Sector Generación. Enero 2018. Generadoras de Chile. BR: Ministério de Minas e Energia do Brasil - MME (June 2017).

D. Governance and Regulation

In order to identify the main governance and regulation barriers and drivers, the bodies responsible for national and local transport policies were consulted and the main characteristics of bus concessionaires (organization, fleet conditions and direct or indirect incentives for fleet renewal) studied.

Summary of Governance and Markets Barriers and Drivers

- Institutional coordination. A variety of local, metropolitan and national institutions regulate bus types, concession allocation, service quality assurance, fares, subsidies and timetables in the five cities. The lack of institutional coordination among national ministries and/or local and regional transport system managers is the main barrier in most of the cities. In many cases, fragmented governmental authorities have failed to integrate transport system planning and policies.
- Market competition. The high concentration of public transport service delivery by a few companies with strong market power can lead to low service levels and high fares. While limited competition is a significant barrier in most cities, bus operators resist changing operating practices and technologies. In São Paulo and Santiago (both shortly to hold tendering processes) the requirements to enter the bidding processes are complex and limit the eligibility of foreign companies. In Mexico City, Buenos Aires and Montevideo, the concession processes allow operators to stay in the market indefinitely (except for BRT and transport corridor operators in Mexico City).
- Policy priorities. Electromobility has attracted broad interest and is now beginning to enter the policy agendas in all five countries. The new transport bidding processes in São Paulo and Santiago provide potential opportunities for the introduction of new bus technologies. In Buenos Aires, the expiration of bus concessions presents fresh opportunities for re-organizing the city's public transport system.

Complex institutional coordination and limitations to market competition are the main barriers identified in the five cities. New concessions may provide opportunities to introduce clean technologies. Electromobility is on the policy agenda and there is potential to increase clean bus manufacturing in the region.

- Bus procurement. The lack of new concessions, together with the automatic renewal of expiring concessions, makes it difficult for some cities to design a formal framework containing incentives for adopting new technologies. Bus concessions in Buenos Aires, Mexico City and Montevideo are granted directly to concessionaires with no competitive tendering. Although Santiago and São Paulo have initiated some tendering opportunities, some elements still present barriers to new bidders. Contracts are generally signed for a minimum of 10 years, except for Montevideo where there are no fixed time limits. All the cities provide a set of incentives for concessionaires to renew their fleets: Buenos Aires and São Paulo offer encouragement in the form of "carrots" such as attractive secondary markets for buses, while Buenos Aires, Mexico City and Montevideo have "sticks" such as subsidy reductions and non-renewal of concessions.
- Strategic partners. Electricity providers can act as partners in the deployment of BEBs by installing or facilitating charging infrastructures, subsidizing energy tariffs and forging innovative business and financial partnerships with bus operators (e.g. financing, bus or battery leasings, battery reuse and energy purchasing agreements with fixed electricity prices for the duration of contracts)
- Economic development. There is potential for increasing clean bus manufacturing capacity in the region, especially in Argentina, Brazil and Mexico, where vehicle manufacturers are already working to produce electric, CNG and hybrid buses.

E. Funding and financing

The gap between urban transport needs and their provision is often blamed on the lack of appropriate funding and financing streams. There is no doubt that the higher upfront costs of clean bus technology are a major strain on already limited budgets.

Summary of Funding and Finance Barriers and Drivers

- **Funding availability.** Cities typically lack sufficient financial resources to support adequate levels of public transport serving very large catchment areas. The five cities under study are no exception. The funding of bus fleets in these cities depends on a variety of public sources, commercial banks and bus suppliers, often using partial credit guarantees. Only Mexico City and São Paulo have funds to cover a portion of the differential cost for accessing clean bus technology.[22] Bus suppliers provide substantial financing in all the cities, using their extensive knowledge of market conditions and motivation to sell their product. At present concessionaires are experiencing difficulties to obtain finance even for conventional bus technologies.
- **Finance markets.** The maturity of bus financing markets is closely related to the quality of local public transport systems (regulatory power, financial sustainability and market structure, including levels of competition among operators). Limited financing sources and lack of funds for promoting clean technologies are major barriers. In Brazil, the main financing programs require buses to be made domestically with a majority local content. Meanwhile, currency instability in Brazil remains a significant barrier to international financing of bus transportation.

22 Brazil's Fundo Clima expired in 2017. Efforts are being made to reactivate it. This program includes the requirement for vehicles to contain a proportion of domestically manufactured components. Mexico's clean bus technologies program has provided $10 million to support 800 CNG buses, but this program is dependent on annual renewal in the national budget.

- **Subsidies.** Most of the cities have direct public subsidies to help cover capital and operational costs. Most of them, except Mexico City, also have some level of subsidies for diesel fuel. The subsidies are designed to ensure that public transport is affordable to users and that concessionaires' revenues are adjusted accordingly. However, this type of subsidies presents a strong disadvantage to cleaner vehicles powered by non-fossil fuel over the conventional diesel vehicles.
- **Budgetary pressure.** Most of the cities are under pressure to reduce, or at least to cap the level of subsidies for bus transportation, as well as keep fares low. This makes it more difficult to secure new financing and funding for clean technologies.
- **High capital costs.** The higher upfront costs of clean buses can exacerbate funding and financing challenges. The cash flow for a typical bus project is usually high at the outset in view of the initial outlay on the vehicles. Whereas financing can be used to access capital up front, financing mechanisms are generally debt or equity related, implying that over time the revenue stream from one or more funding sources (e.g., user tariffs) can be used to pay back the debt incurred at the outset, as well as for defraying operating and maintenance costs and payments to private operators.
- **Financial institutions.** Commercial banks have minimal knowledge of the bus market and are unwilling to take risks on new technologies. Most of the cities finance their bus fleets from public sources, commercial banks and bus suppliers. An exception is Buenos Aires, where commercial banks have some low-level participation, and Montevideo, where the national pension fund is the main financier. Partial credit guarantees are often supported by public bodies.
- **Innovation.** Innovative business, ownership and procurement models that reward low TCO (e.g. leasing, rental, energy company participation, service contracts) can help overcome high upfront costs. This means that longer-term cost savings can be anticipated in purchasing decisions, which ensures that vehicles will remain affordable for operators and users alike. These business models are new to the five cities and require further analysis and development.

Cities typically lack sufficient resources for fully meeting public transport needs using current technologies. The higher upfront costs of clean buses can exacerbate funding and finance challenges, especially since commercial banks have only minimal knowledge of these technologies.

Self Evaluations

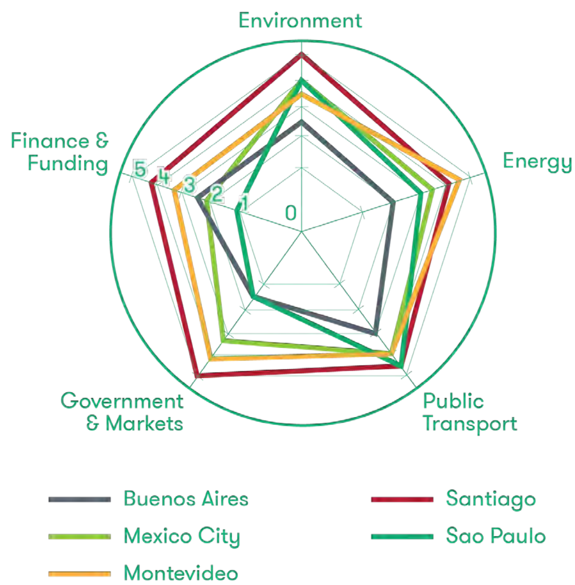
The diagnosis of the five factors was validated and enhanced as the result of input from LAC counterparts during the Iguassu Falls workshop. The goal was to evaluate Latin American and Caribbean cities based on the experience and expertise of the participating stakeholders. The self-assessment mechanism enabled a broader benchmarking on clean buses and led to a better understanding of the most critical issues in the region, although some results might have been constrained by participants' knowledge and viewpoints.

A key finding of the evaluation was that although the environmental, health and social benefits of clean buses are recognized, resources have not been allocated to subsidize technology change, and price incentives or tax penalties to encourage the use of cleaner fuels have not been introduced in most of the cities or countries represented by the workshop attendees. Moreover, there is still an absence of common technical standards for CNG propulsion, or electric bus charging or leasing schemes used to finance buses and/or batteries. A further point is that although many cities have piloted certain clean bus technologies, little information on such projects has been published.

Most of the cities surveyed have set standards for urban bus emissions, and technology change has been led by specific institutions. There has also been progress on electricity tariffs (night tariffs, peak, non-peak rates, etc.) and most cities have re-assessed the capacity of their energy systems in readiness for introducing clean buses (electric / CNG) fleets on a large scale. The five cities have all made environmental commitments to adopt clean bus technologies.

Figure 4.6 shows the self-assessment outcomes for the five cities. Santiago gained the highest average score (between 4 and 5 for all the areas evaluated), while Montevideo came in second, with balanced results in the different areas (except perhaps in relation to financing, as detected in the diagnosis done by the Project).

Figure 4.6: Self-evaluation results for the Five Cities



Source: Steer

Mexico City presents better results on environmental policy and public transport, although there are still public transport management issues that need to be improved to increase the uptake of new technologies. São Paulo produced similar results to the other cities, although it scored lower than expected on finance, given that city has several financing mechanisms. Buenos Aires scored lowest on the government theme, reflecting the overlapping responsibilities of different authorities in the public transport area.

Based on the diagnosis of the current situation in each of the five cities, we now offer general recommendations for generating improvements in each of the five enabling factors to advance the deployment of clean bus technologies.

General Recommendations

5

While each city faces distinct technical, economic and institutional issues, we were able to generate a set of general recommendations based on analysis of the barriers and drivers to clean bus implementation in the five cities.

To meet the NDC targets and countermand the increasing threat of global warming, countries in Latin America must rapidly scale-up the adoption of clean vehicle technologies in public transport, as well as the transport sector in general. The study reviewed, city by city, the costs and feasibility of several clean technologies, including CNG and electric. Recommendations specific to each city are provided in Chapter 6 (City-specific Recommendations).

The present chapter provides guidance which applies to cities in LAC in general (i.e. in addition to the cities covered by the study). Given the recent, global advances in the life and costs of batteries, electric vehicles seem set to dominate the future of clean technologies in Latin America and worldwide. While the recommendations below apply mainly to the evaluation and adoption of any clean technology in the area of public transport, they tend to point to the increased use of electric buses.

1. The selection of clean bus technology should consider both corridor-specific performance requirements (e.g. distance, speed, capacity, noise) as well as the availability of city-wide infrastructure.

For high-capacity, trunk corridors the optimal technology may differ from that for feeder lines and commuter routes. City-wide requirements for cross-route compatibility, flexibility and redundancy should also be taken into account.

2. A Total Cost of Ownership (TCO) methodology is recommended to evaluate the financial performance of clean technology buses, particularly BEBs.

TCO captures both the higher upfront costs of BEBs and their lower operating costs over the span of a vehicle's life. It is necessary to assess the cost of batteries, which is the single biggest item determining the higher cost of electric vehicles.

3. Improving data collection on air and noise pollution is essential in order to capture more fully the benefits of clean vehicle technology.

While air quality monitoring has improved across cities in Latin America, gaps remain in identifying particular sources of pollution and using monitoring stations to track urban air quality. Since air quality is the single biggest beneficiary of the introduction of clean technologies, it is vital for cities to measure and collect reliable data on air and noise pollution caused by vehicles using traditional fossil fuels.

4. Public Authorities should provide stakeholders timely and up-to-date information on the capacity of power distribution networks and the adequacy of the charging infrastructure.

Lack of reliable and relevant data creates uncertainty and undermines the willingness of public transport agencies and bus operators to consider moving to electric vehicles. The energy sector must collaborate closely with the transport and environment ministries and agencies in order to achieve greater clarity on these issues.

5. City and national governments could join hands with research institutes and academia to share the state-of-the-art battery technology with respect to electric vehicles.

The lack of information noted on energy-related issues also affects technology aspects regarding the performance of batteries and the related operational performance of electric vehicles. This restrains efforts by national and city governments to move forward on the clean vehicle agenda. There is a pressing need at the city, national and international level for research and dissemination efforts to educate stakeholders. Since BEB technology is rapidly improving, with impacts on performance levels and TCO, it is vital that information on the latest improvements is communicated and distributed widely within the PT community.

6. Policies which address market distortions in the operations of conventional vehicles and harmonize emissions standards will do much to improve the economic outcomes arising from private sector involvement in the adoption of clean vehicles.

Market distortions are the single biggest risk to introducing and scaling up electric vehicles in LAC. With the exception of Mexico City, our sample cities possess inadequate emissions standards, and provide direct public subsidies for operational and capital costs as well as for diesel fuel. With the price of diesel artificially lower, the financial accounting of vehicle operations tends to favor conventional vehicles. Moreover, lower emissions standards allow conventional vehicles to ignore some of the externalities generated by them, thus also impacting the financial optics in favor of conventional, fossil fuel-powered vehicles. Addressing these sources of market distortion will be challenging, but this is essential for enabling a more realistic assessment of the financial and economic performance of clean vehicles.

7. Improving market competition and concession processes can advance the deployment of clean buses.

Cities such as Santiago and Shenzhen have, for example, encouraged the participation of third parties such as energy and vehicle leasing companies to share financial burdens and risks and expand the possibilities for BEBs. In addition, innovative business models (e.g., vehicle leasing, rentals, third party involvement, service contracts) can spread risks and help overcome high upfront costs so that longer-term cost savings can be anticipated in purchasing decisions, which should ensure that vehicles will remain affordable for operators and users alike.

City-specific Recommendations and Implementation Roadmaps

6

The specific recommendations, and implementation roadmaps, for each of the five cities suggests timeframes, levels of priority and necessary stakeholder involvement. Strategic questions should be considered before launching a Clean Bus Plan. These questions will guide cities towards making an appropriate choice of clean bus technologies and their deployment.

Objectives	Project Selection	Barriers and Drivers	Recommendations
What is to be achieved?	What are the right projects to achieve it?	What are the main barriers and drivers?	How can we overcome those barriers and take advantage of the opportunities?
How does this link with the city's objectives?			Which institutions are responsible for their implementation?

Source: Steer

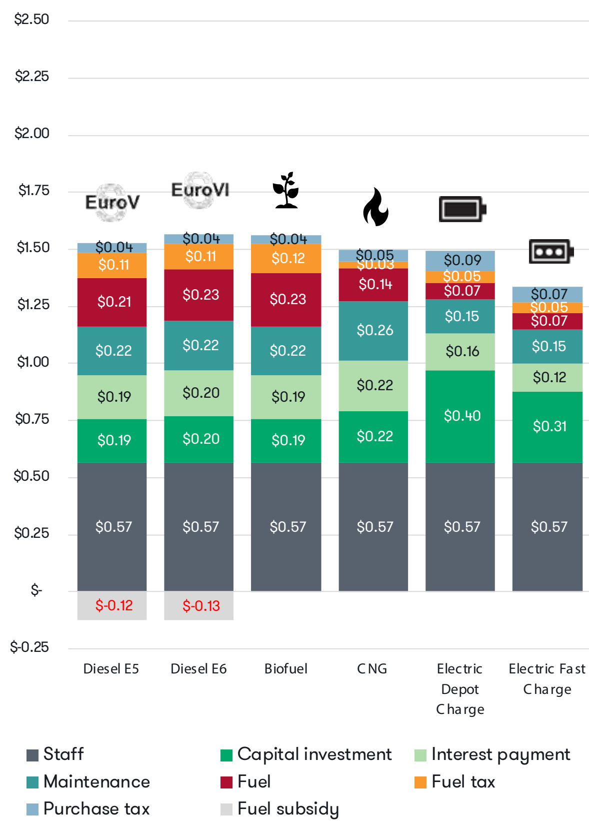
A. Buenos Aires

TCO comparison for clean bus technologies in Buenos Aires revealed a wide difference between traditional diesel technologies and electric buses .Diesel fuel subsidies make electric buses even less attractive. Pre-tax BEB prices in Buenos Aires (comparing the same models of bus), are higher than in São Paulo and Santiago by 36% and 42% respectively. High interest rates for bus financing increase the TCO for buses that are already expensive to purchase.

Figure 6.1 shows a scenario in which the same purchasing arrangements for BEBs in São Paulo are applied in Buenos Aires. The figure assumes increased market competition that reduces bus prices, and a lower interest rate (an annual simulated rate of 7.5%), that could be achieved through revolving and guarantee funds using a mix of currently available funding and financing resources in Buenos Aires.

- **National and local funds:** credit lines from the National Bank or the creation of a fund to capture the cost of externalities caused by other transport modes, such as on-demand transport apps or city taxes.

Figure 6.1: TCO/km. for buses in Buenos Aires, assuming São Paulo bus prices and reduced interest rates



Source: Steer for the World Bank based on various sources summarized in Appendix A.

- **National subsidies:** The current diesel subsidy is $8,500 USD/year per bus. This could be redirected to setting up a revolving fund or to guarantee a financing mechanism with lower interest rates and longer payback periods.
- **Local and international lending options:** These could include Green Bond issuance, International Finance Corporation (IFC) support, Climate Investment Funds (CIF) financing, and / or Export Credit Agencies (ECAs) support.

Two main plans are currently being developed in Buenos Aires, both promoting low-carbon public transport and providing good opportunities for the introduction of clean buses: the National Transport and Climate Change Action Plan (PANTyCC) and the Clean Mobility Plan.

Table 6.1: Key recommendations for the PANTyCC (Buenos Aires)

	Recommendations	Status	Timeframe			Stakeholders		
			Short Term	Medium Term	Long Term	Government Local	Government Nation	Private sector
ENV4	Include emission and noise reduction elements in cost-benefit evaluation processes.	Desirable				L	N	
ENE1	Conduct technical analysis of energy system capacity to support large-scale bus fleets.	Essential				L	N	P
GOV4	Specify the lead entity or body to coordinate clean bus deployment strategies and conduct periodic stakeholder outreach to gauge reactions to Clean Buses	Supportive				L	N	P
FFF2	Develop mechanisms to facilitate access to green funds	Supportive					N	
FFF3	Diversify and incentivize access to finance mechanisms.	Supportive					N	P
FFF8	Evaluate the feasibility of budget reassignment from other ministries to incentivise clean bus projects	Desirable					N	

Source: Steer

PANTyCC

The PANTycc includes a variety of initiatives intended to reduce environmental impacts caused by the transport sector, mainly by promoting public transport buses powered by alternative, cleaner energy sources. There is therefore a clear opportunity to align with the local government to bolster its efforts and pursue the introduction of cleaner buses. A few key actions have been identified as a starting point for the successful implementation of the PANTyCC. The suggested timeframes and stakeholder types are listed in Table 6.1.

The first key action is to define a leading agency, institution or task force to ensure that all the efforts complement one another. The second key action is to ensure that the data gathered and the lessons learnt in the course of PANTyCC and Clean Mobility Plan implementation are fully disseminated and shared. Socio-environmental assessments should be included together with details of financial project evaluation methodologies.

When clean buses are introduced on a larger scale, it will be important to evaluate the requirements for electric / gas network and charging / fuelling infrastructure investments and their associated financing implications.

To assist promotion of actions within the PANTyCC targeted at public transport buses powered by cleaner energy sources, funding and financing mechanisms could be investigated and tested, either by developing structures or systems to facilitate access to green funds, or by evaluating ways to diversify and encourage access to financing mechanisms with national government support. Using model sensitivity results, reduced interest rates and lower bus prices (similar to prices in other cities in the region), such an approach would make these technologies more competitive. These actions could initially be tested, and later scaled up, leading to the introduction of clean buses in Buenos Aires, and to serve as a catalyst for further expansion throughout Argentina.

Clean Mobility Plan

The Clean Mobility Plan aims to reduce emissions and improve air quality. The various initiatives being pursued under this plan, including the clean bus technology pilot program, are important for facilitating the introduction of these technologies across the country. A few key actions have been identified as effective starting points for the implementation of the Clean Mobility Plan. The suggested timeframes and stakeholder types are listed in Table 6.2

The clean bus technology pilot program, currently being developed for implementation, provides an important opportunity to test the feasibility of introducing clean technologies. Implementing these efforts in parallel with the clean bus program presents a valuable opportunity to develop an integrated database on emissions, and on variables to monitor and evaluate clean bus implementation policies.

Lack of knowledge (e.g. whether specific technologies can be used in the city/country or not) was identified as a barrier for concessionaires to embark on piloting clean buses. Data collected from pilot projects should serve as evidence of the benefits and challenges of the different technologies.

Table 6.2: Key recommendations for the Clean Mobility Plan (Buenos Aires)

	Recommendations	Status	Timeframe			Stakeholders		
			Short Term	Medium Term	Long Term	Government Local	Government Nation	Private sector
ENV2	Strengthen urban bus emission standards	**Essential**				L	N	
ENV4	Include emissions and noise reduction elements in cost-benefit evaluation processes	Desirable				L	N	
ENV5	Evaluate prioritizing zero/low emission zones or corridors	Supportive				L		
ENE3	Create common technical standards for bus charging	Desirable				L	N	
PT2	Promote independent and open knowledge transfer of performance data from pilots	Supportive			▶	L	N	
GOV1	Strengthen concession conditions with mechanisms to guarantee bus payments or reduce risks of default	**Essential**			▶	L	N	P
GOV3	Pursue regulatory & contractual frameworks to promote energy company participation in BEB deployment	Desirable				L	N	P
FFF1	Evaluate the potential for cross-modal subsidies to support public transport	Desirable			▶	L		
FFF2	Develop mechanisms to facilitate access to green funds	Supportive			▶		N	
FFF3	Dversify and incentivise access to finance mechanisms	Supportive			▶	L	N	
FFF6	Explore leasing schemes for buses and batteries and guarantees to reduce technical risks	Desirable				L	N	
FFF7	Create incentives for clean buses and fuels that support emission reduction goals	Supportive			▶	L	N	

Source: Steer

To ensure that all concessionaires, manufacturers, investors and other key stakeholders can trust the evidence presented, we recommend that the government support an independent, transparent technical assessment process designed to facilitate knowledge transfer by making pilot performance data readily available to the general public and interested parties.

Bus acquisition, charging infrastructure and operating costs should be shared with the public in order to engender better decision-making processes. The need for financing instruments to achieve lower interest rates (and possible funding mechanisms) is important for clean bus deployment. These mechanisms might include cross-modal subsidies, improved access to green funds, bonds, or to other long-term financial instruments with the aim of achieving competitive TCO for clean bus technologies. Finally, the pilot results could help identify clean bus technologies that are worth pursuing in Buenos Aires (based on local costs, benefits and feasibility), and it is recommended that the evidence be used at the national level to support the development of fresh incentives for the use of clean fuels, and to help make clean bus technologies more attractive to the different stakeholders.

Stakeholders

The key stakeholders in Buenos Aires for clean bus implementation are:

The Ministry of Environment and Sustainable Development (MAyDS) and the Ministry of Transport -- the leading national agencies involved in implementation of the PANTyCC.

The CNRT (National Transport Commission), a decentralized entity of the Ministry of Transport responsible for overseeing the bus transport system within the AMBA region.

The Secretary of Transport of the CABA Government, responsible for the implementation of the Clean Mobility Plan.

Other stakeholders that should be involved wholly or partially in the process include the Ministry of Energy and Mining, energy companies and bus operators' trade associations.

B. Mexico City

Although clean buses have a low TCO in Mexico City, upfront costs for hybrid and battery electric buses are 50% to 75% higher than for diesel buses. This is a clear deterrent for cleaner technologies. Providing financial incentives to reduce interest rates for purchasing clean buses may be necessary to encourage their use.

Setting up a revolving fund to improve the financial conditions for clean bus purchases or accessing other available financing mechanisms can help encourage the switch to clean technologies. Other financial incentives to guarantee funds include:

- **National and local funds**: government to underwrite loan guarantees or leasing payment mechanisms with public funds such as the National Fund for Climate Change, or other locally available funds[23], to extend debt periods and/or enable reduced interest rates.
- **Local and international lending options:** a green bond issue, International Finance Corporation (IFC) support, Climate Investment Funds (CIF) financing, and Export Credit Agencies (ECAs) support.

23 The Mobility Law for Mexico City describes two possible mechanisms to promote better public transportation systems and cleaner technologies: the public fund for mobility and roadway safety (Fondo Público de Movilidad y Seguridad Vial) and the public transport financing fund (Fondo de Promoción para el Financiamiento del Transporte Público).

Such mechanisms may be applied to the upfront payment over the total credit life. A scenario in which a financial mechanism is used to reduce the interest rate to 6.5%[24] (from the current 12.5%) for hybrid and electric buses is shown in the TCO comparison in Figure 6.2.

Two main types of public transport projects currently underway in Mexico City are both candidates for clean bus implementation:

- New BRT Lines;
- Fleet renewal process on traditional bus corridors.

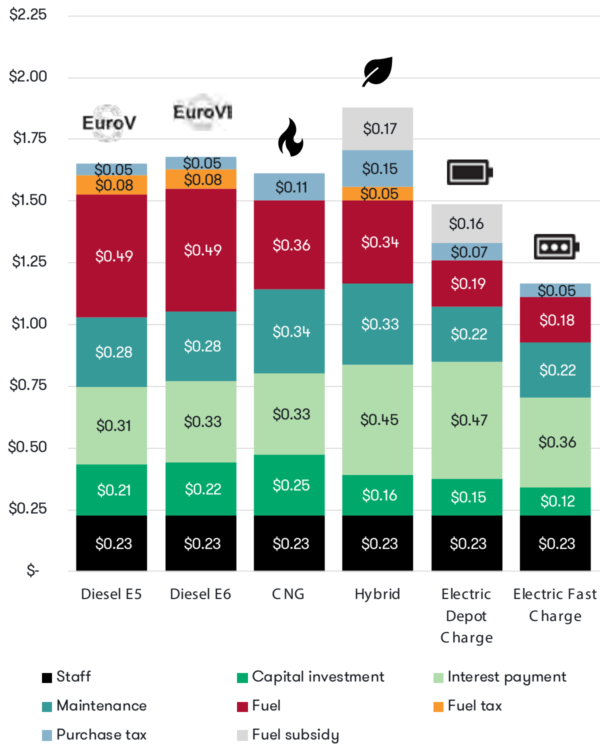
New BRT Lines

The planned BRT network expansion represents an opportunity for clean buses, since the system as structured reduces the financial risk for creditors, and facilitates the implementation of zero- or low-emission corridors. The system consists of individual concessions for each component:

- Operational and monitoring system audits;
- Fare collection operators;
- Fare collection trust funds;
- Public and private bus concessionaires;
- Metrobús.

24 This rate is similar as the green bond issue in 2016 in MXN, at an interest rate of 6.2% over five years.

Figure 6.2: TCO/km comparisons for buses in Mexico City, assuming interest rates



Source: Steer for the World Bank based on various sources summarized in Appendix A.

A few key actions have been identified as effective starting points for the incorporation of clean buses in these network expansions. The suggested timeframes and stakeholder types are listed in Table 6.3.

BRT systems have been implemented, taking into account the specific conditions of each corridor. For example, Line 1 uses bi-articulated buses, Lines 2, 3, 5 and 6 have articulated buses, Line 4 operates with Hybrid and Euro V low-platform, 12m buses, and the recently-opened Line 7 has double- decker Euro VI buses. This shows that route compatibility analyses can consider different potential technologies, such as hybrid buses for routes with higher commercial speeds and long-distance services, BEBs for shorter routes with lower speeds or the land availability and configuration to support required charging infrastructure.

Table 6.3: Key recommendations roadmap for new BRT lines in Mexico City

	Recommendations	Status	Timeframe: Short Term	Timeframe: Medium Term	Timeframe: Long Term	Stakeholders: Government Local	Stakeholders: Government Nation	Stakeholders: Private sector
ENV5	Evaluate prioritizing zero/low emission zones or corridors	Supportive				L		P
PT1	Conduct route compatibility analysis with clean bus options to define the best suitable technologies	Desirable				L		P
PT2	Promote independent and open knowledge transfer of performance data from pilots	Supportive				L	N	P
PT3	Promote benefits of noise and emissions reduction and study changes to land use restrictions for depots and terminals	Supportive				L		
GOV1	Strengthen concession conditions with mechanisms to guarantee bus payments or reduce risks of default	**Essential**				L	N	P
GOV3	Pursue regulatory and contractual frameworks to promote energy company participation in BEB deployment	Desirable				L	N	P
FFF1	Evaluate the potential for cross-modal subsidies to support public transport	Desirable				L	N	
FFF2	Develop mechanisms to facilitate acces to green funds	Supportive				L		
FFF4	Decouple the credit payment from the tariff	**Essential**				L		
FFF5	Integrate small operators in the fare trust funds managed by an external trustee	Desirable				L		

Source: Steer

Table 6.4: Key recommendations roadmap for fleet renewal in Mexico City

	Recommendations	Status	Timeframe: Short Term	Timeframe: Medium Term	Timeframe: Long Term	Stakeholders: Government Local	Stakeholders: Government Nation	Stakeholders: Private sector
ENV4	Include emission and noise reduction elements in cost-benefit evaluation processes	Desirable	■			L	N	
GOV1	Strengthen concession conditions with mechanisms to guarantee bus payments or reduce risks of default	**Essential**	■			L	N	P
GOV3	Pursue regulatory and contractual frameworks to promote energy company participation in BEB deployment	Desirable		■		L	N	P
FFF1	Evaluate the potential for cross-modal subsidies to support public transport	Desirable		■	■	L		
FFF2	Develop mechanisms to facilitate access to green funds	Supportive	■			L	N	

Source: Steer

Fleet renewal processes on traditional bus corridors

Public funding instruments such as the National Fund for Climate Change, aimed at reducing the differential purchase cost between diesel and CNG buses, and other bus scrapping funds, are budgetary instruments that are not always available to concessionaires.

Strengthening these other revolving funds, together with the mechanisms to guarantee against payment default, would help improve the uptake of clean buses on those corridors where their efficiency is proven. Fare collection devices are desirable on these services.

Mexico City does not possess a public transport registry nor an up-to-date inventory of buses, concessions and routes, which makes it extremely difficult to define effective policy actions and measure their impacts. The implementation of a public transport registry, as specified by current law, is recommended in the short term.

Stakeholders

Metrobús: As a public planning institution, Metrobús can set the standards for new corridors, procure new concessions and develop new payment formulas for clean bus services.

SEDEMA: Mexico City's Secretariat of Environment is the public agency responsible for environmental protection and sustainable development, with air quality, climate change and sustainable mobility as its key focus areas. SEDEMA was responsible for establishing the conditions that led to the creation of Metrobús in 2005. It also managed the carbon bond financing mechanisms for several projects, as well as other public transport-related financing and funding mechanisms in Mexico City.

SEMOVI: Mexico City's Secretariat of Mobility manages public transport concessions in Mexico City, and at present directs the fare trust fund expansion among the various public transport providers. SEMOVI currently manages the "Fund for Taxis, Mobility and Pedestrians", created in 2015 to collect 1.5% of the cost of each trip made on app-based mobility services to encourage public transport and active mobility in the city.

SEFIN: Responsible for leading on local economic policy, the Secretariat of Finance sets the budget for public transport operators such as SM1 and STE, and provides funding for their bus fleets when required.

FONADIN through Banobras: runs the Federal Public Transportation Support Program (PROTRAM) focused on mass transit infrastructure. FONADIN has been a major funding source for national BRT and Metro projects since its creation in 2008.

C. Montevideo

High costs are one of the main barriers to the uptake of clean buses in the region, both in terms of vehicle purchase price and associated financing costs. BEB prices in Montevideo are 45% higher than in São Paulo and 50% higher than in Santiago. To improve opportunities for adoption of clean buses in Montevideo, an open market for bus acquisition is the key to lowering BEB prices in line with international market levels.

If BEB acquisition prices were reduced to the same level as in São Paulo, electric buses would have a TCO of only $0.33 /km more than diesel buses (i.e.s $0.05/km less than the current diesel subsidy).

The current funding for diesel subsidies (or other available resources), could be reallocated to provide incentives for clean buses via revolving funds which provide guarantees for creditors or direct subsidies. The available local mechanisms include:

- **Diesel subsidy** (Fideicomiso del Combustible): This is a money-back incentive provided to bus operators based on the number of kilometers driven. This may represent a saving in the case of electric buses.
- **Uruguayan Trust for Energy Saving and Efficiency** (FUDAEE) is a support mechanism providing financial leverage for projects and activities that promote energy efficiency.
- **The Plan for Energy Efficiency** grants credit guarantees to improve energy efficiency.

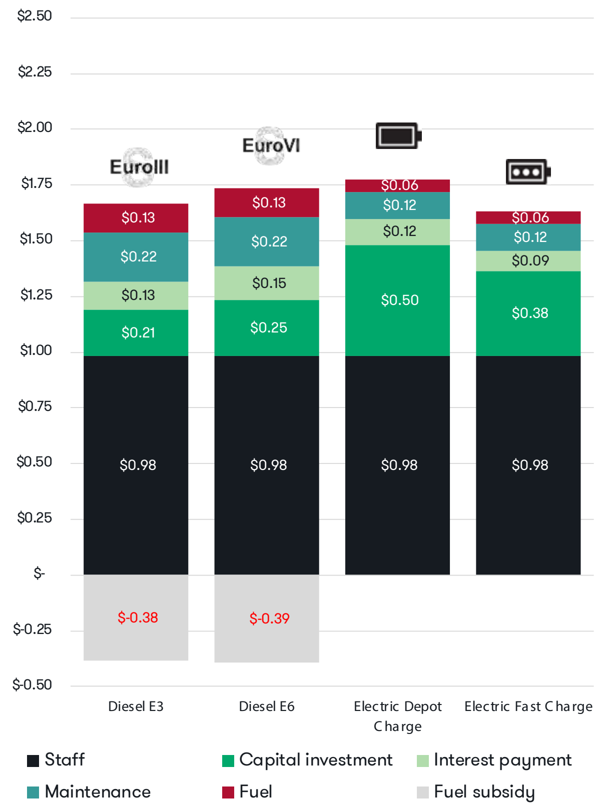
International mechanisms can also be used to improve financial credit conditions (e.g. better interest rates). Such mechanisms may include:

- Green bond issuance;
- International Finance Corporation (IFC);
- Climate Investment Funds (CIF);
- Export Credit Agencies (ECAs).

These mechanisms would help to augment the savings from the funds currently applied to the diesel subsidy.

In November 2017, the national government launched the project "Towards an efficient and sustainable urban mobility system in Uruguay".

Figure 6.3: TCO/km. assuming the same acquisition price as São Paulo for BEBs and an interest rate of 5.5%



Source: Steer for the World Bank based on various sources summarized in Appendix A.

Funded by the Global Environmental Facility (GEF), the project is led by MIEM and MVOTMA, and aims to:

- Contribute to the development of public policies to reduce GHG from the transport sector by optimizing transport energy consumption, conducting studies on the life cycle and impacts of batteries, etc.
- Promote the electrification of the transport sector by implementing pilot projects to test five electric buses by different bus concessionaires.
- Contribute to a culture change towards a smaller carbon footprint, and promote sustainable transport.

The project involves an investment of over $21.7 million to support the government´s actions and meet the project´s targets over a four-year period.

At a local level, the Municipality of Montevideo (IMM) is working towards implementing different initiatives contained in its Mobility Plan for Montevideo 2010-2020, which has been aligned with national environmental objectives and energy efficiency goals. The Plan sets out nine strategic objectives, with four related of them to public transport:

- Promote sustainable transport,
- Rationalize the current metropolitan transport system (STM),
- Promote an integrated transport system (fare integration), and
- Promote energy efficiency in the public transport sector.

Multiple projects are being pursued to meet the strategic objectives, notably the implementation of segregated corridors and the integration of public transport. In a 2017 report, the Municipality expounded a strategy to introduce electromobility into public transport to increase the reliability of the system.

Towards an efficient and sustainable urban mobility system in Uruguay

The implementation of the five bus pilots in Montevideo could be an opportunity to test and evaluate the performance of clean technologies, and to provide evidence for the introduction of relevant standards. The knowledge, outcomes and evidence gathered from these initiatives should be openly shared and disseminated using independent and transparent methods to increase stakeholders' confidence level in the transport system. Bus purchasing, tariff and operating costs data should be also shared in order to inform better decision-making. Promoting consolidated and competitive fleet acquisition processes would also be beneficial to the uptake of clean buses.

The high cost of buses with cleaner technology was found to be a major obstacle for bus concessionaires. It is therefore recommended that mechanisms to help them access available funds should be explored and evaluated. This could be achieved through the provision of information, advice on funding processes, or even by creating new funds to improve the appeal of clean bus technologies.

Table 6.5: Key recommendations for the project "Towards an efficient and sustainable urban mobility system in Uruguay"

	Recommendations	Status	Timeframe			Stakeholders		
			Short Term	Medium Term	Long Term	Government Local	Government Nation	Private sector
ENV3	Create standards for secondary use, recycling and/or final disposal of vehicle batteries	Essential				L	N	
ENV4	Include emission and noise reduction elements in cost-benefit evaluation processes.	Desirable				L	N	
ENE3	Create common technical standards for bus charging	Desirable				L	N	P
PT2	Promote independent and open knowledge transfer of performance data from pilots	Supportive				L	N	P
FFF2	Develop mechanisms to facilitate access to green funds	Supportive					N	
FFF8	Evaluate the feasibility of budget reassignment from other ministries to incentivize clean bus projects.	Desirable					N	

Source: Steer

Mobility Plan for Montevideo 2010-2020

Montevideo's mobility plan and its urban mobility resilience actions are identified as opportunities for the introduction of clean buses. Some key actions are listed in Table 6.6

To advance the Municipality's strategy to introduce electromobility in its public transport system, common technical standards for bus charging need to be analyzed and introduced. This will help to open the market by providing the flexibility of choosing among different suppliers, and reduce the need to customize infrastructure for each project. As the capital costs for BEBs are a major obstacle for concessionaires in Montevideo, multiple options should be explored to mitigate this barrier, such as evaluating leasing schemes for buses and batteries and providing guarantees to reduce technical risks.

To encourage bus concessionaires to renew their fleets and promote cleaner technologies, we recommend studying the financing mechanisms that are currently available to bus concessionaires. This will help identify existing financing options and their feasibility for assisting the rollout of new technologies.

The above analysis should provide a clear idea of current challenges and the steps that need to be taken to overcome them.. In addition to evaluating available financing mechanisms, the study should, look closely at current bus operation subsidies to identify any incentives such as diesel subsidies that may undermine the competitiveness of the new technologies.

Stakeholders

The recommendations listed above are relevant for the following key stakeholders:

Ministry of Energy and Mines (MIEM) and Ministry of Housing, Land-use and Environment (MVOTMA), jointly responsible for the project "Towards an efficient and sustainable urban mobility system in Uruguay".

Municipality of Montevideo (IMM): responsible for implementing the Mobility Plan and overseeing bus services in the city.

Table 6.6: Key recommendations for the Mobility Plan for Montevideo 2010-2020

	Recommendations	Status	Timeframe Short Term	Timeframe Medium Term	Timeframe Long Term	Stakeholders Government Local	Stakeholders Government Nation	Stakeholders Private sector
ENV2	Strengthen urban bus emission standards	Essential				L	N	
ENV5	Evaluate prioritizing zero/low emission zones or corridors	Supportive				L		
ENE3	Create common technical standards for bus charging	Desirable				L	N	P
PT1	Conduct route compatibility analysis with clean bus options to define the best suitable technologies	Desirable				L		
FFF3	Diversify and incentivize access to finance mechanisms.	Supportive				L		
FFF6	Explore leasing schemes for buses and batteries and guarantees to reduce technical risks	Desirable				L		P

Source: Steer

D. Santiago

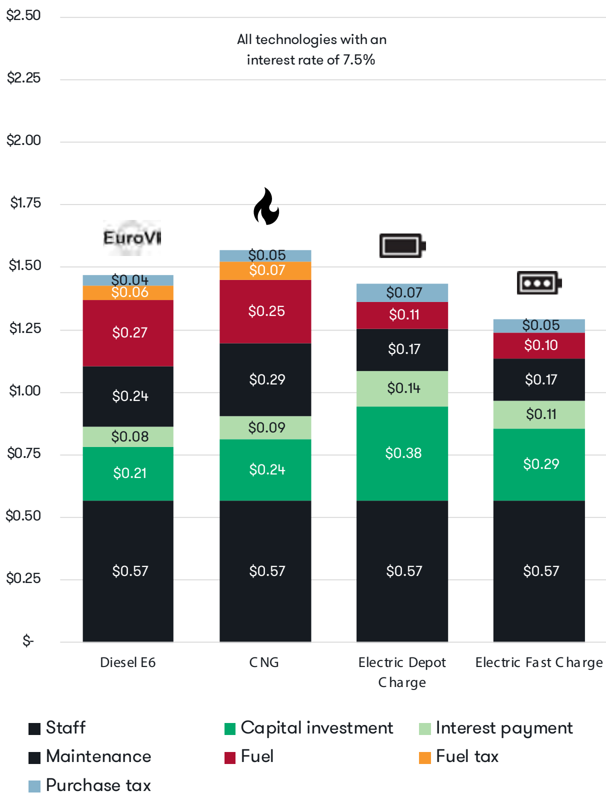
Battery electric buses benefit from financing incentives that reduce interest rates from 7.5% to 5.6%. These incentives enable a competitive TCO for clean technologies, but the main perceived barrier for clean bus uptake was the risk of introducing a technology that is unfamiliar to bus concessionaires.

Santiago has two important initiatives underway that are suitable for clean bus uptake:

- Early uptake: implementing 200 BEBs.
- Tendering process for Transantiago: providing further opportunities to introduce clean buses.

A series of complementary measures will be considered during the implementation process aimed at improving and accelerating clean bus uptake.

Figure 6.4: TCO per kilometer, considering an interest rate of 7.5% for all technologies.



Source: Steer for the World Bank based on various sources summarized in Appendix A.

Early uptake: implementing 200 BEBs.

This project is already underway with, contract arrangements to incorporate additional new buses (BEB and Diesel Euro VI), through fleet expansion and/or renovation.

Table 6.7 lists recommendations to favor risk reduction and to enable maximum learning to be derived from the introduction of electric buses.

The recent financing of BEBs through leasing schemes structured by the private sector (ENEL and ENGIE energy companies), has created an interesting opportunity for other parties to join this market (e.g. other energy companies and new manufacturers). The authorities should also look at ways to attract more potential financiers to this market. The leasing scheme includes the provision of a second battery when the vehicle has reached mid-life. This initiative needs to be analyzed in more detail to ensure that the systems are not overpricing the technological risk, since battery costs continue to decline, and technology is maturing in terms of autonomy and capacity.

Introduction of the 200 BEBs in Santiago provides a unique opportunity to gather relevant real-world operational data from the different technologies. Providing data on clean bus performance for independent and public analysis and peer review in technical reports, will help to ensure that lessons are learned and taken into consideration in future bidding processes. Santiago faces some difficulty to find appropriate spaces for bus depots and operations centers. Providing evidence at e-terminals on noise and emissions reduction could help support changes in land use restrictions with a view to making more spaces available for the necessary transport facilities.

Table 6.7: Recommendation roadmap from implementing and learning from early uptake: implementing 200 e-buses in Santiago

	Recommendations	Status	Timeframe: Short Term	Timeframe: Medium Term	Timeframe: Long Term	Stakeholders: Government Local	Stakeholders: Government Nation	Stakeholders: Private sector
ENV4	Include emission and noise reduction elements in cost-benefit evaluation processes.	Desirable					N	P
ENE1	Conduct technical analysis of energy system capacity to support large-scale bus fleets.	Essential					N	P
PT1	Conduct route compatibility analyses with Clean Bus options to define the best suitable technologies.	Desirable					N	P
PT2	Promote independent and open knowledge transfer of performance data from pilots.	Supportive					N	P
PT3	Promote benefits of noise and emissions reduction and study changes to land use restrictions for depots and terminals.	Supportive				L	N	P
GOV1	Strengthen concession conditions with mechanisms to guarantee bus payments or reduce risks of default.	Essential					N	
GOV4	Specify the lead entity or body to coordinate Clean Bus deployment strategies and conduct periodic stakeholder outreach to gauge reactions to Clean Buses.	Supportive					N	
FFF4	Decouple the credit payment from the tariff.	Essential					N	
FFF6	Explore leasing schemes for buses and batteries and guarantees to reduce technical risks.	Desirable					N	P

Source: Steer

Tendering process for Transantiago: providing more opportunities for clean buses

The tendering process that is currently under preparation, and similar bidding exercises over the next few years, present a unique opportunity to incorporate new technologies via a competitive process. The sheer number of buses required will generate interest from many bus manufacturers. Table 6.8 lists the main recommendations for making the tendering processes even more competitive and efficient in terms of obtaining the best combination of transport technologies, reducing risks and bringing down costs.

The previously aborted tendering process defined Euro VI as the standard for new buses, in conformity with the definition in the recently approved Environmental Decontamination Plan. We suggest that this norm should be maintained for the new process. While the previous tendering process simply specified the number of BEBs required, it would be better for the new process to clearly specify the services required, to define corridors, appropriate terminals, etc., and to determine the size and characteristics of the new fleet.

Although the MTT has been leading BEB implementation, other elements of the electromobility strategy (2016-17) call for more specific leadership to ensure better inter-sectoral coordination, and private sector engagement. We recommend, for example, looking carefully at cost and risk reduction opportunities such as those related to the present battery replacement scheme at bus life mid-term.

Elements for success

Key elements for the successful introduction of clean buses at scale in Santiago include:

- MTT leads implementation, but works closely with the Energy and Environment Ministries;
- The existence of a framework that allows as much competition as possible;
- Private energy companies provide financing (leasing) and reducing risks;
- Incentives provided for cleaner technologies, and
- Ex-post performance analyses and public information sharing.

Stakeholders

The main stakeholders for clean bus deployment in Santiago include:

- Ministry of Transport and Telecommunications (MTT)
- 3CV (MTT) as the technical authority for performance measurements
- Ministry of Environment
- Ministry of Finance
- Ministry of Energy
- Consorcio Movilidad Eléctrica (Public – Private Working Group)
- Manufacturers
- Energy Companies

Table 6.8:Recommendation roadmap for the new tendering processes for Transantiago

	Recommendations	Status	Timeframe			Stakeholders		
			Short Term	Medium Term	Long Term	Government Local	Government Nation	Private sector
ENV5	Evaluate prioritizing zero/low emission zones or corridors.	Supportive	■	■		L	N	
PT1	Conduct route compatibility analyses with clean bus options to define the best suitable technologies.	Desirable	■	■			N	P
PT2	Promote independent and open knowledge transfer of performance data from pilots.	Supportive	■	■	■		N	P
PT3	Promote benefits of noise and emissions reduction and study changes to land use restrictions for depots and terminals.	Supportive	■	■		L	N	P
GOV3	Pursue regulatory and contractual frameworks to promote energy company participation in BEB deployment.	Desirable		■			N	
GOV4	Specify the lead entity or body to coordinate clean bus deployment strategies and conduct periodic stakeholder outreach to gauge reactions to Clean Buses.	Supportive	■				N	
FFF3	Diversify and incentivize access to finance mechanisms.	Supportive	■				N	
FFF4	Decouple the credit payment from the tariff.	**Essential**	■				N	
FFF6	Explore leasing schemes for buses and batteries and guarantees to reduce technical risks.	Desirable	■	■		L	N	P
FFF7	Create incentives for clean buses and fuels that support emission reduction goals.	Supportive	■				N	

Source: Steer

E. São Paulo

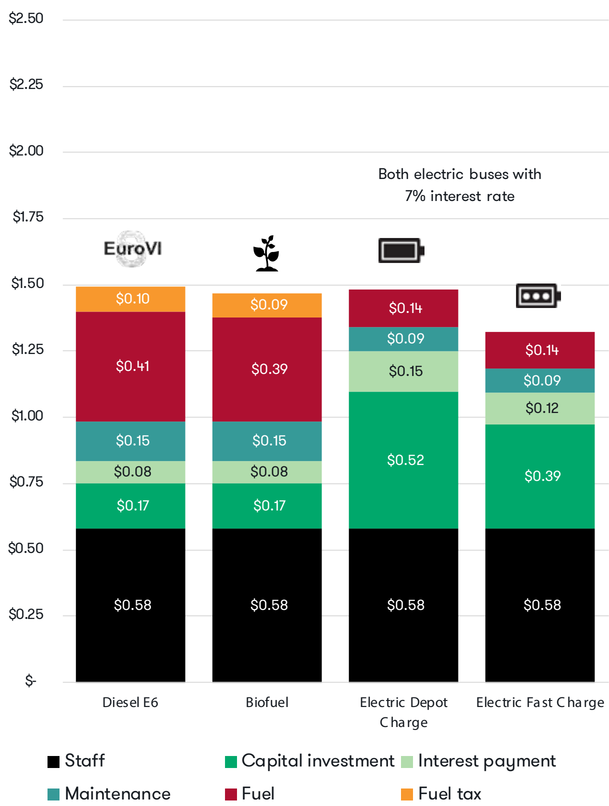
The present value analysis on the TCO per kilometer shows that biofuel buses are more competitive than the other clean bus technologies in this city, although electric buses are less than 10% higher than the other two evaluated.

Providing financial incentives for zero-emission technologies to reduce the interest rate from the current high 11.1% may enable BEBs to be more competitive with the other bus technologies (credits with 7% interest rate have been previously available for fleet purchase).

The mechanisms available in São Paulo for funding the appropriate financial incentives and establishing guarantee funds or direct subsidies, are the following:

- The **Fundo Especial do Meio Ambiente e Desenvolvimento Sustentável (FEMA)** provides low interest loans to support projects for the improvement and/or recovery of environmental quality.

TCO/km for buses in São Paulo, assuming an interest rate of 7% for BEBs



Source: Steer for the World Bank based on various sources summarized in Appendix A.

- The **National Bank for Economic and Social Development – BNDES** offers a credit line called FINAME to finance the manufacture and purchase of accredited domestically-produced machinery and equipment. This includes financing for buses, trucks, and other machinery.
- The **Paulista Development Agency** has promoted sustainable development through long-term credit operations for small and medium-sized companies in São Paulo. The agency has a funding program with a technology incentive line called the Linha Economia Verde. One item within this credit line refers to the substitution of fossil fuels with clean fuels for use in public and private transportation (natural gas, biodiesel, ethanol, electricity, etc), fleet renewal and switching from diesel-powered buses to biodiesel, ethanol or electric. However, none of São Paulo's bus fleet has been financed with this credit line to date.
- The **Caixa Econômica Federal (Federal Housing Bank)**, has a credit line called REFROTA as part of the Pro-Transportation Program funded by the FGTS (Fundo de Garantia do Tempo de Serviço – Workers' Guarantee Fund), which is available for financing (under the control of the Ministry of Cities) the renewal or expansion of bus fleets for companies that have concessions or permission to run urban transport services.

Other financial mechanisms in São Paulo include international lending options such as:

- Green bonds,
- International Finance Corporation (IFC) support,
- Climate Investment Funds (CIF), or
- Financing and Export Credit Agencies (ECAs) support.

Figure 6.5 shows the effect of lower interest rates on the TCO per kilometer for different clean bus technologies.

Table 6.9: Roadmap for São Paulo's new bus tendering process

	Recommendations	Status	Timeframe			Stakeholders		
			Short Term	Medium Term	Long Term	Government		Private sector
						Local	Nation	
ENV3	Create standards for secondary use, recycling and/or final disposal of vehicle batteries.	Essential					N	
ENV5	Evaluate prioritizing zero/low emission zones or corridors.	Supportive				L		
ENE3	Create common technical standards for bus charging.	Desirable				L	N	P
ENE4	Evaluate the possibilities and economies of lower tariffs for slow charging at night.	Supportive				L	N	P
PT1	Conduct route compatibility analyses with clean bus options to define the best suitable technologies.	Desirable				L		P
PT2	Promote independent and open knowledge transfer of performance data from pilots.	Supportive				L	N	P
GOV3	Pursue regulatory and contractual frameworks to promote energy company participation in BEB deployment.	Desirable				L	N	P
GOV4	Specify the lead entity or body to coordinate clean bus deployment strategies and conduct periodic stakeholder outreach to gauge reactions to clean buses.	Supportive				L		
FFF1	Evaluate the potential for cross-modal subsidies to support public transport.	Desirable				L	N	
FFF3	Diversify and incentivize access to finance mechanisms.	Supportive				L	N	
FFF6	Explore leasing schemes for buses and batteries and guarantees to reduce technical risks.	Desirable				L	N	P

Source: Steer

São Paulo's New Bus Tendering Process

Evaluation of the current bus routes that could operate exclusively with clean buses facilitates planning, cost evaluation, charging infrastructure installation and results monitoring. The identification of high pollution areas, and creation of zero- or low-emission zones or corridors restricted to clean buses, could enable their gradual implementation in city areas liable to benefit most from early investment.

The bus tendering process could also include route compatibility analyses to define the priorities for BEB implementation, selecting routes with the potential for service efficiency improvements to overcome current technology limitations. Manufacturers can also play an active role in the introduction of clean buses, offering maintenance, battery leasing or substitution programs (at least in the first stage of the procurement process) and helping to transfer knowledge to concessionaires.

The terms of the bidding processes should enable a range of interested parties, such as energy companies, financial institutions, manufacturers and others, to participate directly in the concessions. This could help minimize the risks associated with the limited financial capacity of bus concessionaires and/or their concern about technology risks (e.g. by facilitating leasing schemes or capital contributions). However, to be fully effective it will also be necessary to revisit the commercial model and strengthen the concession rules with mechanisms that can guarantee or reduce the long-term risks of default on payments.

New bus corridors with clean buses

Network planning and the construction of new bus corridors and terminals represent an opportunity simultaneously to implement zero- or low-emission corridors. It also provides an opportunity to introduce value-for-money methodologies that include emission and noise reduction factors in the cost-benefit evaluation processes. The corridors should be evaluated by taking into account the external benefits to the urban population arising from improved environmental quality and better health outcomes due to emissions and noise reduction. This would encourage cleaner technologies to be selected where, although the direct (internal) costs may be higher, the new technologies will in due course provide better value-for-money solutions.

The City government can promote the benefits of reduced noise and pollutant emissions, and study normative changes to land use restrictions for bus depots and terminals. São Paulo is currently mapping noise levels, which will help establish noise reduction targets in critical areas and stimulate the implementation of corridors operating with BEBs.

We recommend diversifying and encouraging access to available financing mechanisms. In addition to the options described above, new projects could be financed through land value capture mechanisms linked to other measures, which would require an integrated approach to planning by the Mobility and Urban Planning Secretariats.

Table 6.10: Roadmap for new bus corridors with clean buses in São Paulo

	Recommendations	Status	Timeframe			Stakeholders		
						Government		Private sector
			Short Term	Medium Term	Long Term	Local	Nation	
ENV4	Include emission and noise reduction elements in cost-benefit evaluation processes.	Desirable				L		
ENV5	Evaluate prioritizing zero/low emission zones or corridors.	Supportive				L	N	
PT2	Promote independent and open knowledge transfer of performance data from pilots.	Supportive			▶	L	N	P
PT3	Promote benefits of noise and emissions reduction and study changes to land use restrictions for depots and terminals.	Supportive				L	N	P
GOV3	Pursue regulatory & contractual frameworks to promote energy company participation in BEB deployment.	Desirable				L	N	P
FFF3	Diversify and incentivize access to finance mechanisms.	Supportive			▶	L	N	

Source: Steer

Stakeholders

These recommendations would require actions to be taken by local, state and national government entities, as follows:

Local government - São Paulo Transporte SA (SPTrans): subordinated to the Municipal Secretary of Mobility and Transport, manages all the municipal bus routes in São Paulo.

Local government – Municipal Secretariat for Green Spaces and the Environment (SVMA): responsible for climate change, air quality and atmospheric emissions at the municipal level. The SVMA, together with other municipal secretariats and institutions, form the São Paulo Municipality Climate Committee, an advisory body created in 2009 by the previous city law on climate change (Law No. 14,933 of 2009).

São Paulo State Government: responsible for the provision of metropolitan public transport systems, including metropolitan buses managed by EMTU (Metropolitan Urban Transportation Company of São Paulo).

National government - Ministry of Cities: manages financing programs, as well as the credit line REFROTA, of the Pro-Transportation Program, which uses the National Workers Guarantee Fund to finance the renewal or expansion of bus fleets.

National government - Ministry of Environment: manages the non-reimbursable climate fund (Fundo Clima) which is an instrument of the National Policy on Climate Change. The fund aims to finance studies and projects to reduce GHGs emissions and adapt to climate change impacts.

Ministry of Industry, Foreign Trade and Services (MDIC): is working with GIZ and Rota 2030 to develop plans to promote the electromobility industry in Brazil.

Conclusions

While clean bus uptake may be constrained by various barriers depending on environmental, energy, regulatory, institutional and financial contexts, there are mechanisms for overcoming these barriers and for fostering an enabling environment for their uptake in the region.

Since the operating and maintenance costs of battery electric buses are lower, these buses are the best option from the TCO point of view in Mexico City and Santiago. However, concessionaires are reluctant to pilot these technologies due to their limited knowledge of the operational and maintenance requirements involved. It is true that these technologies have operational constraints requiring evaluation prior to their implementation.

Even in cities where BEBs at present have higher TCOs then diesel buses, the reduction of diesel subsidies would help to encourage the adoption of clean bus technologies. On the negative side, other city- and corridor-specific barriers may increase implementation costs given the need for depot reconfiguration, electric power network extensions and costs involved in the battery-charging infrastructure.

Clean buses are an opportunity to incorporate new third parties in schemes to provide new fleets and generally improve public transport services, reduce fleet financing costs and relieve pressure on user fares and / or public subsidies. Overcoming barriers to clean bus deployment will involve active stakeholder participation, a transparent approach to technical performance and implementation costs, and an extensive review of available financing mechanisms.

Pilot projects are essential for measuring the real-world consumption, performance, capacity, costs and compatibility of clean buses on specific routes. The tendering processes for fleet purchasing must be open and competitive, and contain clearly defined bus performance requirements. Moreover, innovative contractual and business models should be pursued to reward low TCO technologies, share risks and overcome the challenges represented by high upfront costs.

Implemented together, the recommended innovations in public transport, environmental policy, energy and infrastructure, governance and markets and funding and finance can help cities to accelerate the deployment of clean bus technologies that are capable of yielding significant economic, social and environmental benefits.

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Appendix A: Key Assumptions for World Bank TCO Analysis

Following are key data inputs and assumptions underlying World Bank TCO estimates. As noted, clean bus costs are quite dynamic and these inputs represent only a snapshot in time.

Table A.1: Key data inputs and assumptions underlying World Bank TCO Analyses - Buenos Aires

	Units	Diesel Euro V	Diesel Euro VI	CNG bus	Biofuel bus	Electric bus Depot	Electric bus Fast charge
Vehicle Acquisition*	USD	$170,000	$180,000	$200,000	$170,000	$425,000	$367,030
Second battery Acquisition	USD	-	-	-	-	$170,000	-
Fuel performance	km/lt, km/kWh, km/m3.	1.96 km/lt	1.96 km/lt	1.90 km/m3	1.76 km/lt	0.78 km/kWh	0.87 km/kWh
Fuel Costs*	USD/lt, USD/kWh, USD/m3	0.63 USD/lt	0.66 USD/lt	0.33 USD/m3	0.63 USD/lt	0.10 USD/kWh	0.103 USD/kWh
Maintenance Costs	USD/km	0.22	0.22	0.26	0.22	0.15	0.15
Infrastructure Costs**	USD	$0	$0	$0	$0	$12,500	$7,000
Labor Costs	USD/year	$41,400	$41,400	$41,400	$41,400	$41,400	$41,400
Interest rate	%	17.50%	17.50%	17.50%	17.50%	17.50%	17.50%
Useful life	Years	10	10	10	10	10	10

Sources: Instituto Metropolitano Protransporte de Lima, Agrale, Comisión Nacional de Regulación del Transporte, Ministerio de Ambiente y Desarrollo Sustentable, Ministerio de Energía, interview with Metbus Chile, Steer.

*Including taxes. ** Part or all the cost of infrastructure may be included in Fuel Costs.

Table A.2: Key data inputs and assumptions underlying World Bank TCO Analyses - Mexico City

	Units	Diesel Euro V	Diesel Euro VI	Hybrid bus	CNG bus	Electric bus Depot	Electric bus Fast charge
Vehicle Acquisition*	USD	$220,000	$230,000	$360,000	$264,000	$330,000	$285,000
Second battery Acquisition	USD	-			-	$132,000	-
Fuel performance	km/lt, km/Kwh, km/m3	1.85 km/lt	1.85 km/lt	2.7 km/lt	1.37 km/m^3	0.78 km/kWh	0.87 km/kWh
Fuel Costs*	USD/lt, USD/kWh, USD/m3	1.06 USD/lt	1.06 USD/lt	1.06 USD/lt	0.49 USD/m^3	0.14 USD/kWh	0.16 USD/kWh
Maintenance Costs	USD/km	0.28	0.28	0.33	0.34	0.22	0.22
Infrastructure Costs**	USD	$0	$0	$0	$0	$12,500	$7,000
Labor Costs	USD/year	$15,882	$15,882	$15,882	$15,882	$15,882	$15,882
Interest rate	%	12.65%	12.65%	12.65%	12.65%	12.65%	12.65%
Useful life	Years	10	10	10	10	10	10

Sources: Interview with CISA (metrobus and corridor concessionaire group), interview with Metbus Chile, Steer.

*Including taxes. ** Part or all the cost of infrastructure may be included in Fuel Costs.

Table A.3: Key data inputs and assumptions underlying World Bank TCO Analyses - Montevideo

	Units	Diesel Euro III	Diesel Euro VI	Battery Electric Bus Depot	Battery Electric Fast Charge
Vehicle Acquisition*	USD	$150,000	$180,000	$450,000	$388,620
Second battery Acquisition	USD	-	-	$180,000	-
Fuel performance	km/lt, km/Kwh, USD/lt,	2.50 km/lt	2.50 km/lt	0.78 km/kWh	0.87 km/kWh
Fuel Costs* **	USD/kWh, USD/km	0.32 USD/lt	0.32 USD/lt	0.045 USD/kWh	0.05 USD/kWh
Maintenance Costs	USD/km	0.22	0.22	0.12	0.12
Infrastructure Costs***	USD	-	-	$12,500	$12,500
Labor Costs	USD/year	$70,701	$70,701	$70,701	$70,701
Interest rate	%	13.50%	13.50%	13.50%	13.50%
Useful life	Years	15	15	10	10

Sources: Municipalidad de Montevideo, Intendencia de Montevideo, Administración Nacional de Usinas y Transmisiones Eléctricas (UTE), Decreto 411/010 del Ministerio de Economía y Finanzas, ANCAP, Ministerio de Industria, Energía y Miniería, Ministerio de Energía de Argentina, interview with Metbus Chile, Steer.

* Including taxes. **Subsidized by about 75%. *** Part or all the cost of infrastructure may be included in Fuel Costs.

Table A.4: Key data inputs and assumptions underlying World Bank TCO Analyses - Santiago

	Units	Diesel Euro VI	CNG bus	Battery Electric Bus Depot	Battery Electric Fast Charge
Vehicle Acquisition*	USD	$196,964	$225,267	$300,000	$259,090
Second battery Acquisition	USD	-	-	$120,000	-
Fuel performance	km/Kwh, km/m3, km/lt	2.15 km/lt	1.84 km/m^3	0.78 km/KWh	0.87 km/KWh
Fuel Costs*	USD/kWh, USD/m3, USD/lt	0.69 USD/lt	0.60 USD/lt	0.083 USD/kWh	0.091 USD/kWh
Maintenance Costs	USD/km	0.24	0.29	0.17	0.17
Infrastructure Costs**	USD	$0	$0	$12,500	$7,000
Labor Costs	USD/year	$44,278	$44,278	$44,278	$44,278
Interest rate	%	7.50%	7.50%	5.60%	5.60%
Useful life	Years	10	10	10	10

Sources: Interviews with Vule Metrogas, Enel and Metbus; Bloomberg, Transantiago, Comisión Nacional de Energía and Steer.

*Including taxes. ** Part or all the cost of infrastructure may be included in Fuel Costs.

Table A.5: Key data inputs and assumptions underlying World Bank TCO Analyses - São Paulo

	Units	Diesel Euro VI	Biofuel bus	Battery Electric Bus Depot	Battery Electric Fast Charge
Vehicle Acquisition*	USD	$120,000	$120,000	$311,140	$268,700
Second battery Acquisition	USD	-	-	$124,456	-
Fuel performance	km/Kwh, km/lt	1.82 km/lt	1.91 km/lt	0.78 USD/kWh	0.87 USD/kWh
Fuel Costs*	USD/kWh, USD/lt	0.93 USD/lt	0.926 USD/lt	0.11 USD/kWh	0.12 USD/kWh
Maintenance Costs	USD/km	0.15	0.15	0.09	0.09
Infrastructure Costs**	USD	$0	$0	$12,500	$7,000
Labor Costs	USD/year	$40,468	$40,468	$40,468	$40,468
Interest rate	%	11.10%	11.10%	11.10%	11.10%
Useful life	Years	10	10	10	10

Sources: Federação Nacional do comércio de Combustíveis e de Lubrificantes, Asociación Brasileña de Vehículos Eléctricos, ICCT: International Scenario Study on Public Policies for Electric Vehicles in Public and Private Fleets in Urban Areas, Interview with Metbus Chile and Steer.

*Including taxes. ** Part or all the cost of infrastructure may be included in Fuel Costs.

Appendix B: TCO Estimates for Each of the Five Cities

The following Tables summarize TCO by bus technology for each of the five cities.

Table B.1: World Bank Clean Bus TCO Estimates ($USD/km) - Buenos Aires

Cost Parameter	Diesel Euro V	Diesel Euro VI	Biofuel bus	CNG bus	Electric bus Depot	Electric bus fast charge
Fuel	0.21	0.23	0.23	0.14	0.07	0.07
Fuel tax	0.11	0.11	0.12	0.03	0.05	0.05
Road tax	0.00	0.00	0.00	0.00	0.00	0.00
Purchase tax	0.04	0.04	0.04	0.05	0.12	0.09
Maintenance	0.22	0.22	0.22	0.26	0.15	0.15
Capital investment*	0.19	0.20	0.19	0.22	0.55	0.42
Interest payment	0.19	0.20	0.19	0.22	0.54	0.42
Staff	0.57	0.57	0.57	0.57	0.57	0.57
Total	1.53	1.57	1.57	1.50	2.05	1.77

*No tax included

Table B.2: World Bank Clean Bus TCO Estimates ($USD/km) - Mexico City

Cost Parameter	Diesel Euro V	Diesel Euro VI	CNG bus	Hybrid bus	Electric bus Depot	Electric Bus Fast Charge
Fuel	0.49	0.49	0.36	0.34	0.19	0.18
Fuel tax	0.08	0.08	0.00	0.05	0.00	0.00
Road tax	0.00	0.00	0.00	0.00	0.00	0.00
Purchase tax	0.05	0.05	0.11	0.15	0.07	0.05
Maintenance	0.28	0.28	0.34	0.33	0.22	0.22
Capital investment*	0.21	0.22	0.25	0.34	0.31	0.24
Interest payment	0.31	0.33	0.33	0.45	0.47	0.36
Staff	0.23	0.23	0.23	0.23	0.23	0.23
Total	1.65	1.68	1.61	1.88	1.49	1.29

*Including taxes and interests.

Table B.3: World Bank Clean Bus TCO Estimates ($USD/km) - Montevideo

Cost Parameter	Diesel Euro III	Diesel Euro VI	Electric Bus Depot	Electric Bus Fast
Fuel	0.13	0.13	0.06	0.06
Fuel tax	0.00	0.00	0.00	0.00
Road tax	0.00	0.00	0.00	0.00
Purchase tax	0.00	0.00	0.00	0.00
Maintenance	0.22	0.22	0.12	0.12
Capital investment*	0.21	0.25	0.72	0.55
Interest payment	0.13	0.15	0.43	0.33
Staff	0.98	0.98	0.98	0.98
Total	1.67	1.74	2.31	2.05

*Including taxes and interests.

Table B.4: World Bank Clean Bus TCO Estimates ($USD/km) - Santiago

Cost Parameter	Diesel Euro VI	CNG bus	Battery Electric Bus	Battery Electric Fast
Fuel	0.27	0.25	0.11	0.10
Fuel tax	0.06	0.07	0.00	0.00
Road tax	0.00	0.00	0.00	0.00
Purchase tax	0.04	0.05	0.07	0.05
Maintenance	0.24	0.29	0.17	0.17
Capital investment*	0.21	0.24	0.38	0.29
Interest payment	0.08	0.09	0.11	0.08
Staff	0.57	0.57	0.57	0.57
Total	1.47	1.57	1.39	1.26

*Including taxes and interests.

Table B.5: World Bank Clean Bus TCO Estimates ($USD/km) - São Paulo

Cost Parameter	Diesel Euro VI	Biofuel bus	Electric Bus Depot	Electric Bus Fast
Fuel	0.41	0.39	0.14	0.14
Fuel tax	0.10	0.09	0.00	0.00
Road tax	0.00	0.00	0.00	0.00
Purchase tax	0.00	0.00	0.00	0.00
Maintenance	0.15	0.15	0.09	0.09
Capital investment*	0.17	0.17	0.52	0.39
Interest payment	0.08	0.08	0.25	0.19
Staff	0.58	0.58	0.58	0.58
Total	1.49	1.47	1.51	1.53

*Including taxes and interests.


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