grütter consulting

Assessment of Commercial EV Demand in Brazil

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Abbreviations

AC	Air Conditioning
AFD	French Development Agency (Agence Française de Développement)
BAU	Business as Usual
BCRP	Central Bank of Brazil (Banco Central do Brasil)
BEB	Battery Electric Buses
BNDES	Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico)
CAF	Andean Development Corporation (Corporación Andina de Fomento)
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CF	Cash Flow
CFF	Cities Finance Facility
DGEE	Directorate General of Energy Efficiency
ECT	Postal Services of Brazil (Empresa Brasilera de Correios e Telégrafos)
EDP	Energy company of Portugal in Brazil (company in the electricity)
EIRR	Economic Internal Rate of Return
EU	Executing Units
EV	Electric Vehicle
FA	Financial Assistance
FIRR	Financial Internal Rate of Return
GHG	Greenhouse Gases
GIZ	German Cooperation Agency - GmbH (Deutsche Gesellschaft für Internationale Zusammenarbeit - GmbH)
GPAE	Policy and Economic Analysis Management
PHEV	Plug-in hybrid electric vehicle
IDB	Inter-American Development Bank
IEA	International Energy Agency
INEI	National Institute of Statistics and Informatics
ISC	Selective Consumption Tax
KfW	Reconstruction Loan Corporation (Kreditanstalt für Wiederaufbau)
LCV	Light Commercial Vehicle
MME	Ministry of Mines and Energy (Ministério de Minas e Energia)
MS	Ministry of Health (Ministério da Saúde)
MTPA	Ministry of Transport (Ministério dos Transportes, Portos e Aviação Civil)
NDC	Nationally Determined Contributions
NGV	Natural Gas Vehicles
OPEX	Operational Expenditure
OPI	Programming and Investment Offices
PHEV	Hybrid electric vehicle
PROPARCO	Promotion and Participation for Economic Cooperation (Promotion et de Participation pour la Coopération Economique)
TA	Technical Assistance
TCO	Total cost of ownership
TTW	tank-to-wheel
UNEP	United Nations Environment Programme
WACC	Weighted Average Capital Cost
WTW	well-to-wheel

Contents

1. Introduction

The objective of this report is to identify the market potential of commercial EVs and outline steps on how to overcome barriers which prevent Brazil from materializing the market potential.

The focus is on assessing the 2030 potential market for commercial electric vehicles (EVs) in Brazil and contrast this with their current commercial viability. This includes an analysis per vehicle category (buses, taxis, light commercial vehicles) of relevant purchase criteria including the total cost of ownership, total capital and equity investment, profitability and risk. It assesses factors which hinder achieving the potential and looks at the potential impact of financial instruments as well as technical assistance to close the gap. This results in an outline of possible investment areas and projects per vehicle category as well as technical assistance required to close the gap.

The report focuses on pure electric vehicles in the areas of urban buses, taxis and urban freight vehicles. The report partially includes an overlap with the diagnostic report due to each report intended to be a stand-alone report.

2. Current Commercial EV Market in Brazil

Brazil has still a very incipient EV market especially in relation to its vehicle market size. Small fleets of buses, taxis as well as light commercial vehicles are however being operated in various cities.

2.1. Brazilian Fleet in Numbers

According to data from the Brazilian government's Ministry of Infrastructure, through the National Traffic Directorate (DENATRAN), Brazil currently has 107,585,150 registered vehicles (NOV 2020), of which: 57,852,963 are cars; 2,873,263 are trucks; 419,519 are minibuses; 23,788,071 are motorcycles; and 659,346 are buses.

Between 2012 and 2018, Brazil had 10,666 electrified vehicles on the streets. In 2019, the circulating fleet of electric cars reached 22,524 models in battery. Data from the Brazilian Association of Electric Vehicles (ABVE) show that 15,556 vehicle models have been registered in Brazil as of October 2020, and ABVE forecasts more than 41,500 electric cars by the end of 2020. The forecast result will be 60% higher than that obtained in 2019 and three times higher than in 2018, which demonstrates a steady growth. ABVE shows that 15,556 vehicle models have been registered in Brazil until October 2020.

The 2019 Circulating Fleet Report prepared by Sindipeças shows that the Brazilian vehicle fleet grew by 2.5% compared to 2018. The result exceeds by 0.6 percentage points what was observed in the passage from 2017 to 2018 (1.9%). Last year there were 45.9 million units in circulation, including cars, light commercial vehicles, trucks and buses. There were also 13.1 million motorcycles on public roads last year, an increase of 0.6% in the number of units in circulation.

According to the Circulating Fleet Report prepared by the National Union of the Automotive Vehicle Components Industry (SINDIPEÇAS) and the Brazilian Association of the Auto Parts Industry (ABIPEÇAS) in April 2020 (Base 2019), flex-fuel vehicles account for 69.5% of the country's fleet and gasoline vehicles, 19.5%. Diesel vehicles barely exceed 10%.

Based on RENAVAN data, ANFAVEA reported that the majority of vehicles in Brazil in 2020 run on the flex-fuel model (85.2%) and that only 10.8% are diesel and 3% gasoline. Electric cars only represent 1% of the total number of vehicles.

According to the National Association of Motor Vehicle Manufacturers (ANFAVEA), 1,904,714 level vehicles; 90,936 trucks; and 18,405 buses were produced in 2020, of which 15,471 are buses for urban transportation. According to the Circulating Fleet Report prepared by the National Union of the Industry of Components for Automotive Vehicles (SINDIPEÇAS) and the Brazilian Association of the Auto Parts Industry (ABIPEÇAS) of April 2020 (Base 2019), flexible vehicles accounted for 69.5% fleet in the country and gasoline vehicles, 19.5%. Diesel vehicles are just over 10%.

2.2. Main National Transport Policies

As described in the diagnosis, in Brazil, Law No. 12,187 of 2009 establishes the National Climate Change Policy (PNMC) which sets out the principles, objectives, guidelines and instruments for adaptation, mitigation of the adverse effects of climate change; emissions, source, greenhouse gases, impact on climate change; vulnerability to climate variability and extreme events.

The PNMC also aims to reduce anthropogenic emissions of greenhouse gases in relation to their different sources, in addition to encouraging the development of the Brazilian Emissions Reduction Market (MBRE). The National Policy also establishes that official financial institutions will make available specific lines of credit and financing for the development of actions and activities that respond to the objectives of this Law and are aimed at inducing the behavior of private agents to comply with and implement the PNMC, within the scope of their actions and social responsibilities.

The Ministry of Science, Technology, Innovation and Communications (MCTI) also emphasizes that specific sectoral plans were prepared for other sectors of Brazilian industry. The Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in the Manufacturing Industry (Industrial Plan) aims at reducing greenhouse gas emissions generated by industrial processes and by the use of energy in industry, by increasing energy efficiency and materials use, and preparing the sector for the challenges as well as the opportunities of the low-carbon economy, setting an overall emissions reduction target for the manufacturing industry of 5% over the baseline emissions scenario in 2020.

Annual estimates of Greenhouse Gas emissions in Brazil in 2020, according to the Ministry of Science, Technology, Innovation and Communications, show that the Energy sector had a 7.0% reduction in emissions compared to 2015. This decrease was due to the decrease in industrial activity and fossil fuel consumption in road transport, due to the country's economic recession.

The Transport and Urban Mobility Sector Plan for Climate Change Mitigation and Adaptation (PSTM) seeks to contribute to the mitigation of GHG emissions in the sector, through initiatives that lead to the expansion of freight transport infrastructure and the increased use of more energy-efficient modes and, in the urban mobility sector, to the increased use of efficient public passenger transport systems, contributing to the fulfillment of the commitments voluntarily undertaken by Brazil.

2.3. Brand New Electric Vehicles (VE) in Brazil by 2020 & 2021

In the first half of 2020, 7,568 electric cars were sold, according to the Brazilian Electric Vehicle Association (ABVE). According to ABVE, the national electric vehicle market will grow from 300% to 500% in the next five years, with the potential to reach 2 million electric vehicles by 2030.

- In 2020, six new electric vehicle models will arrive in Brazil. In 2021, there will be ten new models of hybrid and electric cars. In both cases, the vehicles are not produced in Brazil and continue to be imported from the United States, Europe and South Asia. Every year, the number of hybrid and electric cars launched and sold in Brazil increases. Luxury brands such as Audi, Porsche and Volvo are investing to increase their presence in these segments. But also others, such as Jeep, Fiat and Peugeot, have launched new models.

- Nowadays, Mercedes Bens is also testing electric vehicles that could be manufactured in Brazil in the next few years, in addition to companies that already operate and manufacture electric vehicles in Brazil, such as Eletra, Volvo and BYD (Eletra is a Brazilian company that develops and integrates electric traction systems for low-emission buses. Its main specialty is electric traction systems for trolleybuses. The company has also developed a series of hybrid buses, which operate with an electric motor and two power sources. Since 2009, Volvo has started manufacturing Diesel series hybrid buses. In 2016, it introduced two new hybrid bus models. The first was the articulated hybrid and the second model is a plug-in hybrid bus, which allows external battery recharging. In 2014, BYD created an electric bus factory in Campinas, São Paulo. In 2018 it had the capacity to produce 720 electric buses per year. Marcopolo is one of the world's leading manufacturers of bus bodies and solutions for public transportation. Currently the company presents two models of 100% electric buses, developed in partnership with the Chinese company BYD.

2.4. Demand Depends on Feasibility for Electric Vehicles in Brazil

Several other texts indicate the feasibility of implementing electric vehicles in Brazil, such as: Prospective Study of the Automotive Sector Final Report (2009); National Energy Efficiency Plan - basic premises and guidelines (Ordinance No. 594, of 2011); The role of BNDES in the development of the Brazilian automotive sector (2012); Sector Bulletin 41 Hybrid and electric vehicles: public policy suggestions for the segment (2015); and Discussion paper Environmental and economic impacts of electric and plug-in hybrid vehicles: a literature review (2015).

The 2030 Goals in the Energy Sector aim to increase the share of sustainable bioenergy in the Brazilian energy matrix to approximately 18% by 2030; ensure 45% renewables in the energy matrix - including hydroelectric - by 2030; ensure between 28% and 33% of non-hydro renewables - solar, wind, biomass, ethanol - in the Brazilian energy matrix by 2030; and increase the sustainable use of renewables, excluding hydro, to at least 23% of electricity generation in Brazil by 2030.

When considering public policies, tax incentives, Brazil's goals in the global emissions reduction agendas, it is clear that there is a real demand for migration of the energy matrix that serves the transportation sector with petroleum derivatives for biofuels and electric power. Potentially, all cars in Brazil could be electric, mainly in public transport, but also in last mile freight, private passenger vehicles, cabs, motorcycles and scooters. However, the real demand for electric vehicles will only be confirmed when there is technical, economic and financial feasibility to migrate the technology, in addition to a network of vehicle suppliers, maintenance and recharging. In 2020, electric vehicles accounted for only 1% of the national fleet.

2.5. Incentives for Electric Mobility in Brazil

The International Assessment of Public Policies for Electromobility in Urban Fleets conducted by the Efficient Propulsion Systems Project (PROMOB-e) highlights that the market for electric and hybrid vehicles in Brazil is still incipient when compared to the total sales of electric vehicles in the world (more than 1.2 million in 2017). Here presents some consumer incentives for the purchase of electric vehicles, such as:

- IPVA exemption for electric and hybrid vehicles in Rio Grande do Sul, Maranhão, Piauí, Ceará, Rio Grande do Norte, Sergipe and Pernambuco.

- IPVA reduction for electric and hybrid vehicles in São Paulo, Mato Grosso do Sul and Rio de Janeiro (1% - 4% of the final value of the vehicle).
- Exemption or reduction of tax rates on imports of electric and hybrid vehicles - previously taxed at 35% - including products and parts.
- Reduction of tax rates on the import of parts and equipment for the production of electric and hybrid buses.
- Exemption from municipal rodízio in the city of São Paulo for electric and hybrid fuel motor vehicles every day of the week.
- More convenient financing conditions at BNDES-Fundo Clima - electric or hybrid or ethanol buses with lower rates and longer terms than those available for traditional buses (rates between 1.0% and 4.8%).

3. Commercial EV Market Potential in Brazil

3.1. Scenarios

The market potential can be assessed against the target to limit the global temperature increase to below 2 degrees Celsius, in line with the Paris Declaration on Electro-Mobility (Paris Declaration on Electro-Mobility and Climate Change & Call to Action, 2015), which asks for 20% of the vehicle stock to be electric by 2030. This has been modelled by the authors with a “high growth scenario” which goes beyond official government targets. It shows the potential EV market for commercial vehicles if an aggressive strategy is pursued and if instruments are in place which enable realization of this scenario. Its core target is that 100% of newly registered vehicles in the targeted commercial vehicle sectors are by 2030 electric. No scrapping policies are required to implement such a strategy as existing fossil vehicles are kept in accordance with their normal commercial lifespan. The potential EV market size is determined for the years 2022 to 2030. With 100% of newly registered vehicles in this area being electric, the 20% vehicle stock target of the Paris Declaration can be met or surpassed by these vehicle categories. To achieve an overall target of 20% of the vehicle stock of all vehicle categories to be electric, the targeted categories (urban buses, taxis, LCVs) which today are already close to being commercially viable, will have to achieve a level above 20% as other vehicle categories such as trucks are still far away from being commercially viable[1].

Report 3 will include also a Business as Usual (BAU) market development of EVs based on the decrease of EV prices until 2030.

3.2. Urban Electric Buses

The following table shows the projected cumulative and annual number of Battery Electric Buses (BEBs) under a high growth strategy.

Table 1: Urban E-Buses: High Growth Scenario 2025 and 2030

Parameter	2025	2030
Cumulative e-buses	8,500	56,000
Market share (% of stock)	4%	27%
Sales share (% of new registrations)	22%	100%

Source: Grutter Consulting, see database (Grutter Consulting, 2020)

[1] For details on scenarios see Country Diagnostic Report Brazil

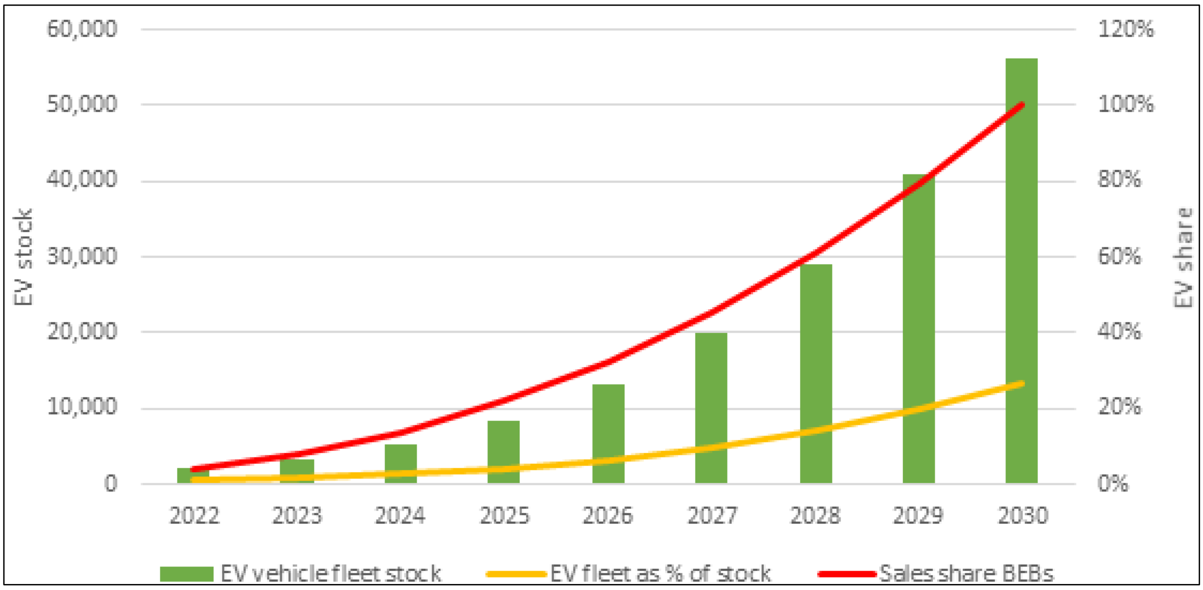
With a high growth scenario a market share of around 27% is targeted by 2030 equivalent to 56,000 electric buses operating in the country. The main parameters for the high growth market potential are outlined in the following table.

Table 2: High Growth Scenario Electric Urban Buses 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock buses	200,139	201,316	202,501	203,693	204,891	206,097	207,310	208,530	209,757
Sales BEBs	552	1,147	2,024	3,223	4,781	6,732	9,112	11,953	15,129
Stock BEBs	2,076	3,222	5,246	8,468	13,249	19,981	29,093	41,046	56,175
Share BEBs of stock	1%	2%	3%	4%	6%	10%	14%	20%	27%

Source: Grutter Consulting, report 1

Figure 1: Urban Electric Bus High Growth Scenario

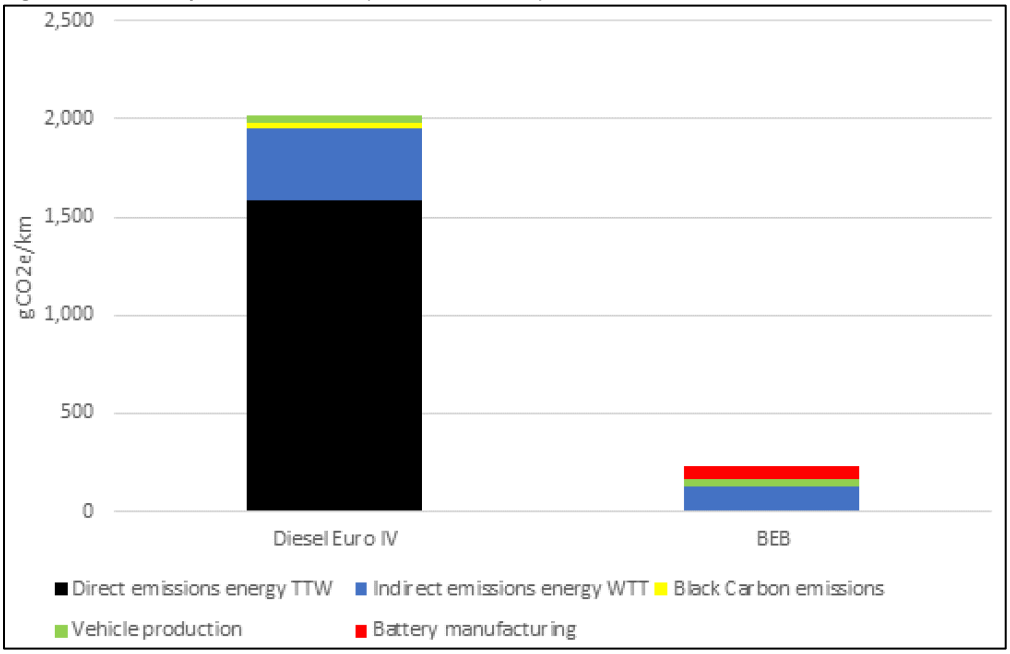


Source: Grutter Consulting

A BEB can reduce well-to-wheel (WTW) Greenhouse Gas (GHG) emissions in Brazil by 93% and cradle to grave emissions by 89% compared to a diesel unit (see figure below)[2].

[2] The figure does not take into account biodiesel share as upstream emissions of latter are unknown.

Figure 2: GHG Impact Urban Bus (12m urban bus)



Source: Grutter Consulting, mileage and energy consumption based on values for Brazil: 59 l/100km fuel consumption; 66,000km/a; Euro V bus; BEB 1.1 kWh/km with average battery size of 310 kWh/km; 110kgCO2/kWh upstream battery emissions; grid factor 0.119 kgCO2/kWh; upstream diesel and BC based on UNFCCC and COPERT; vehicle manufacturing based on mobitool/EU; vehicle lifespan diesel 15 years and BEB 16 years; lifespan battery 8 years; all sources in Annex

3.3. Electric Taxis

The following table shows the projected cumulative and annual number of electric taxis under a high growth strategy.

Table 3: Electric Taxis: High Growth Scenario 2025 and 2030

Parameter	2025	2030
Cumulative e-taxis	23,000	176,000
Market share (% of stock)	6%	41%
Sales share (% of new registrations)	22%	100%

Source: Grutter Consulting, see database (Grutter Consulting, 2020)

The following table shows the main parameters for the high growth market potential of electric taxis.

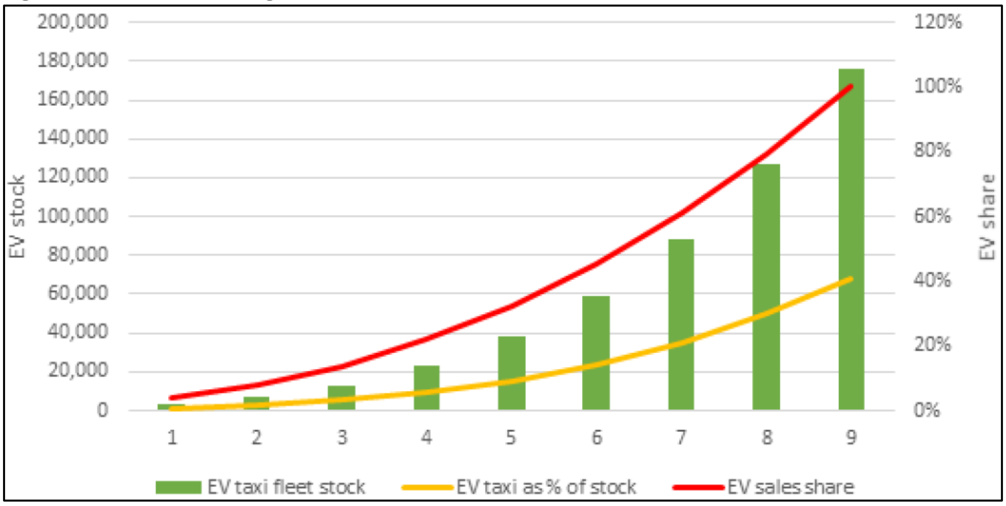
Table 4: High Growth Scenario Electric Taxis 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock taxis	381,240	387,317	393,491	399,763	406,136	412,610	419,187	425,869	432,657
Sales e-taxis	1,664	3,490	6,222	10,007	14,993	21,326	29,153	38,624	49,375
Stock e-taxis	3,278	6,768	12,990	22,997	37,991	59,316	88,469	127,092	176,468
Share e-taxis of stock	1%	2%	3%	6%	9%	14%	21%	30%	41%

Source: Grutter Consulting, average commercial lifespan of taxi 10 years

As of 2030 more than 400,000 e-taxis would be electric with this scenario.

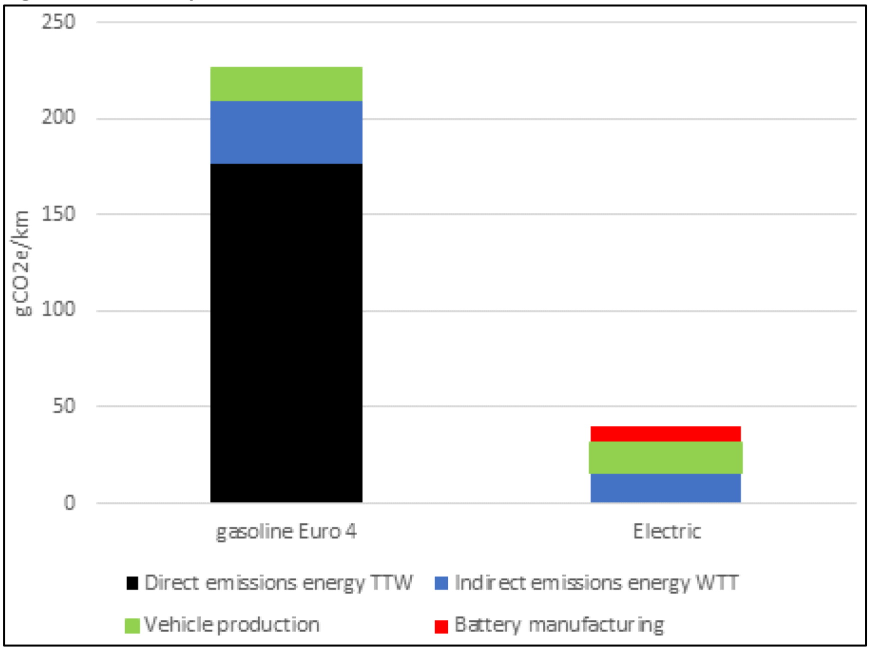
Figure 3: Electric Taxi High Growth Scenario



Source: Grutter Consulting

An electric taxi can reduce WTW emissions in Brazil by 65% and cradle to grave emissions by 54% (see figure below)[3].

Figure 4: GHG Impact Electric Taxi



Source: Grutter Consulting, mileage and energy consumption based on values for Brazil based on Chevrolet Onix: 7.8 l/100km; 52,000km/a; e-taxi based on Jace40 with 0.13 kWh/km; 40 kWh battery size; 110kgCO2/kWh upstream battery; upstream gasoline based on UNFCCC; vehicle manufacturing based on mobitool/EU; 10 year lifespan vehicle and battery; carbon grid factor 0.119 kgCO2/kWh

3.4. Light Commercial Vehicles (LCVs)

The following table shows the projected cumulative and annual number of electric LCVs under a high growth strategy.

[3] Excludes usage of ethanol as upstream effects are unclear and potentially very high.

Table 5: Electric LCVs: High Growth Scenario 2025 and 2030

Parameter	2025	2030
Cumulative e-LCVs	290,000	2,280,000
Market share (% of stock)	3%	23%
Sales share (% of new registrations)	22%	100%

Source: Grutter Consulting, see database (Grutter Consulting, 2020)

The following table shows the main parameters for the high growth scenario of LCVs.

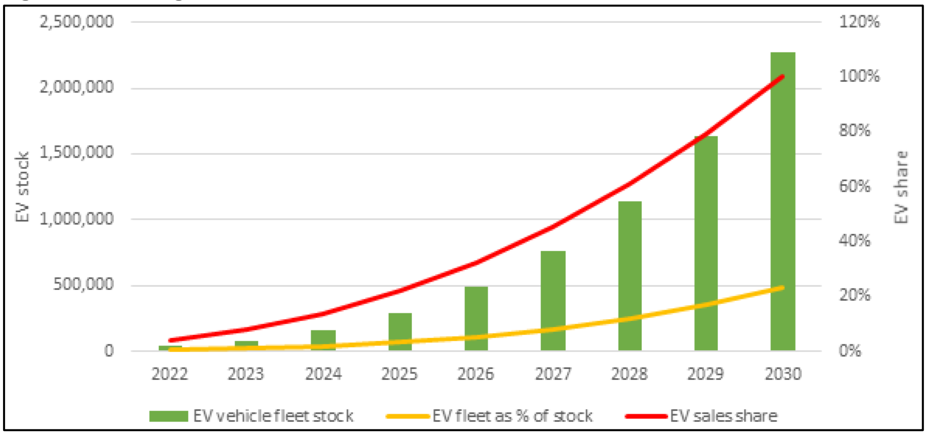
Table 6: High Growth Scenario Electric LCVs 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock LCVs	8,537,299	8,679,530	8,824,131	8,971,141	9,120,600	9,272,550	9,427,030	9,584,085	9,743,755
Sales e-LCVs	21,408	44,935	80,164	129,030	193,451	275,351	376,675	499,403	638,875
Stock e-LCVs	38,159	83,094	163,258	292,287	485,739	761,090	1,137,765	1,637,168	2,276,043
Share e-LCVs of stock	0%	1%	2%	3%	5%	8%	12%	17%	23%

Source: Grutter Consulting, report 1

As of 2030 more than 2.7 million e-LCVs would operate in Brazil with this scenario.

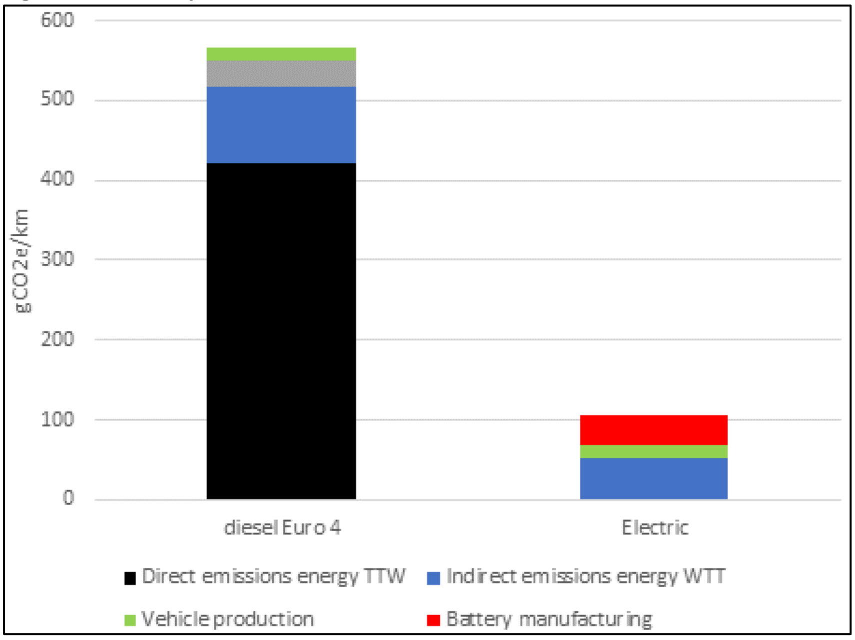
Figure 5: LCV High Growth Scenario



Source: Grutter Consulting

LCVs are a very diverse segment of vehicles with different vehicle sizes and very different usage patterns and therefore also very different mileage as well as lifespan of usage. Based on an LCV as used by many delivery services (4t load capacity) an electric LCV can reduce WTW emissions in Brazil by 91% and cradle to grave emissions by 81% (see figure below).

Figure 6: GHG Impact Electric LCV



Source: Grutter Consulting

Source: Grutter Consulting, mileage and energy consumption based on values for Brazil based on JAC iEV1200T and diesel Volkswagen delivery, major assumptions include 35,000km annual mileage, 15.7 l/100km and 0.44 kWh/km e-LCV, 15-year lifespan, 8-year lifespan of battery, battery set of 97kWh, 110kg CO_2/kWh battery (ICCT, 2018), grid factor 0.119 kgCO_2/kWh

4. Financial Assessment of Commercial EVs in Brazil

4.1. Introduction

The financial assessment is made per vehicle type based on local data. Following parameters are assessed:

- Total cost of ownership (TCO) per kilometre comparing the fossil with the electric unit: The TCO is calculated in financial and economic terms, values are not discounted for the TCO,
- Incremental upfront capital investment required and incremental equity capital required with current financing schemes,
- Profitability of investing in an EV instead of a fossil vehicle by calculating the Financial Internal Rate of Return (FIRR) and the Economic Internal Rate of Return (EIRR) of the incremental capital expenditure: the FIRR is compared to the Weighted Average Capital Cost (WACC) for the transport sector in Brazil,
- Differential cash flow,
- Discounted payback time of differential investment (using the WACC as discount rate).

The different indicators are used as they point out various criteria important for investment decisions: life-cycle profitability, capital exposure and risk, opportunity cost or benefit and liquidity. Variations of the different parameters (e.g. loan terms) are made to assess the sensitivity of results. This also gives an indication of the types of financial instruments which can be used to promote EVs and their potential impact.

The financial analysis is a comparison of investment options. It does not assess the financial viability of operating the specific vehicle (as example in public transport diesel buses could be operating at a loss and e-buses could continue to be operated at a loss) nor the financial soundness and creditworthiness of an enterprise. For latter other factors need to be contemplated such as revenues, debt and equity levels etc. The financial analysis is a comparison of investing pari passu in electric instead of fossil units. All calculations are performed in constant real 2020 USD.

Total Cost of Ownership (TCO)

Looking at the TCO is a way of assessing the long-term value of a purchase to a company. When comparing the TCO of vehicles the valuation criteria is cost per km. When comparing costs of EVs with such of other technologies only expenditures are relevant which differ between the two technologies. Cost components such as drivers cost or overhead management will not change when using EVs – therefore usage of such company-sensitive data can be avoided. Critical for our purpose and therefore included in the analysis here are the following cost parameters:

- CAPEX: This includes the vehicle, charging infrastructure, grid connections, vehicle depot upgrades and battery replacement,
- OPEX: This includes energy, maintenance (vehicle plus infrastructure components) and finance costs.

The lifespan of the vehicle (which can be different for EVs and for fossil units) and the annual mileage are other parameters of importance for calculations. Insurance costs are not included as these are not necessarily tied to the vehicle value and are of minor magnitude. The same holds true of vehicle registration fees. The economic costs of emissions are included for the determination of economic TCOs.

WACC

The WACC is calculated with the following equation:

$$WACC = r_e \times W_e + r_d \times W_d \times (1 - T_c)$$

where:
r_e Cost of equity
W_e Percentage of financing by equity
R_d Cost of debt
W_d Percentage of financing by debt
T_c Corporate tax rate

The following table shows the parameters for determining the WACC for Brazil for the transport sector.

Table 7: WACC Transport Sector Brazil (all rates in USD)

Parameter	Value	Source
Cost of equity	12.8%	(UNFCCC, 2019), value for transport sector of Brazil
Share of equity financing	20%	Banks are willing to finance 80% with loans
Cost of debt	9.9% / 9.4%	Promobe, 2020 for fossil versus electric units
Share of debt financing	80%	Banks are willing to finance 80% with loans
Corporate tax rate	34%	Deloitte, 2020
WACC	7.8% / 7.5%	Calculated for fossil versus electric units

4.2. Financial Analysis E-Buses

4.2.1. General Data

Calculations are realized for the standard bus as used in Brazil which is a 12m low-floor entry bus unit with 2 access doors. For the standard bus a diesel option is calculated. 2 options for BEBs have been included in the calculations:

- An overnight charged BEB with a battery set of 420 kWh[4],
- A BEB with batteries capable of fast-charging and a battery set of 200 kWh (C-rate of minimum 0.65) which allows to re-charge for additional 100km within around 20 minutes using a 300 kW charger.

The following tables indicate the diesel bus specific values, the overnight BEB and the fast-charged BEB specific values. The annual mileage of the bus assumed for all technologies is 66,000 km[5].

Table 8: Baseline Fossil Bus Parameters

Parameter	Value	Source
Diesel usage	59 l/100km	Euro V bus, based on WRI cited in PROMOB-e
Maintenance cost diesel bus	0.15 USD/km	PROMOB-e
Cost of diesel	0.66 USD/l	https://www.globalpetrolprices.com/
CAPEX diesel bus	150,000 USD	PROMOB-e Euro V bus
Lifespan fossil bus	15 years	1 million km default
Loan conditions	9 years 80% 9.9%	PROMOB-e

Table 9: BEBs Common Parameters

Parameter	Value	Source
Specific electricity usage	1.1 kWh/km	Chinese average, (ADB, 2018), includes AC usage
Maintenance cost	0.11 USD/km	(ADB, 2018) based on 70% of diesel bus cost
Lifespan bus	16 years	2x battery
Lifespan battery @ 80% SOH	8 years	current guarantee levels of BEBs is 8 years with a SOH of 80%
CAPEX charger excluding installation per kW	120 USD/kW	Standard Chinese chargers, 2 nozzles
CAPEX charger installation	2,500 USD/bus	Civil works for chargers, 2 buses per charger, 5,000 USD per charger
Cost per bus depot upgrade	7,500 USD/bus	Coverage of bus and chargers with roof, no paving, includes labour (20m^2 per bus, 250 USD/m^2 material and 150 USD/m^2 labour)
Cost grid connection of chargers per bus	30,000 USD/bus	Compact sub-stations for groups of chargers, 20kV cables from connection substation to the compact substation, 400V cables from compact substation to charger (these are **not** grid upgrades)
Lifetime charger	10 years	standard value provided by ABB
Lifetime bus depot upgrades	20 years	standard value for construction investments

[4] The battery set was determined based on the average distance per workday, the electricity consumption rate, a 20% operational reserve rate (to avoid buses getting stranded), a 10% higher consumption risk rate (e.g. due to high temperatures causing extensive usage of the AC or congestion resulting in additional AC usage or driver with less than average skills) and 20% loss of State of Health (SOH) of batteries over 8 years.

[5] PROMOB-E, 2020

Lifetime grid connection	20 years	standard value used by power companies
Maintenance chargers, grid connection, depot	2%	Percentage of CAPEX
Loan conditions	14 years 80% 9.4%	PROMOB-e

Table 10: BEB Overnight Charged Bus

Parameter	Value	Source
CAPEX bus	284,000 USD	Based on bus with 350 kWh battery set and additional cost for larger battery set
CAPEX batteries	200 USD/kWh	LFP batteries
Battery capacity	420 kWh	Calculated based on workday range with sufficient reserves (standard reserve 20% plus reserve for severe traffic conditions/climate/driver, plus loss of SOH batteries 20% in 8 yrs)
Charger power	50 kW	Calculated based on available charging time and daily average electricity usage

Table 11: BEB Fast Charged Bus

Parameter	Value	Source
CAPEX bus	250,000 USD	Based on standard fast-charged bus
CAPEX batteries	250 USD/kWh	NMC batteries
Battery size	200 kWh	Calculated based on workday range with sufficient margins and battery sets cum C-rates as offered in the market (see Annex)
Night charger power	40 kW	Calculated based on available charging time and daily average electricity usage
Fast-charger power	300 kW	Calculated for additional 100km in 20 minutes
Number of buses per fast-charger	8 buses / charger	Calculated for small fleets (average in PR China 6-10 buses)

For e-buses it is assumed that only buses are financed and not the charging infrastructure, grid connections and depot upgrades. With company instead of project finance and sufficient collateral of debtors, FIs, would be willing to finance also other investment components. Otherwise they will be reluctant as charger, depot and grid connections are basically sunk costs without re-sale value. Using them as collateral is thus for banks not acceptable, whilst buses, if insured, can be used as collateral.

4.2.2. TCO

The following table shows the results of the TCO calculation.

Table 12: TCO Calculations (USD of 2020)

Parameter	Diesel	BEB overnight	BEB fast
CAPEX bus	150,000	284,000	250,000
CAPEX charging infrastructure	0	8,500	12,113
CAPEX grid connection	0	30,000	30,000
CAPEX depot upgrade	0	7,500	7,500
Total CAPEX	**150,000**	**330,000**	**299,613**
Battery replacement yr 8	0	42,000	25,000
Energy cost yr 1	25,700	6,534	6,534
Maintenance cost bus yr 1	9,900	6,930	6,930

Maintenance cost infra yr 1	0	920	992
Finance cost average per year	6,862	13,011	11,453
Economic costs yr 1	6,450	345	345
TCO financial per km	**0.76**	**0.74**	**0.68**
TCO economic per km	**0.87**	**0.75**	**0.68**

Source: Grutter Consulting

Following conclusions are drawn:

- Comparing total costs over the bus lifetime, BEBs have a comparable TCO to diesel.
- The TCO of fast-charged BEBs is slightly lower than of overnight charged BEBs – this option is therefore not only from an operational risk perspective better (in case of higher than expected energy consumption or usage of the bus for longer routes, batteries can be quickly re-charged) but also from a financial perspective.

4.2.3. Capital and Equity Investment

A comparison is made of the required capital, in term of loans and as equity (see the following table).

Table 13: Capital Demand (USD of 2020)

Capital investment BEB relative to diesel bus (per unit)	BEB overnight		BEB fast-charged	
	Absolute	%	Absolute	%
Additional capital investment	180,000	120%	149,613	100%
Additional loan demand	107,200	89%	80,000	67%
Additional equity requirement	72,800	243%	69,613	232%

Source: Grutter Consulting

BEBs require a 2x higher capital investment than diesel buses[6]. The most important impact is however on the required equity: this increases by the factor 3.5. Equity is required for the additional investments as well as to par the loans. Due to higher total capital investment keeping a 20% owners capital requirement for a loan results in much higher levels of owners capital needed. This places a serious problem for bus operators.

4.2.4. Relative Profitability

The relative profitability assesses the FIRR of the incremental investment for BEBs based on the operational savings of BEBs versus diesel units:

- The FIRR of overnight charged BEBs is 8% and of fast-charged BEBs of 12.6% which is above the WACC.
- The EIRR is 14% respectively 20%.

The investment in BEBs is thus profitable.

4.2.5. Discounted Payback

The discounted payback looks at the number of years required to recover the initial incremental investment from savings of BEBs relative to diesel buses. Annual incremental savings of using a BEB versus a diesel bus are discounted. The discounted payback gives a good indication of the risk the

[6] 2x higher capital investment is identical to incremental 100%

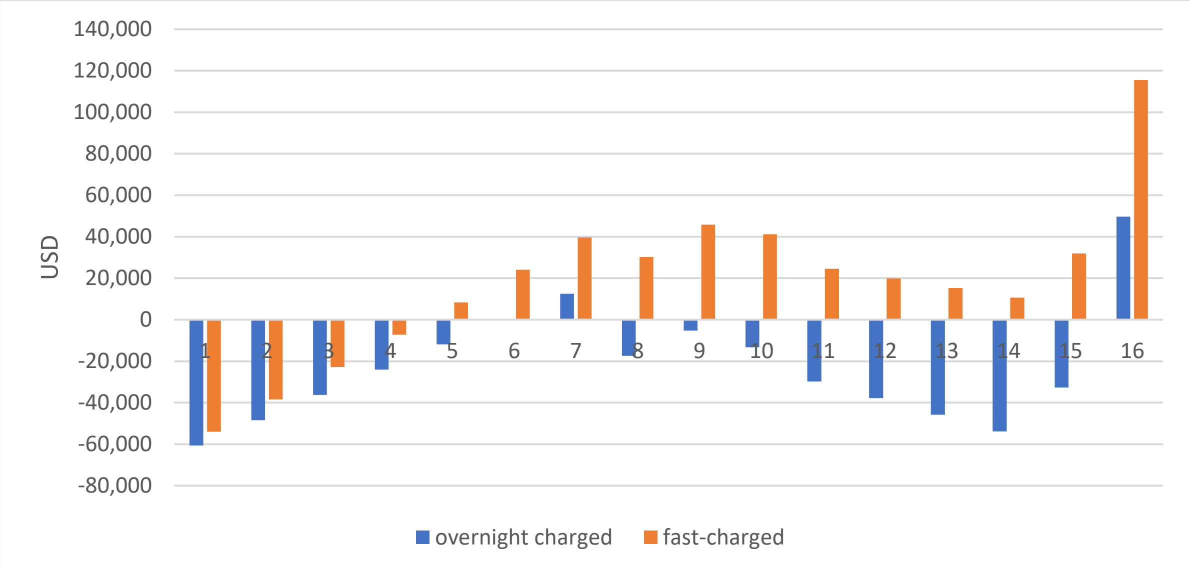
entrepreneur is facing and how much time his capital is tied up and not available for alternative investments.

In both cases the discounted payback shows that the initial incremental investment is not recovered during the asset lifetime of 16 years. This is also due to required re-investments in year 8 in batteries and in year 10 in chargers.

4.2.6. Cash Flow

Cash Flow (CF) calculations are important to assess liquidity aspects of an investment. The CF is calculated without discounting based on the owners capital invested. It is based on the differential outflow of cash for CAPEX and OPEX of a BEB versus a diesel bus. Only cash outflows are considered as revenues (cash inflows) are identical between a BEB and a diesel bus. The cumulative CF turns positive in years 6 but then negative again in year 8 at least for overnight charged buses due to replacement batteries.

Figure 7: Cumulative Differential Cash Flow Diesel and Electric Bus



Source: Grutter Consulting

The cumulative CF turns negative again after year 8 due to purchase of battery replacement and year 10 due to charger replacement. The differential cumulative CF also decreases due to longer loan tenure of e-bus compared to BEB (loan repayment incl. interest is cash outflow).

4.2.7. Summary Financial Assessment

The following table summarizes the financial assessment of BEBs, taking as comparison base the average between the two assessed technology options for BEBs.

Table 14: Summary Financial Assessment BEBs

Criteria	Result	Assessment
TCO	Comparable for fossil and electric units	Non-discounted the cumulated lifetime costs for BEBs are comparable to fossil buses
Capital investment	2x of a conventional bus	Significantly higher capital requirement incl. higher loan demand, negative impact on debt to equity ratio
Equity investment	3.5x of a conventional bus	Significantly higher equity demand which might overstretch the capabilities of enterprises
Profitability	10%	Investment in e-buses is profitable

Discounted Payback	Incremental investment is not recovered with savings during asset lifetime	The investment in e-buses is not profitable and the payback time is long, even going beyond the asset lifetime. This indicates a high risk profile of the investment.
Cash Flow	Negative cumulative CF	The investment in BEBs will affect the liquidity position of the companies in a negative manner and will affect negatively the solvency ratio for a long period.

Summarized the investment in BEBs with the current financial conditions and business models is profitable, but at a high risk, requires a significant increase in owners capital and results in potentially serious liquidity problems. BEBs will require a different financial structuring and significant financial incentives to be a viable business proposal in Brazil.

4.2.8. Variation of Parameters / Incentive Schemes

The impact on financial parameters of using concessional loans and of upfront investment grants is assessed.

Concessional Loan Usage

The following table indicates the parameters used for a concessional loan.

Table 15: Concessional Loan Parameters

Parameter	Current conditions	Concessional conditions
Loan tenure	14 years	14 years
Interest rate	9.4%	3.7%
Lending rate	80% of bus investment	80% of total investment

The concessional interest rate is based on a 1.25% rate from the GCF (0.75% interest rate and 0.5% commissions fees factored into the interest rate) for 30% of the loan and 70% of the investment from AFD/co-financers at 4.8% interest rate.

The following table compares the financial results with and without a concessional loan.

Table 16: Impact of Concessional Loan Conditions

Parameter	overnight charged BEB	fast charged BEB
TCO financial old	0.75	0.68
TCO financial new	0.64	0.59
FIRR old	8.1%	12.6%
FIRR new	8.1%	12.6%
Additional equity old	243%	232%
Additional equity new	120%	100%
Discounted Payback in years old	never	never
Discounted Payback in years new	11	8

Source: Grutter Consulting

The TCO is reduced significantly and the dynamic repayment period is now much shorter than the asset lifetime. It can be concluded that concessional loans are sufficient to make investments in e-buses profitable in Brazil. Grant financing for investments is not required.

Investment Grant

An upfront grant of 20% on the total initial investment combined with concessional finance is modelled. The following table shows the impact of an upfront grant combined with a concessional loan.

Table 17: Impact of 20% Upfront Grant + Concessional Loan Conditions

Parameter	overnight charged BEB	fast charged BEB
TCO financial old	0.75	0.68
TCO financial new	0.58	28.21
FIRR old	8.1%	12.6%
FIRR new	18.5%	28.1%
Additional equity old	243%	232%
Additional equity new	0%	0%
Discounted Payback in years old	never	never
Discounted Payback in years new	6	5

Source: Grutter Consulting

The grant finance obviously has a positive impact on financial indicators – however, as mentioned previously, it is not considered as necessary in the case of Brazil.

4.3. Financial Analysis E-Taxis

4.3.1. General Data

Calculations are realized for the standard gasoline taxi as used in Brazil. The following tables indicate the general parameters, the fossil taxi specific values and the e-taxi specific values. The average mileage assumed of taxis is 52,000 km[7]. The loan conditions for e-taxis as well as fossil taxis are based on 9.9% interest rate with a tenure of 9 years (GIZ, 2019).

Table 18: Baseline Gasoline Taxi Parameters

Parameter	Value	Source
Gasoline usage	7.8 l/100km	urban gasoline, https://www.noticiasautomotivas.com.br/onix/
Maintenance cost	0.01 USD/km	https://www.noticiasautomotivas.com.br/onix/
CAPEX	12,000 USD	Chevrolet Onix, 2021, https://www.noticiasautomotivas.com.br/onix/
Lifespan	10 years	https://g1.globo.com/rj/rio-de-janeiro/noticia/2020/03/27/prefeitura-do-rio-anuncia-que-vida-util-de-taxis-passara-de-8-para-10-anos-devido-a-pandemia.ghtml

Table 19: E-Taxi Parameters

Parameter	Value	Source
Specific electricity usage	0.13 kWh/km	https://www.jacmotors.com.br/veiculos/eletricos-detalhes/iev40
Maintenance cost	0.006 USD/km	40% below fossil excl. tyres
Lifespan	10 years	Idem fossil
Lifespan battery @ 70% SOH	10 years	Idem lifespan taxi due to high mileage
Home charging share	70%	Assumption, only re-charge if above-average mileage or night shifts
Public fast-charging share	30%	
CAPEX e-taxi	39,000 USD	Jac 40, https://www.jacmotors.com.br/veiculos/eletricos-detalhes/iev40
CAPEX home charger 7.4kW	2,000 USD	Includes wall-box installation
Lifetime charger	10 years	standard value based on ABB

[7] Based on TRANSPORTE EM NÚMEROS Indicadores Anuais do Transporte Público with 160km daily mileage and 330 operating days

4.3.2. TCO

The following table shows the results of the TCO calculation.

Table 20: TCO Calculations (USD of 2020)

Parameter	gasoline	e-taxi
CAPEX taxi	12,000	39,000
CAPEX charging infrastructure	0	2,000
Total CAPEX	**12,000**	**41,000**
Energy cost	3,334	983
Maintenance cost	482	289
Finance cost average p.a. during loan term	549	1,784
Economic costs of emissions year 1	451	32
Lifespan in years	10	10
TCO financial per km	**0.11**	**0.13**
TCO economic per km	**0.12**	**0.14**

Source: Grutter Consulting

Comparing total costs e-taxis have comparable financial and economic TCOs to gasoline units.

4.3.3. Capital and Equity Investment

A comparison is made of the required capital, in term of loans and equity (see following table).

Table 21: Capital Demand (USD of 2020)

Comparison e-taxi to gasoline taxis	Absolute	%
Additional capital investment	29,000	242%
Additional loan requirement	21,600	225%
Additional equity requirement	7,400	308%

Source: Grutter Consulting

E-taxis require a capital investment factor 3 of a gasoline unit. The required equity increases by the factor 4. This can place a serious problem for taxi owners.

4.3.4. Relative Profitability

The relative profitability assesses the FIRR of the incremental investment for e-taxis (relative to a gasoline unit) based on the operational savings of e-taxis versus gasoline units:

- The FIRR is -3%
- The EIRR is 1%

The investment in e-taxis is thus not profitable.

4.3.5. Discounted Payback

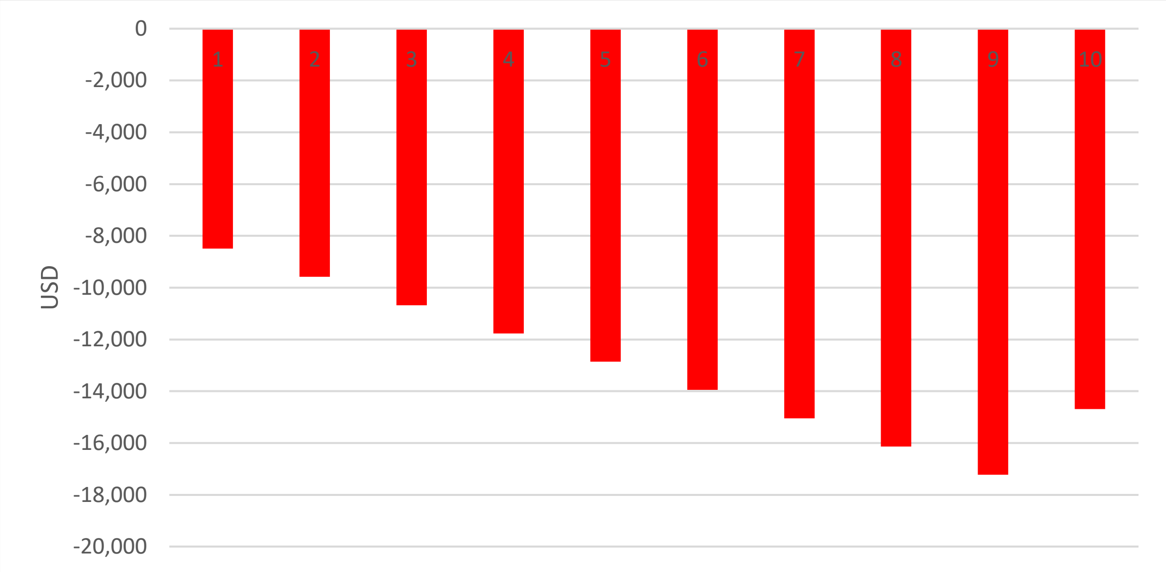
The discounted payback looks at the number of years required to recover the initial incremental investment from savings of e-taxis relative to gasoline units. Annual incremental savings of using an e-taxi versus a fossil taxi are discounted. The discounted payback gives a good indication of the risk the entrepreneur is facing and how much time his capital is tied up and not available for alternative investments.

The discounted payback shows that the initial incremental investment is not recovered during the asset lifespan. This indicates that with current financial conditions the investment is risky.

4.3.6. Cash Flow

Cash Flow (CF) calculations are important to assess liquidity aspects of an investment. The CF is calculated without discounting based on the owners capital invested. It is based on the differential outflow of cash for CAPEX and OPEX of an e-taxi versus a gasoline unit. Only cash outflows are considered as revenues (cash inflows) are identical between an e-taxi and a gasoline unit. The cumulative CF remains negative during the asset lifetime.

Figure 8: Cumulative Differential CF Fossil and e-Taxi



Source: Grutter Consulting

4.3.7. Summary Financial Assessment

The following table summarizes the financial assessment of e-taxis.

Table 22: Summary Financial Assessment E-Taxis

Criteria	Result	Assessment
TCO	25% higher for e-taxis compared to gasoline units	Non-discounted the cumulated lifetime costs for e-taxis are higher than those of gasoline units.
Capital investment	3x of a conventional taxi	Significantly higher capital requirement incl. higher loan demand
Equity investment	4x of a conventional taxi	Significantly higher equity demand which might overstretch the capabilities of taxi owners
Profitability	-3%	Investment in e-taxis is not profitable
Discounted Payback	Incremental investment is not recovered	This indicates a high risk profile of the investment.
Cash Flow	Negative cumulative CF	The investment in e-taxis will affect the liquidity position of the taxi owner in a negative manner and will affect negatively the solvency ratio and the working capital ratio.

Summarized the investment in e-taxis with current financial conditions and business models is profitable but not sufficient concerning the involved risk and equity exposure and thus commercially not viable. Another major risk is that revenues will be lower when using an e-taxi. The average daily driving range is thereby not the only parameter to consider as peak days have much higher mileage (and much higher income). Taxis are also driven during weekends (Friday to Sunday) or on special days with double shifts or 24 hours as this is the most profitable period. During such days the driving range of the e-taxi will be insufficient without re-charging. Home-charging takes 6-8 hours and is too slow. Also public chargers available are in general too slow. A fast-charging urban network is required to ensure that e-taxi owners do not lose a significant part of their revenues.

4.3.8. Variation of Parameters / Incentive Schemes

The impact on financial parameters of using concessional loans and of upfront investment grants is assessed.

Concessional Loan

The following table indicates the parameter used for a concessional loan.

Table 23: Concessional Loan Parameters

Parameter	Current conditions	Concessional conditions
Loan tenure	9 years	9 years
Interest rate	9.9%	5.7%
Lending rate	80% of CAPEX	80% of CAPEX incl. home charger

The concessional interest rate is based on a 1.25% rate from the GCF (0.75% interest rate and 0.5% commission; commissions fees factored into the interest rate) for 30% of the loan and 70% of the investment from AFD/co-financers at 4.8% interest rate plus 2% spread of the national banking system.

The following table compares the financial results with and without a concessional loan.

Table 24: Impact of Concessional Loan Conditions

Parameter	e-taxi
TCO financial old	0.13
TCO financial new	0.12
FIRR old	-3%
FIRR new	-3%
Additional equity old	308%
Additional equity new	242%
Discounted Payback in years old	never
Discounted Payback in years new	never

Source: Grutter Consulting

The concessional loan does not improve significantly the financial parameters and is thus alone not sufficient to attract investors.

Investment Grant

An upfront grant of 20% on the total initial investment combined with concessional finance is modelled. The following table shows the impact of an upfront grant.

Table 25: Impact of 20% Upfront Grant (concessional financial conditions)

Parameter	e-taxi
TCO financial old	0.13
TCO financial new	0.11
FIRR old	-3%
FIRR new	4.8%
Additional equity old	308%
Additional equity new	0%
Discounted Payback in years old	never
Discounted Payback in years new	never

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces and reaches the level of gasoline units.
2. The FIRR increases but is still below the WACC.
3. Owners capital requirements are 0.
4. The risk and the capital exposure of the entrepreneur is reduced significantly but the investment is still not recovered during the asset lifetime.

It can be concluded that the grant is interesting and has a positive impact. However, it does not resolve the financial issues. This is to a certain extent due to the very low cost of locally manufactured gasoline units and the limited market and high price of EVs.

4.4. Financial Analysis Electric LCVs

4.4.1. General Data

Calculations are realized for a standard LCV used for cargo purposes in urban settings. The following photo shows the type of LCV assessed in the case of Brazil. The annual assumed mileage is 35,000 km. The finance conditions considered are the same as for taxis (9.9% interest rate and 9 years loan tenure).

Photo: LCV Assessed for Brazil

Table 26: Baseline Diesel LCV Parameters

Parameter	Value	Source
Diesel consumption	15.7 l/100km	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=39452
Maintenance	0.02 USD/km	Review reports
CAPEX	37,000 USD	Volkswagen delivery
Lifespan	15 years	Based on annual mileage

Table 27: E-LCV Parameters

Parameter	Value	Source
Specific electricity usage	0.44 kWh/km	https://www.biodieselbr.com/noticias/qualidade/motor/caminhoes-com-tecnologias-alternativas-ao-diesel-irao-ganhar-mais-espaco-no-pais-041120,
Maintenance	0.01 USD/km	50% of fossil version
Lifespan	15 years	Same as fossil version, 2x exchange batteries
Lifespan battery @ 70% SOC	8 years	Replacement assumed in year 8
Charging at home average	90%	In general mileage of less than 50% maximum range and thus limited need for public charging
Charging fast-chargers	10%	
CAPEX e-LCV	64,000 USD	JAC iEV1200T, 7.5tGVWR, 4t cargo max
CAPEX home charger 7.4kW	2,000 USD	Wall-box installation
Lifetime charger	10 years	ABB
Battery size	97 kWh	https://www.uol.com.br/carros/noticias/redacao/2020/09/24/jac-iev1200t-como-e-andar-no-unico-caminhao-eletrico-a-venda-do-brasil.htm
Drive range electric (max.)	180 km	Depends on load

4.4.2. TCO

The following table shows the results of the TCO calculation.

Table 28: TCO Calculations (USD of 2020)

Parameter	Diesel	e-LCV
CAPEX LCV	37,000	64,000
CAPEX charging infrastructure	0	2,000
Replacement battery cost in year 7		19,400
Total CAPEX	**37,000**	**66,000**
Energy cost	3,620	1,558
Maintenance cost	850	425
Finance cost average p.a. during loan term	1,693	2,928
Economic costs of emissions year 1	1,115	73
Lifespan in years	15	15
TCO financial per km	**0.23**	**0.25**
TCO economic per km	**0.26**	**0.26**

Source: Grutter Consulting

Comparing total costs over the LCV lifetime e-LCVs have slightly higher financial and economic TCOs than diesel units.

4.4.3. Capital and Equity Investment

A comparison is made of the required capital total, in term of loans and as equity (see following table).

Table 29: Capital Demand (USD of 2020)

Comparison e-LCV to gasoline LCV	Absolute	%
Additional capital investment	29,000	78%
Additional loan	21,600	73%
Additional equity	7,400	100%

Source: Grutter Consulting

E-LCVs require 2x the capital investment compared to diesel units.

4.4.4. Relative Profitability

The relative profitability assesses the FIRR of the incremental investment for e-LCVs based on the operational savings of e-LCVs versus diesel units:

- The FIRR is -1%
- The EIRR is 7%.

The investment in e-LCVs is thus not profitable.

4.4.5. Discounted Payback

The discounted payback looks at the number of years required to recover the initial incremental investment from savings of e-LCVs relative to fossil units. Annual incremental savings of using an e-LCV versus a diesel LCV are discounted. The discounted payback gives a good indication of the risk the entrepreneur is facing and how much time his capital is tied up and not available for alternative investments.

The discounted payback shows that the initial incremental investment is not recovered during the asset lifespan.

4.4.6. Cash Flow

Cash Flow (CF) calculations are important to assess liquidity aspects of an investment. The CF is calculated without discounting based on the owners capital invested. It is based on the differential outflow of cash for CAPEX and OPEX of an e-LCV versus a fossil unit. Only cash outflows are considered as revenues (cash inflows) are identical between an e-LCV and a diesel unit. The cumulative CF is never positive over the lifetime of the asset. This is due also to battery replacement investment required in year 8.

Figure 9: Cumulative Differential Cash Flow Fossil versus Electric LCV

Source: Grutter Consulting

The cumulative CF decreases initially due to higher cash outlays for loan repayment of electric LCVs.

4.4.7. Summary Financial Assessment

The following table summarizes the financial assessment of e-LCVs.

Table 30: Summary Financial Assessment e-LCVs

Criteria	Result	Assessment
TCO	Higher TCOs of e-LCVs than of diesel LCVs	
Capital investment	2 higher than a conventional LCV	Higher capital requirement incl. higher loan demand
Equity investment	2x higher than a conventional LCV	Higher equity demand
Profitability	Negative	Investment in e-LCVs is not profitable
Discounted Payback	Incremental investment is not recovered	The payback time is very long. This indicates a high risk profile of the investment.
Cash Flow	Cumulative negative CF over asset lifetime	The investment in e-LCVs results in a cumulative negative liquidity impact

Summarized the investment in e-LCVs with current financial conditions and business models is not profitable, has a high risk and a very long payback time.

4.4.8. Variation of Parameters / Incentive Schemes

The impact on financial parameters of using concessional loans and of upfront investment grants is assessed.

Concessional Loan

The following table indicates the parameter used for a concessional loan.

Table 31: Concessional Loan Parameters

Parameter	Current conditions	Concessional conditions
Loan tenure	9 years	9 years
Interest rate	9.9%	5.7%
Lending rate	80% of CAPEX	80% of CAPEX including home charging

The concessional interest rate is based on a 1.25% rate from the GCF (0.75% interest rate and 0.5% commission; commissions fees factored into the interest rate) for 30% of the loan and 70% of the investment from AFD/co-financers at 4.8% interest rate plus 2% spread of the national banking system.

The following table compares the financial results with and without a concessional loan.

Table 32: Impact of Concessional Loan Conditions

Parameter	e-LCV
TCO financial old	0.25
TCO financial new	0.23
FIRR old	-1%
FIRR new	-1%
Additional equity old	100%
Additional equity new	78%
Discounted Payback in years old	never
Discounted Payback in years new	12

Source: Grutter Consulting

The concessional loan improves the liquidity situation and the TCOs without having a major impact in other areas.

Investment Grant

An upfront grant of 20% on the total initial investment combined with concessional finance is modelled. The following table shows the impact of an upfront grant.

Table 33: Impact of 20% Upfront Grant (concessional financial conditions)

Parameter	e-LCV
TCO financial old	0.25
TCO financial new	0.20
FIRR old	-1%
FIRR new	9.4%
Additional equity old	100%
Additional equity new	no equity
Discounted Payback in years old	never
Discounted Payback in years new	8

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO is now significantly lower and below the value of diesel units,
2. The FIRR is positive and above the WACC,
3. The risk and the capital exposure of the entrepreneur is reduced with a dynamic payback time (discounted with the new WACC) at 8.

It can be concluded that the grant resolves the major commercial investment problems.

5. Possible Business Models Investment Projects

5.1. Urban Buses

5.1.1. Barriers and Interventions Options

Currently, in most of the 5570 cities in Brazil, the main public transportation bidding model consists of joint contracting of the operation and fleet of the same supplier. In this way, the supplier is the one who makes the financial contribution with its own resources or the bank loan with guarantees along the lines of credit available directly with the banks without the intermediation of the local government. In some cases, the tenders allow the creation of consortia or another entity (even public-private) that will provide operation and fleet for public transportation. Larger cities tend to have higher quality requirements and newer fleets. Smaller cities often buy used buses from larger cities to provide public transportation in the interior of Brazil. There is a large resale market for used buses throughout Brazil that contributes to the viability and profitability of public transport operators in large Brazilian cities.

The following table summarizes main barriers towards massive e-bus deployment in Brazil. The barrier source gives an indication of what type of changes are required from an institutional perspective and the barrier elements which concrete aspects need to be altered.

Table 34: Barriers towards e-Bus Deployment in Brazil

Barrier Type	Concrete Aspects
Initial investment costs	The differential CAPEX between the initial investment of an EV with respect to a conventional vehicle makes the acquisition difficult for most public transport services, considering that they generally require the intervention of local authorities in the financial deficit due to the difference between the technical tariff and the tariff to the public. In addition, this technology incorporates a considerable investment in charging infrastructure.
Lack of knowledge of the technology	Although pilot projects have been carried out in the main cities this is not the case for medium and smaller cities. The technicians who prepare the bids also only have limited know-how about e-mobility ecosystems and might thus design suboptimal tenders. As example tenders might request buses to be capable of operating for 250km without re-charge thus pre-empting a certain technology solution (slow charging overnight) which might be technically, financially and operationally a suboptimal solution.
Reinvestment for battery replacement	Considerable reinvestments must be made in year 7 or 8.
Financial barriers	in general, transport systems do not have financial solvency, which increases the investment risk for traditional financiers, who, considering the payment history of previous loans, prefer not to participate in these schemes. This barrier makes evident the need for the active participation of the national and local government in the structuring of new financing schemes that guarantee payment to the financiers, as well as competitive financing conditions to which the systems can have access.

Source: Grutter Consulting

The **weak credit subjects** will result in a problem of accessing loans and having favourable loan conditions. A separation of bus ownership and bus operations, as has been done successfully e.g. in Mexico City, Santiago de Chile or Bogota can bring in other and financially stronger players which can provide the required owners capital and which can access finance at more favourable conditions. This could also be done with the municipality or government purchasing buses and then leasing or renting them to operators as is done e.g. in various cities worldwide.

Concessional loans and investment subsidies are critical to de-risk the investment and to create an attractive financial framework. This includes longer loan tenures, concessional interest rates, higher lending rates, payment guarantees and upfront investment subsidies worth around 20% of the total CAPEX which allows a 3rd party or a bus operator to invest in e-buses whilst receiving an adequate return on investment, an acceptable payback period, limits his equity and capital investment and financial exposure to a comparable rate as for fossil buses and allows for a positive cash-flow.

The asset separation model could be an instrument to alleviate the financial investment barriers identified. Report 3 will also look at other alternative business and delivery models.

The asset separation model proposes to open the participation of new actors in the bus procurement and operation system to implement electric mobility projects. Traditionally, private participation is limited to the operators of the routes, but under this new business model it is possible to involve new actors that can invest in one or more components of the project: vehicle fleet, recharging infrastructure or even the adaptation of bus depots for electric mobility. The main advantage of this model is that capital costs are divided, which is one of the barriers identified for electromobility projects, and it also favours the reduction of capital access costs.

In this model there would be a shareholder or "fleet provider" that would purchase the project assets. The asset owners would lease or rent the assets to the operators, in exchange for a payment. This means that, unlike traditional fleet acquisition, in this model the operators would not make the fleet investment and would not own the equipment.

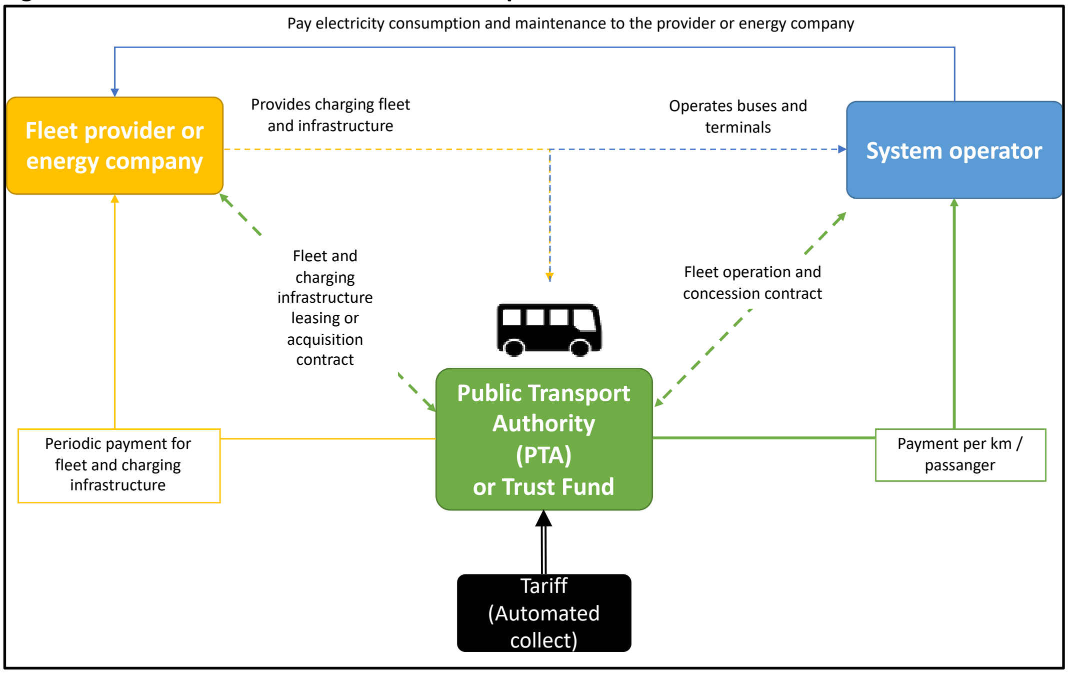
The following sections explain the roles of the actors according to the structure proposed as a business model.

1. **Fleet provider (for example energy company):** is responsible for acquiring the vehicle fleet, the charging infrastructure and its installation. The fleet provider may enter into a lease contract with the transport authority and, if necessary, an asset care and maintenance contract with the operator. This actor will finance the fleet through its own resources, as well as the acquisition of debt. The financing arrangements are their full responsibility.
   The fleet provider will receive a lease payment, which includes the acquisition value of the assets, finance charges and a profit margin. The payment of the lease payments will be the responsibility of the lessee, which in this case will be the management company or transport authority in the city where the project is implemented. The lease contract is expected to have an extension of 15 years, preferably in coordination with the concession period assigned to the operator of the units.

2. **Vehicle fleet operator:** is responsible for the operation of the service and will have a legal relationship with the transport authority, or managing company, through a service provision contract during the concession period, which could eventually be 15 years.
   The operator is responsible for paying other operating expenses such as personnel, energy consumption and other services associated with the operation. It is worth mentioning that in the asset separation model, the vehicle fleet operator could be remunerated through a payment per kilometer that covers its operating costs and a profit margin.

3. **Transport authority (PTA) or Trust Fund:** it is the one who signs the contracts with the project participants, makes the various payments according to the payment priorities and centralizes the collected fare resources. Depending on the type of contract established with the vehicle fleet provider, the transport authority could also be the owner of the assets.
For this model to be attractive and successful, a secure source of payment is required, a situation that would attract new investors, especially for those interested in the vehicle fleet supply process. This could be achieved through the establishment of guarantees by national or local governments, which would generate lower risk conditions for investors in the face of possible unexpected variations in demand, for example.

Figure 10: Business Models Based on Asset Separation



Source: Grutter Consulting

5.1.3. Potential Investment Projects

The following table lists potential bus investment projects for Brazil.

Table 35: Potential Investment Projects e-Buses Brazil

ID	Ownership	Project	Nu. of units	Estimated CAPEX	Estimated GHG impact[8]	Timeline
1	Public	Urban Public Transportation in Curitiba: BRT East/West	70 28m buses	67 MUSD	230,000 tCO_2 reduced	2024
2	Public	Urban Public Transportation in Curitiba: Inter 2	50 12m and 30 18m buses	46 MUSD	190,000 tCO_2 reduced	2024
3	Public	Urban Public Transportation in Teresina	20 13m buses	6 MUSD	40,000 tCO_2 reduced	2023
4	Public	Urban Public Transportation to integrate 9 cities in Florianopolis Metropolitan Area	358 buses of which 3 8m, 312 12-13m, 43 15-18m	130 MUSD	720,000 tCO_2 reduced	2023 to 2027

[8] Cumulative lifespan of units

5	Public	Urban Public Transportation / Fleet Renovation in Niteroi	400 12m buses	126 MUSD	780,000 tCO_2 reduced	2022 to 2026
6	Public	Belo Horizonte Municipality	900 buses of which 90 8m, 700 12m, and 190 18m	374 MUSD	1,940,000 tCO_2 reduced	2025 to 2027

Source: Grutter Consulting: Details see Excel sheet

5.1.6. Some Requirements for Other Business Models for EV Public Transport Operation

The interviews with transportation authorities to identify potential projects for pipeline showed that municipalities have a real interest in implementing electric mobility in public transportation. However, there are resource limitations for the acquisition of a more expensive and still little known technology in Brazil. Among the cities listed in the Pipeline of projects it stands out that - if resources and feasibility exist - Curitiba, Niteroi and Belo Horizonte seem to be the most prepared cities to implement electric mobility in public transport.

5.1.5. Other Potential EV Projects

One should also highlight the initiatives of the city of São Paulo, which presents a Fleet Transition Plan signed with the operators in September 2020 that foresees the renewal of 1,300 to 1,800 buses per year. In the metropolitan area São Paulo, the cities of Guarulhos and Campinas area working on a dialog for public electric mobility for the region. This process is headed by SPTrans and EMTU. Others cities in São Paulo region might be also included.

In Rio de Janeiro, there is a BRT System with 123km with deficit of 200 articulated buses and the municipality is willing to implement 200 electric articulated buses (18 meters, with AC). Rio de Janeiro is also building a new BRT line (20km, exclusive lanes) which will demand 200 buses. The municipality mentioned to be willing to have electric articulated buses (18 meters, with AC).

It is necessary to revise the legislation, reformulate the bidding process, reformulate the concession contracts in effect, in addition to updating the feasibility studies so that it is possible to implement a new management model for public transportation that allows the separation of the provision of operations from the provision of the fleet in large Brazilian cities.

Similar to what already happens with large freight and air transport operators, in many cases carriers and airlines do not own fleets. The fleets are provided by other institutions, leasing systems, consortiums, and even energy companies.

There is a pilot project in Brazil that foresees the implementation of 300 electric vehicles for last mile freight distribution. In this specific project, the vehicles will be provided by the power company, which will no longer sell energy but will start selling services embedded in the power distribution company's equipment.

As public transportation is the prerogative of the municipality in Brazil, it will be necessary to customize business models to each local reality, even understanding that larger cities tend to behave in a similar way. Once the best viability for separating the operation and fleet has been demonstrated, there is clear signalling from local governments that the migration will happen gradually.

5.1.7. Challengers for Private Transport Projects and it Funding

During the interview process and previous research there was an expectation to identify electric mobility projects with the private sector. To this end, interviews were conducted with banks, including BNDES which has a specific credit line for mobility, and PROPARCO (the PROPARCO planning cycle in Brazil goes until 2021 with no projects proposed for the Pipeline after 2023). A different and specific credit line for electric mobility in Brazil was not identified. It is noteworthy that for the financing of equipment in Brazil, 70% of the items of electric vehicles must be of national origin, which does not currently apply to electric cars in Brazil that imports most of its components. In general, it is important to highlight that, private operators have difficulties to access credit because they do not have most of the needed guarantees and financial health requirements to access loans from banks.

Report 3 will list the potential investment projects suggested for investment with the fund including the GCF contribution part. The following financial intervention instruments are proposed for e-bus deployment in Brazil:

- Concessional loans from the GCF @ 0.75% which are blended with AFD and co-finance, a long tenure, a high loan share (80% of total investment). This should be capable to cut interest rates by around 50%.
- Grant facility covering up to 20% of the initial total CAPEX (bus, charging infrastructure, grid connection and bus depot upgrade);

5.1.8. Technical Assistance

The following technical assistance activities are deemed important to create favourable market conditions for mass deployment of e-buses:

- Structuring of appropriate concession contracts and concession conditions conducive to e-bus deployment incl. concession length, tariff structuring, concession contracts, guarantees etc.
- Structuring of public transport models which result in stronger and fewer operators e.g. in direction of separation of bus ownership and bus operations.
- Structuring of favourable enabling conditions to foster the entry of financially strong players into the public transport business e.g. as bus owners. This could be private companies or a municipal special purpose vehicle, a public private partnership or municipal/government led purchase of buses.
- Assessment of optimal e-bus technology and charging systems to enable a robust and cost-effective e-bus deployment.
- Structuring of bus tenders and bus contracts in accordance with the special requirements of e-buses.
- Roadmap for e-bus deployment which includes concrete steps and goes beyond just establishing targets.

5.1.9. Foreseen Barriers to the shift to electric Public Transport

The business model proposed above relies on the separation between the bus owner and the operator. It is expected to be found barriers such as: resistance to change from the "business as usual model"; historical data to make further comparisons and feasibility studies; lobby from biofuel players and industries; resistance from manufacturer to shift from diesel to electric business; fear of unemployment in the transport sector due to technology changes; diversification of services provides will affect the traditional transport operation which are providing transport services in Brazil within the last 40 years; pressure from diesel and parts suppliers.

5.2. Taxis and LCVs

5.2.1. Barriers

The deployment of electric taxis and LCVs faces following major barriers:

- Summarized the investment in e-taxis with current financial conditions and business models is profitable but not sufficient concerning the involved risk and equity exposure and thus commercially not viable. Even upfront grants will not change this situation in the short term also due to very low costs of locally manufactured gasoline taxis. Without local manufacturing of electric passenger cars within Brazil with similar features it is not considered as useful to enter this area.
- Lack of information and know-how of options and possibilities of e-mobility in this area. Some companies are interested in EVs but do not have access to information on available models. Vehicle importers are not actively engaging in the business as they have higher profits selling fossil vehicles and their spare parts. In the urban cargo area also vehicles and customer demands vary widely.
- Ownership structures are often a barrier as vehicles are owned by individual drivers and not by the logistics companies or by the cargo company.

5.2.2. Potential Investment Projects

Taxis even with concessional loan conditions and grants are not yet commercially viable. These units will thus not be included in the program. LCVs if manufactured locally could be deployed wider. However, the interest of companies is limited as long as no sound national production base is established. Also, no concrete demand could be identified for such vehicles. Therefore, the fund will postpone intervention in these vehicle categories until its general operational and organisational conditions improve.

6. TA intervention Areas and Instruments

6.1. TA Actors in E-Mobility

The following national and international actors are involved in the promotion of electromobility in the country:

World Bank - WB

The World Bank is investing in Public Electric Mobility in Brazil. One of its projects aims to find a better business model to drive electric mobility in São Paulo, Salvador, Fortaleza, and Belo Horizonte. This project also foresees the development of plans and other models for fleet renewal. The foreseen models include the possibility of fleet financing by banks, energy distribution companies providing service packages, leasing mechanisms for vehicles, recharging structures and batteries, among others. In Belo Horizonte, the studies are at an advanced stage.

Corporación Andina de Fomento - CAF

In August 2019, CAF took part in the events of Climate Week, where it organized the panel "Climate risk assessments as a support tool in planning processes at the subnational level", where topics such as urban challenges to address greenhouse gas emissions, methodologies for assessing climate vulnerability in cities, and public sector experiences in monitoring emissions and planning adaptation actions were discussed.

Also in 2019, CAF developed the study Electromobility in public transport in Latin America, a work that is part of the "Clean Transport" line of work of the Corporation's Urban Mobility strategy. With it, the institution seeks to facilitate and promote the use of low- or zero-emission public transport and complement the support to several cities in the region that have begun this process incipiently in the region, including Brazil.

Cities Finance Facility – CFF- C40

Accompanied by the United Nations (UNEP), GIZ, Euroclima, Caecid and Acciona, carry out frequent events to promote and disseminate electric mobility in Brazil and the Latin American region.

World Resources Institute WRI

Building on a decade of cooperation with the Ministry of Cities, WRI's cities team in Brazil was chosen to lead the development of first-of-its-kind guidelines for Caixa, the agency responsible for providing loans and monitoring project implementation, to assess the quality of all urban mobility projects and to target federal funds only to those that meet the guidelines' criteria.

WRI then piloted the guidelines in four large cities – Florianópolis, Joinville, Juiz de Flora and Pelotas – and offered recommendations that these cities followed to improve their projects. The guidelines were launched at an event co-hosted by the Ministry of Planning and Caixa, and distributed at an event on urban sustainable mobility that drew over 160 people from 40 cities.

UN Environment Programme UNEP

The UN Environment Program, with the support of the European Union, through the EUROCLIMA+ Program and the Spanish Agency for International Development Cooperation (AECID), supports countries in Latin America and the Caribbean to make the transition to electric mobility. To this end, it promotes dialogue, learning and regional exchange. The *Electric Mobility Report for Latin America and the Caribbean* is published periodically. It also includes publications on topics such as barriers, innovative business models, electric mobility systems, vehicle charging, energy efficiency, among others.

German Cooperation Agency – GIZ

For the German Clean Technology Initiative (DKTI) and on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), Deutsche Gesellschaft für Iternationale Zusammenarbeit (GIZ) supported the Brazilian Ministry of Economy in the implementation of the Efficient Propulsion Systems Project (PROMOB-e) in the period between 2017 and 2020. With a budget of EUR 5 million, this project contributed to developing the necessary conditions to promote mobility in Brazil with innovative public policies, standards and business models. As a result, in 2018 ANEEL approved a regulation enabling the implementation and provision of electric vehicle charging services. In addition, in 2019 ANEEL published the call for strategic research and development projects for the structuring of efficient electric mobility solutions, and in September of the same year approved 30 projects worth 104 million euro (GIZ, 2019).

The TUMI E-Bus Mission consisting of GIZ, C40, ICCT, ITDP, UITP and WRI will work in up to five Brazilian cities (not selected yet) to accelerate the e-bus deployment. Tailored technical assistance for the deep dive cities and replication in mentee cities shall help to spur electric bus implementation.

Inter-American Development Bank – IDB

The Inter-American Development Bank (IDB) Group is leading the electrification of the transport sector in Latin America and the Caribbean by driving initiatives to support the modernization of the transport system. Since 2013, the IDB Group has been working with public and private sector actors through the support of more than 51 initiatives in 19 LAC countries, five of them in Brazil. It provides support throughout the project cycle, including the pre-investment, investment, and operation phases.

6.2. Possible TA Interventions within the E-Motion Program

As can be seen, several projects have been developed within the framework of electromobility in the country with the research and development (R&D) program of the National Electric Energy Agency (ANEEL), which suggests that barriers are being overcome to the extent that specific projects are being supported. However, it is key to accelerate the process of breaking down barriers by influencing areas of public policy and technical assistance to the public and private sector in an effort in which the support of companies such as EDP is strategic. Some of the main areas of intervention are presented below:

- Support on electric vehicle procurement policies and public charging infrastructure.
- Technical support on business models and sector re-structuring for the bus sector including new business models separating bus ownership and bus operations, integration of other players with stronger financial background in the public bus sector, and adaptation of bus concession contracts and bus tariff structures.
- Support for the structuring of a national policy for the proper disposal, recycling and elimination of batteries, in order to minimise the pollution of natural resources.
- Support state and municipal governments to prepare bids that consider the conditions for electric mobility in Brazilian cities.

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Annex: Data

General Parameters			
Parameter	**Value**	**Unit**	**Source**
NCV of diesel	43	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of diesel	74.1	gCO_2/MJ	IPCC, 2006, table 1.4
Density of diesel	0.844	kg/l	IEA, 2005
Well-to-tank mark-up factor diesel	23%		UNFCCC, 2014, Table 3
NCV of CNG	48	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of CNG	56.1	gCO_2/MJ	IPCC, 2006, table 1.4
Density of NG	0.714	kg/m^3	IGU, 2012
Well-to-tank mark-up factor CNG	18%		UNFCCC, 2014, Table 3
Methane slip as % of NG consumption TTW	1.1%		Average low and high value of ICCT, 2015, table 4 for crankcase and tailpipe
Methane slip as % of NG consumption WTW	3.4%		Average low and high value of ICCT, 2015, table 4 for well-to-pump and fuelling station plus TTW slip
NCV of gasoline	44.3	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of gasoline	69.3	gCO_2/MJ	IPCC, 2006, table 1.4
Density of gasoline	0.741	kg/l	IEA, 2005
Well-to-tank mark-up factor gasoline	19%		UNFCCC, 2014, Table 3
GWP_{100} of BC	900		Bond, 2013; see also IPCC, 2013, Table 8.A.6
GWP_{100} of CH_4	28		IPCC, 2013, Table 8.A.
BC fraction Euro 2 gasoline passenger car and LCV	25%		EEA, 2020, tabla 3-92
BC fraction Euro 4 gasoline passenger car and LCV	15%		
BC fraction Euro 2 diesel passenger car and LCV	80%		
BC fraction Euro 4 diesel passenger car and LCV	87%		
BC fraction Euro II HDV	65%		
BC fraction Euro IV HDV	75%		
BC fraction Euro 1 Motorcycle	25%		
BC fraction Euro 2 Mot	25%		
Conversion kWh to MJ	3.6	MJ per kWh	https://home.uni-leipzig.de/energy/energy-fundamentals/03.htm#:~:text=Power%20units%20can%20be%20converted,%3D%203.6%20MJ%20%5B
Battery manufacturing emissions	110	$kgCO_2/kWh$	ICCT, 2018, table 1 (per kWh battery set); average value not taking into account 2nd life usage of batteries

Parameter	**Value**	**Unit**
Electricity price home charging	0.08	USD/kWh
Electricity price fast chargers	0.3	USD/kWh
Electricity price consumption buses or medium tension industry day off peak	0.09	USD/kWh
Electricity price consumption buses or medium tension industry night off peak	0.09	USD/kWh
Power charge night per month		USD/kW
Power charge day off-peak per month		USD/kW
ANEEL; average rates; https://www.bnamericas.com/es/noticias/regulador-electrico-brasileno-asigna-bandera-roja-a-tarifas		
Calculation for buses		
Average electricity price overnight charged buses	0.09	USD/kWh
Average electricity price fast charged buses	0.09	USD/kWh

TCO 12m Bus

Parameter	Value	Unit	Source
Distance driven per bus per annum	66,000	km	PROMOB-E
Workday distance driven daily	221	km	Default
Specific electicity usage	1.1	kWh/km	Chinese average; ADB, 2018; includes AC but not heating
Diesel usage	59	l/100km	Euro V bus; based on WRI cited in PROMOB-e for mid 2018 in table 7
Maintenance cost diesel bus incl. labor and tyres	0.15	USD/km	PROMOB-E
Lifespan bus diesel	15	years	default 1 million km
Lifespan bus electric	16	years	max based on battery age; can be 20% more than diesel
Lifespan battery @ 80% SOC	8	years	current guarantee levels

Financial defaults

Parameter	Value	Unit	Source
CAPEX diesel bus	150,000	USD	Euro V bus; based on WRI cited in PROMOB-e for mid 2018 in table 7
CAPEX overnight charged e-bus	284,000	USD	Based on bus with 350 kWh battery set and sur-cost for battery size
CAPEX slow-charged batteries	200	USD/kWh	LFP batteries
CAPEX fast-charged BEB	250,000	USD	Based on standard fast-charged bus
CAPEX batteries fast-charged	250	USD/kWh	NMC batteries
Reduction battery cost in 8 years	50%		US DOE projections, 2017 have a decrease of 12% per annum; applied to 5 years; https://energy.gov/sites/prod/files/2017/02/f34/67089%20EERE%20LIB%20cost%20vs%20price%20m
CAPEX charger excl. Installation per kW	120	USD/kW	Standard chinese chargers, 2 nozzles
CAPEX charger installations civil works	2,500	USD/bus	Civil works for chargers; 2 buses per charger; 5,000 USD per unit
Cost per bus depot upgrade	7,500	USD/bus	Coverage of bus and chargers with roof, no paving, includes labour (20m2 per bus, 250 USD/m2 material and 125 USD/m2 labour)
Cost grid connection of chargers	30,000	USD/bus	Compact sub-stations for groups of chargers; 20kV cables from connection substation to the compact substation, 400V cables from compact substation to chagers; costs not born by electric utility
Maintenance & repair cost of e-buses relative to diesel incl. labour	70%		Based on experience in PR China; ADB, 2018; 10% higher tyre costs; 75% lower maintenance staff and general maintenance; 20% lower repair and spare parts
Maintenance & repair cost of CNG buses relative to diesel incl. labour	120%		Based on CNG and diesel bus operators
Lifetime chargers	10	years	standard value
Lifetime bus depot upgrades	20	years	standard value
Lifetime grid connection	20	years	standard value
Maintenance chargers, grid connection, depot	2%		of investment

Option A: Overnight Charging		
Battery Size Determination overnight charging		
Parameter	**Unit**	**Value**
Daily range workday (max)	km	221
Energy usage day	kWh	243
Risk ratio (higher energy consumption)		10%
Reserve ratio		20%
SOC loss year 8		20%
Battery size required year 8	**kWh**	**420**
Charging required at bus depot overnight		
Parameter	**Unit**	**Value**
Battery capacity	kWh	420
Average daily consumption workday	kWh	243
Time available at depot night	hours	6
Power conversion efficiency of chargers		90%
Charging power required (incl. 1h reserve for slower charging last 20%)	kW	50
Option B: Fast Charging		
Parameter	**Unit**	**Value**
Battery size	kWh	200
C-rate		0.65
Charging in 30 minutes	kWh	65
Average re-charge during day required with 20% reserve ratio	kWh	83
Average share of day electricity		34%
Fast-charger	kW	300
Power conversion efficiency of chargers		90%
Average required re-charge day with 300 kW charger	minutes	18
Number of buses per fast-charger	buses / charger	8
Night charger power		40
Other options are possible e.g. smaller battery and higher C-rate, buses per fast-charger based on max 12 units or time*2 for charging and 3 hour slot		

TCO Buses

12m standard bus, USD 2019

Parameter	Diesel	BEB overnight	BEB fast
CAPEX bus	150,000	284,000	250,000
CAPEX charging infrastructure	0	8,500	12,113
CAPEX grid connection	0	30,000	30,000
CAPEX depot upgrade	0	7,500	7,500
Total CAPEX	150,000	330,000	299,613
Battery replacement yr 8	0	42,000	25,000
Energy cost yr 1	25,700	6,534	6,534
Maintenance cost bus yr 1	9,900	6,930	6,930
Maintenance cost infra yr 1	0	920	992
Finance cost average per year	6,862	13,011	11,453
Economic costs yr 1	6,450	345	345
TCO financial per km	0.76	0.74	0.68
TCO economic per km	0.87	0.75	0.68

timespan of calculation: lifespan of e-buses with replacement investment for fossil buses; end of life value proportional to remaining lifespan

Finance costs based on concessional loan

TCO Taxis

Parameter	Value	Unit	Source
Average battery size	40	kWh	Jac e40; https://www.jacmotors.com.br/veiculos/eletricos-detalhes/iev40
Battery lifespan	10	years	idem to vehicle lifespan
Vehicle lifespan	10	years	e-janeiro/noticia/2020/03/27/prefeitura-do-rio-anuncia-que-vida-util-de-taxis-passara-de-8-para-10-an
Annual mileage	51,810	km	
Daily mileage	157	km	TRANSPORTE EM NÚMEROS Indicadores Anuais do Transporte Público: Modal taxi
Charging at home average	70%		Assumption; only re-charge if above-average mileage or night shifts
Charging fast-chargers	30%		
CAPEX gasoline taxis	12,000		Chevrolet Onix, 2021; https://www.noticiasautomotivas.com.br/onix/
CAPEX e-taxi	39,000		Jac 40; https://www.jacmotors.com.br/veiculos/eletricos-detalhes/iev40
Capex home charger 7.4kW	2,000	USD	wallbox
Gasoline consumption	7.8	l/100km	urban gasoline; https://www.noticiasautomotivas.com.br/onix/
Electricity consumption	0.13	kWh/km	https://www.jacmotors.com.br/veiculos/eletricos-detalhes/iev40
Charger lifespan	10	years	
Maintenance cost gasoline excl. tyres and repairs	0.0093	USD/km	https://www.noticiasautomotivas.com.br/onix/
Maintenance cost total e-taxi	0.00558	USD/km	40% lower

gasoline versus e-taxi

Parameter	gasoline	e-taxi
CAPEX vehicle	12,000	39,000
CAPEX charger	0	2,000
Total CAPEX	12,000	41,000
Energy cost	3,334	983
Maintenance cost	482	289
Finance cost average per loan year	549	1,784
Economic costs yr 1	451	32
Lifespan in years	10	10
TCO financial per km	0.11	0.13
TCO economic per km	0.12	0.14

LCVs

1. Petrol Van

Parameter	Value	Unit	explanation
CAPEX van	37,000	USD	Volkswagen delivery
diesel fuel consumption	15.7	l/100km	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=39452
Maintenance cost	0.02	USD/km	excludes tyres and repairs; stnadard values
Lifespan	15	years	Based on annual mileage
Daily distance driven	106	km	typical of LCV
Annual distance	35,000	km	95% usage

2. E-Van

Parameter	Value	Unit	explanation
CAPEX e-van	64,000	USD	JAC iEV1200T; 7.5tGVWR; 4t cargo max
Range WLTP	200	km	https://www.biodieselbr.com/noticias/qualidade/motor/caminhoes-com-tecnologias-alternativas-ao-diesel-irao-
Battery size	97	kWh	ganhar-mais-espaco-no-pais-041120; https://www.uol.com.br/carros/noticias/redacao/2020/09/24/jac-iev1200t-
Cost battery	19,400	USD	Based on 200 USD/kWh per battery
electricity consumption	0.44	kWh/km	https://www.uol.com.br/carros/noticias/redacao/2020/09/24/jac-iev1200t-como-e-andar-no-unico-caminhao-eletr
Maintenance cost	0.01	USD/m	50% of fossil (as only engine maintenance is included; no tyres, no repairs)
Lifespan van	15	years	assumed same as fossil
Lifespan battery	8	years	
Capex home charger 7.4kW	2,000	USD	
Lifespan charger	10	years	
Charging at home average	90%		Assumption
Charging fast-chargers	10%		Exceptional if long distances were made

fossil versus e-van

Parameter	diesel	e-van
CAPEX vehicle	37,000	64,000
CAPEX charger	0	2,000
Total CAPEX	37,000	66,000
Battery replacement		19,400
Energy cost	3,620	1,558
Maintenance cost	850	425
Finance cost average per year	1,693	2,928
Economic costs yr 1	1,115	73
Lifespan in years	15	15
TCO financial per km	0.23	0.25
TCO economic per km	0.26	0.26