Assessment of Commercial EV Demand in Colombia

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Abbreviations

AC	Air Conditioning
AECID	Spanish Agency for International Development Cooperation
AFD	French Development Agency
BAU	Business As Usual
BEB	Battery Electric Buses
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CF	Cash Flow
CFF	Cities Finance Facility
DNP	National Planning Department
EIRR	Economic Internal Rate of Return
EV	Electric Vehicle
FA	Financial Assistance
FINDETER	Territorial Development Finance
FIRR	the Financial Internal Rate of Return
GHG	Greenhouse Gases
GIZ	German International Cooperation
ICCT	International Council on Clean Transportation
IDB	Inter-American Development Bank
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies
IEA	International Energy Agency
LABMOB	Sustainable Mobility Lab
LCV	Light Commercial Vehicle
MADS	Ministry of Environment and Sustainable Development
NAMA	Nationally Appropriate Mitigation Action
PM	Particulate Matter
PNUD	United Nations Development Programme
P4G	Partnering for Green Growth and the Global Goals 2030
SETP	Strategic Public Transportation Systems
SITM	Integrated Mass Transit Systems
TA	Technical Assistance
TCO	Total cost of ownership
UNEP	United Nations Environment Programme
UPME	Mining and Energy Planning Unit
WACC	Weighted Average Capital Cost
WTW	well-to-wheel
WWF	World Wildlife Fund
ZEBRA	Zero Emission Bus Rapid-Deployment Accelerator

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 Colombia from materializing the market potential.

The focus is on assessing the 2030 potential market for commercial electric vehicles (EVs) in Colombia 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 Colombia

Colombia has seen an increase in the EV fleet, both pure hybrids, plug-in hybrids and battery electric vehicles. This increase in the fleet is mainly due to financial incentives from the government, such as tariff exemptions and VAT reductions, favouring the sale of this type of vehicle. This in turn favours the arrival of new electric vehicle manufacturers and the arrival of electric and hybrid vehicles from brands that are already positioned in the country, such as BMW, Mercedes Benz or Renault. As of November 2020, Colombia had an estimated 10,728 EVs including PHEVs.

In Bogotá, the Mayor's Office of Bogotá and Transmilenio granted several contracts for the purchase of 1,485 electric buses, 740 type "Padrón" of 80 passengers and 745 type “Busetón” of 50 passengers (SITP, 2020). With this purchase of electric buses Bogotá will become the capital of electric mobility in Colombia and a reference in Latin America. Medellín has currently 68 electric buses and Cali 35 units.

Two cities have implemented pilot projects for the deployment of electric cabs in the country; Bogota and Medellin. Bogota established various years ago a pilot plan for 50[1] electric cabs. Medellín had a pilot plan for e-cabs which did not take off and is working on a new proposal.

By 2021 it is expected that some 200 LCVs operate in Colombia.

3. Commercial EV Market Potential in Colombia

3.1. Scenario

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

[1] This was the value initially proposed by the programme, however, only 43 vehicles were put into operation.

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 considered in this scenario 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[2].

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	5,984	24,000
Market share (% of stock)	9%	32%
Sales share (% of new registrations)	40%	100%

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

With a high growth scenario a market share of around 32% is targeted by 2030 equivalent to 24,000 electric urban buses operating in the country. The main parameters for the high growth market potential are outlined in the following table.

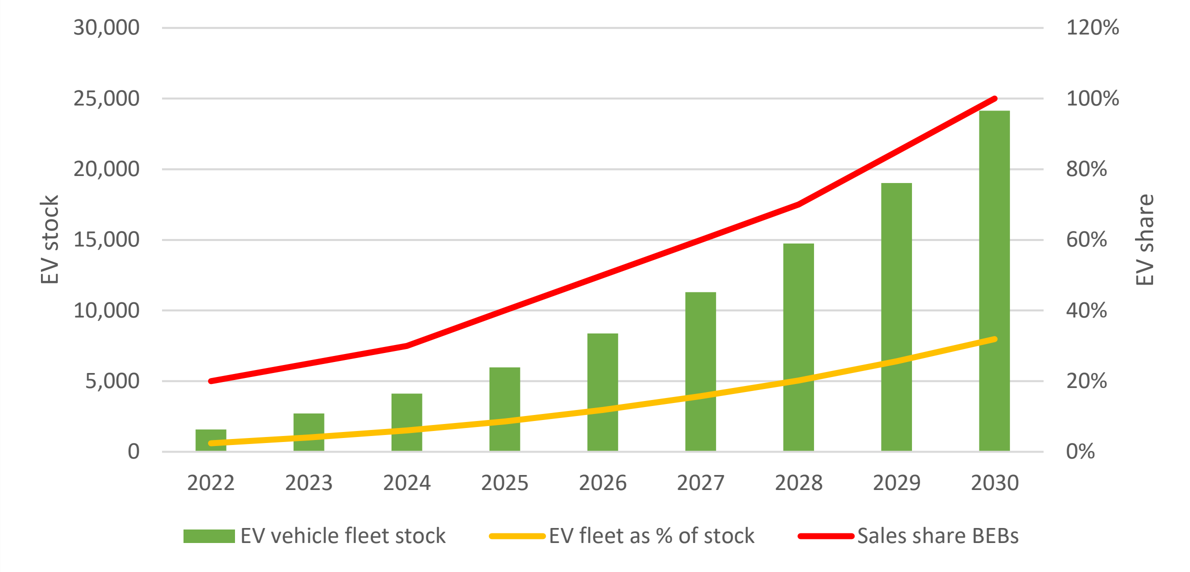
Table 2: High Growth Scenario Electric Urban Buses 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock buses	65,845	67,001	68,178	69,375	70,593	71,833	73,094	74,378	75,684
Sales BEBs	891	1,133	1,384	1,877	2,388	2,916	3,462	4,277	5,120
Stock BEBs	1,590	2,723	4,107	5,984	8,372	11,288	14,749	19,026	24,147
Share BEBs of stock	2%	4%	6%	9%	12%	16%	20%	26%	32%

BEBs: Battery Electric Buses
Source: Grutter Consulting; report 1

[2] For details on scenarios see Country Diagnostic Report Colombia

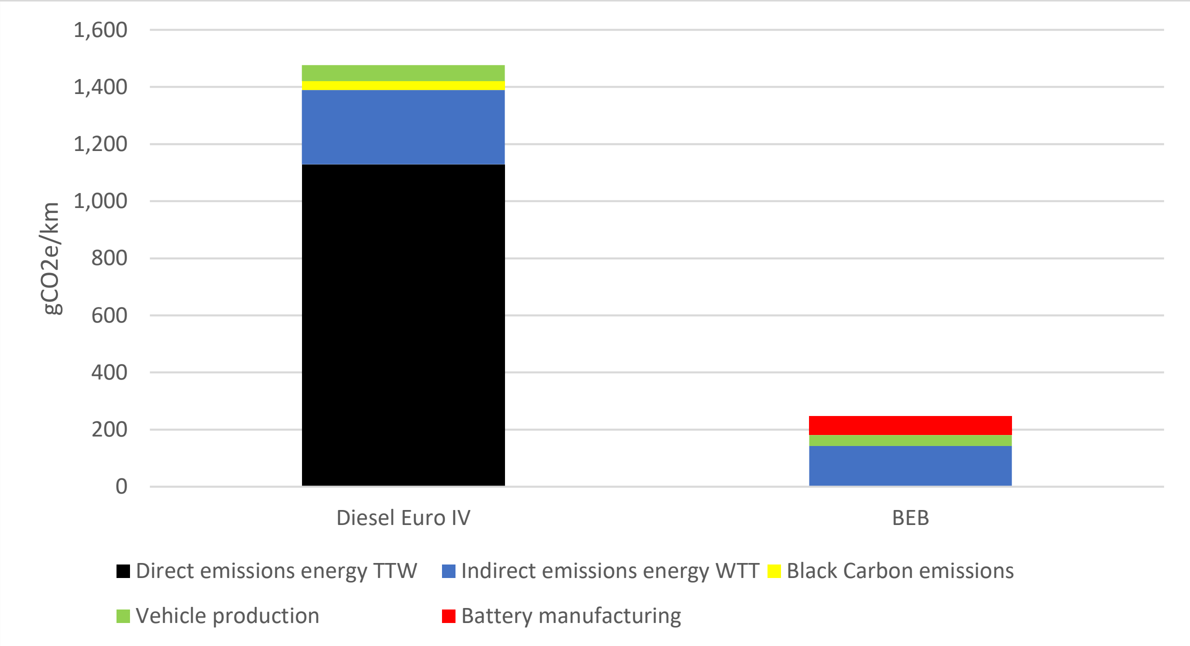
Figure 1: Urban Electric Bus High Growth Scenario



Source: Grutter Consulting

A BEB can reduce well-to-wheel (WTW) Greenhouse Gas (GHG) emissions in Colombia by 90% and cradle to grave emissions by 83% compared to a diesel unit (see figure below).

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



Source: Grutter Consulting; mileage and energy consumption based on values for Colombia: diesel Euro V bus as used by Transmilenio for feeder routes; fuel consumption 42 l/100km; 59,000km/a; BEB with 1.1 kWh/km; battery set average 285 kWh; battery upstream emissions 110 $kgCO_2/kWh$ (ICCT, 2018); grid factor 0.130 $kgCO_2/kWh$; lifespan diesel bus 10 years and BEB 15 years

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	5,200	64,000
Market share (% of stock)	3%	30%
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.

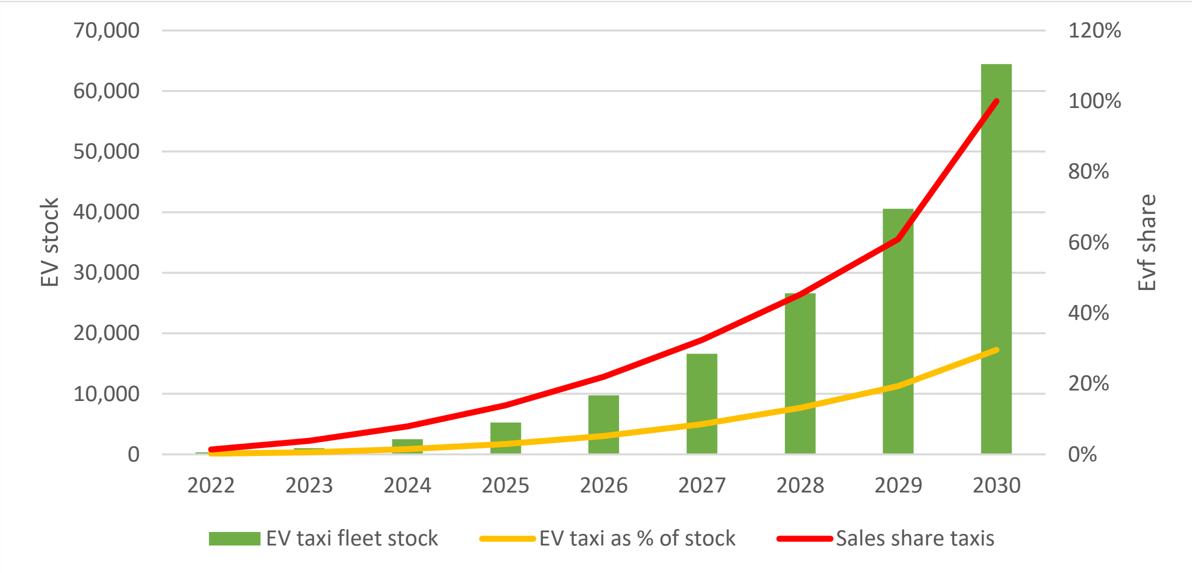
Table 4: High Growth Scenario Electric Taxis 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock taxis	159,478	165,827	172,428	179,292	186,429	193,850	201,566	209,590	217,934
Sales e-taxis	240	695	1,491	2,721	4,479	6,868	9,998	13,989	23,868
Stock e-taxis	340	1,035	2,526	5,247	9,726	16,594	26,592	40,580	64,449
Share e-taxis of stock	0%	1%	1%	3%	5%	9%	13%	19%	30%

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

As of 2030 more than 60,000 e-taxis would be electric with this scenario.

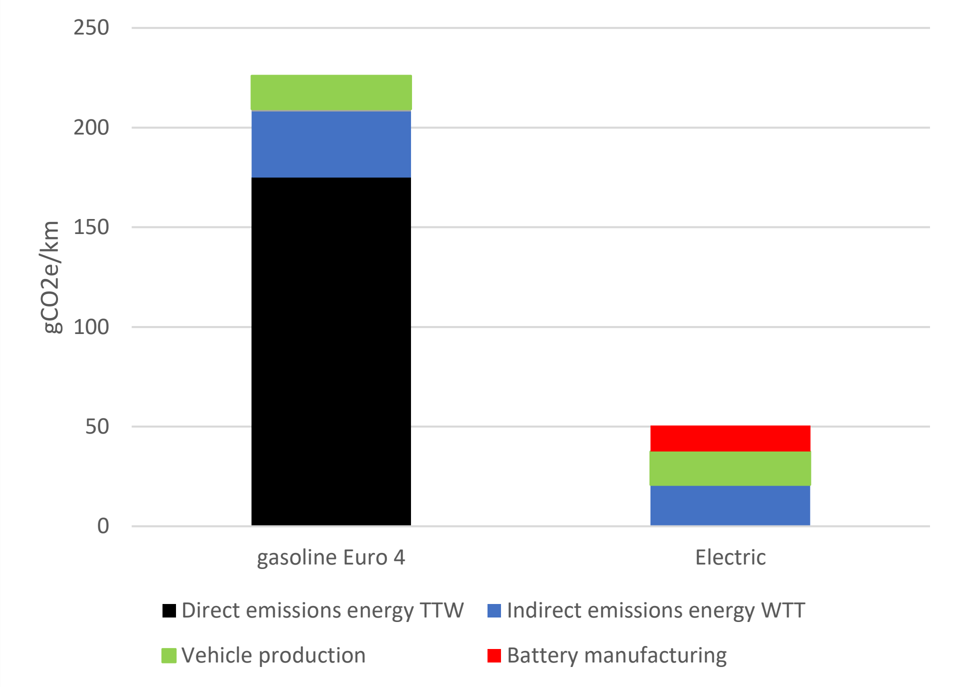
Figure 3: Electric Taxi High Growth Scenario



Source: Grutter Consulting

An electric taxi can reduce WTW emissions in Colombia by 90% and cradle to grave emissions by 78% (see figure below).

Figure 4: GHG Impact Electric Taxi



Source: Grutter Consulting; mileage and energy consumption based on values for Colombia

3.4. Light Commercial Vehicles (LCVs)

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

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

Parameter	2025	2030
Cumulative e-LCVs	27,000	310,000
Market share (% of stock)	2%	24%
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.

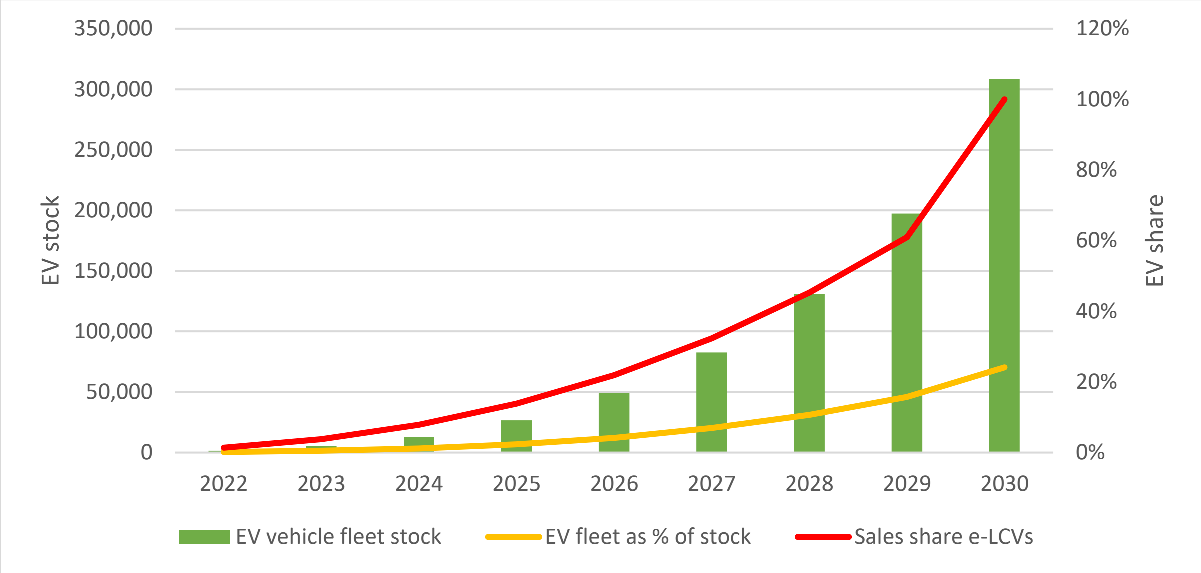
Table 6: High Growth Scenario Electric LCVs 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock LCVs	1,072,851	1,096,677	1,121,033	1,145,929	1,171,378	1,197,392	1,223,985	1,251,167	1,278,954
Sales e-LCVs	1,284	3,646	7,696	13,804	22,340	33,677	48,196	66,292	111,197
Stock e-LCVs	1,610	5,257	12,952	26,757	49,097	82,774	130,971	197,262	308,460
Share e-LCVs of stock	0%	0%	1%	2%	4%	7%	11%	16%	24%

Source: Grutter Consulting, report 1

As of 2030 more than 300,000 e-LCVs would operate in Colombia with this scenario.

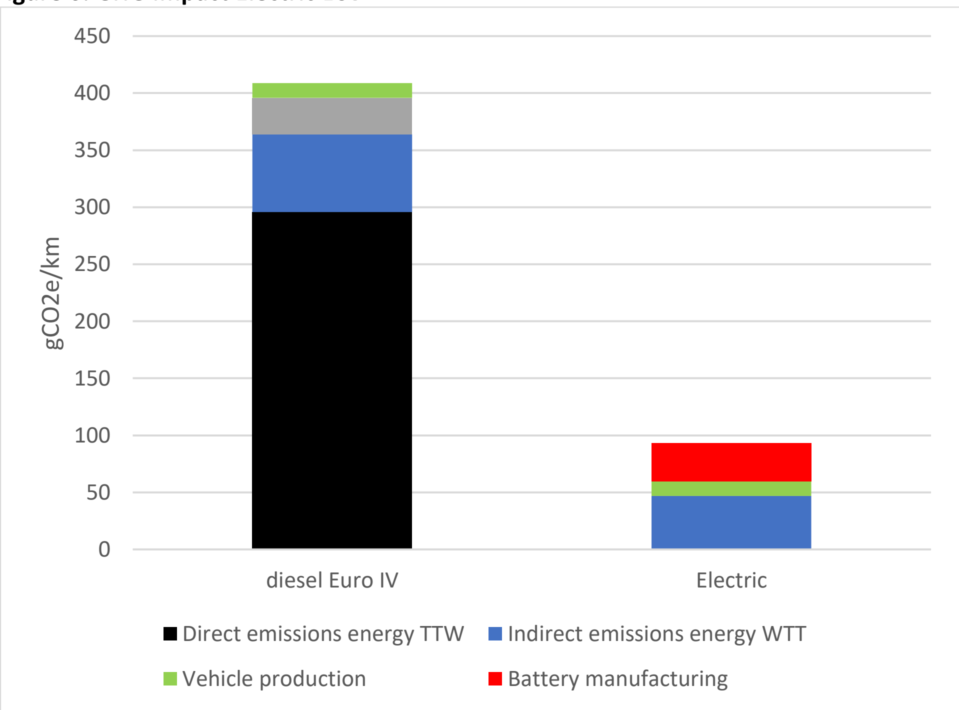
Figure 5: LCV High Growth Scenario



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 a LCV as used by many delivery services (3.7t load capacity) an electric LCV can reduce WTW emissions in Colombia by 88% and cradle to grave emissions by 77% (see figure below).

Figure 6: GHG Impact Electric LCV



Source: Grutter Consulting; mileage and energy consumption based on values for Colombia based on JAC JKR diesel and Stark eLCV; major assumptions include 33,000km annual mileage; 11 l/100km and 0.36 kWh/km e-LCV; 20 year lifespan; 8-year lifespan of battery; battery set of 81kWh; 110kg CO_2/kWh battery (ICCT, 2018); grid factor 0.130 $kgCO_2$/kWh

4. Financial Assessment of Commercial EVs in Colombia

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 Colombia;
- 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 Colombia for the transport sector.

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

Parameter	Value	Source
Cost of equity	11.2%	(UNFCCC, 2019); value for transport sector of Colombia
Share of equity financing	20%	Banks are willing to finance 80% with loans
Cost of debt	9.0%	Grupo BanColombia LIBOR (0.34%) + 8.5-9%
Share of debt financing	80%	Banks are willing to finance 80% with loans
Corporate tax rate	32%	Deloitte, 2020
WACC	7.1%	Calculated

4.2. Financial Analysis E-Buses

4.2.1. General Data

Calculations are realized for the standard bus as used in Colombia 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 370 kWh[3];
- 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 59,000 km[4].

[3] 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.
[4] Average TransMilenio non-trunk route 12m buses

Table 8: Baseline Fossil Bus Parameters

Parameter	Value	Source
Diesel usage	42 l/100km	Average monitored value TransMilenio operators
Maintenance cost diesel bus	0.13 USD/km	Sumatoria, 2021; excludes tyres
Cost of diesel	0.59 USD/l	https://www.globalpetrolprices.com/
CAPEX diesel bus	190,000 USD	Sumatorio, 2021; Euro V bus
Lifespan fossil bus	10 years	Concession contracts diesel

Table 9: BEBs Common Parameters

Parameter	Value	Source
Specific electricity usage	1.1 kWh/km	Chinese average; (ADB, 2018); includes AC usage
Maintenance cost	0.09 USD/km	(ADB, 2018) based on 70% of diesel bus cost
Lifespan bus	15 years	Concession for BEBs
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
Lifetime grid connection	20 years	standard value used by power companies
Maintenance chargers, grid connection, depot	2%	Percentage of CAPEX
Loan rate BEBs	7.4%	Bancoldex, 2015; special credit line; see also Findeter DTF+1%+2% spread (DTF 4.4%)
Loan tenure BEBs	12 years	80% of concession period idem to diesel buses

Table 10: BEB Overnight Charged Bus

Parameter	Value	Source
CAPEX bus	274,000 USD	Based on bus with 350 kWh battery set (base price) with additional cost for larger battery set
CAPEX batteries	200 USD/kWh	LFP batteries
Battery capacity	370 kWh	Calculated based on workday range with sufficient
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	240,000 USD	Based on standard fast-charged bus
CAPEX batteries	250 USD/kWh	NMC batteries
Battery size	250 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 in case of default. 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	190,000	274,000	240,000
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	**190,000**	**320,000**	**289,613**
Battery replacement yr 8	0	37,000	25,000
Energy cost yr 1	14,620	7,983	7,983
Maintenance cost bus yr 1	7,670	5,369	5,369
Maintenance cost infra yr 1	0	920	992
Finance cost average per year	4,118	9,348	8,188
Economic costs yr 1	4,937	992	992
TCO financial per km	**0.76**	**0.78**	**0.72**
TCO economic per km	**0.86**	**0.80**	**0.74**

Source: Grutter Consulting

Following conclusions are drawn:

- Comparing total costs over the bus lifetime of 15 years (valid for BEBs), 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 CNG bus (per unit)	BEB overnight		BEB fast-charged	
	Absolute	%	Absolute	%
Additional capital investment	130,000	68%	99,613	52%
Additional loan demand	67,200	44%	40,000	26%
Additional equity requirement	62,800	165%	59,613	157%

Source: Grutter Consulting

BEBs require a 1.5x higher capital investment than diesel buses[5]. The most important impact is however on the required equity: this increases by the factor 2 to 2.5. 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 5% and of fast-charged BEBs of 10%.
- The EIRR is 10% respectively 16%.

The investment in BEBs is thus marginally profitable i.e. at least in the case of fast-charged BEBs above the WACC level.

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 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 15 years. This is also due to required re-investments in year 8 in batteries and in year 10 in chargers.

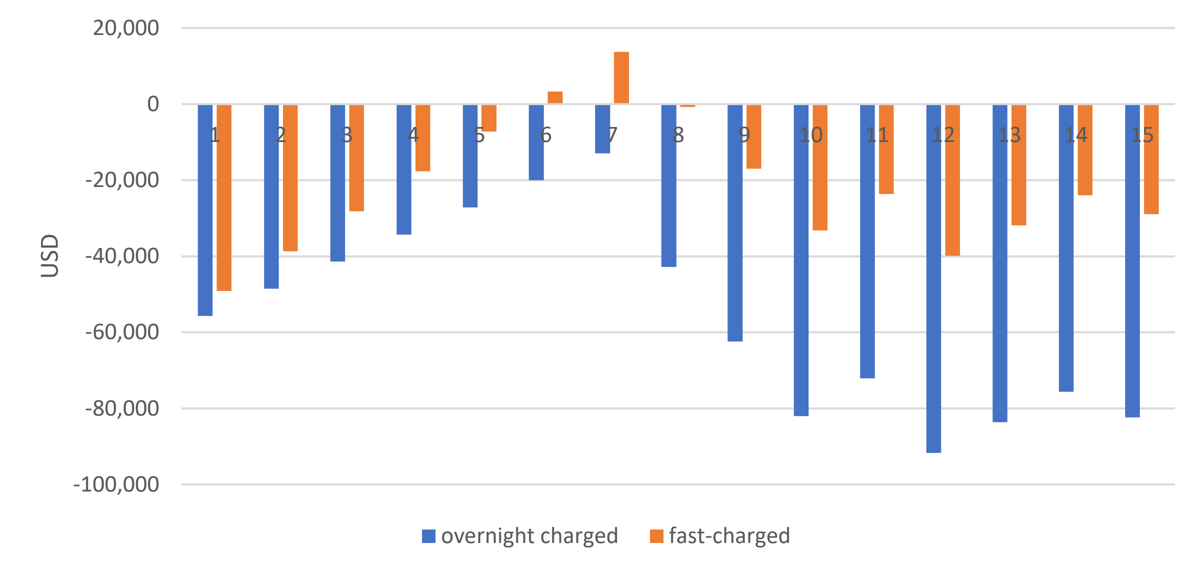
4.2.6. Cash Flow

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

[5] 2x higher capital investment is identical to incremental 100%

as revenues (cash inflows) are identical between a BEB and a diesel bus. The cumulative CF remains negative for the entire asset lifetime.

Figure 7: Cumulative Differential Cash Flow Diesel and BEB



Source: Grutter Consulting

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	1.5x of a conventional bus	Significantly higher capital requirement incl. higher loan demand; negative impact on debt to equity ratio
Equity investment	2.5x of a conventional bus	Significantly higher equity demand which might overstretch the capabilities of enterprises
Profitability	7%	Investment in e-buses is equal to WACC
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 and at least for the loan period the working capital ratio.

Summarized the investment in BEBs with the current financial conditions and business models is not profitable, 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 Colombia.

4.2.8. Variation of Parameters / Incentive Schemes

The impact on financial parameters of concessional loans and 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	12 years	12 years
Interest rate	7.4%	3.2%
Lending rate	80% of bus investment	80% of total investment incl. bus, chargers, grid connection and bus depot upgrade

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% 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	0.80	0.74
TCO financial new	0.71	0.66
FIRR old	4.6%	9.9%
FIRR new	4.6%	9.9%
Additional equity old	165%	157%
Additional equity new	68%	52%
Discounted Payback in years old	never	never
Discounted Payback in years new	never	never

Source: Grutter Consulting

No significant impacts are observed beyond improving cash flow and reducing risks. The concessional loan helps to resolve liquidity issues and results in an improvement of the investment profitability but investment risks remain high with an unsatisfactory payback time. It is clear that concessional loan conditions are an important feature but are not sufficient to tilt an investors decision with the current risk profile of BEBs in the country.

Investment Grant

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

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

Parameter	overnight charged BEB	fast charged BEB
TCO financial old	0.80	0.74
TCO financial new	0.63	0.59
FIRR old	4.6%	9.9%
FIRR new	16.8%	29.1%
Additional equity old	165%	157%
Additional equity new	no equity	no equity
Discounted Payback in years old	never	never
Discounted Payback in years new	11	6

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces considerably with values now clearly lower than for diesel buses.
2. The FIRR increases significantly and is now significantly above the WACC for all types of BEBs indicating a profitable investment.
3. Owners capital requirements are reduced significantly.
4. The risk and the capital exposure of the entrepreneur is reduced greatly. The incremental investment is recovered within 6-11 years which is considered to be a reasonable time-frame.

It can be concluded that the grant combined with the concessional loan resolves fully the profitability and risk issue.

4.3. Financial Analysis E-Taxis

4.3.1. General Data

Calculations are realized for the standard gasoline taxi as used in Colombia. 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 72,500 km[6].

Table 18: Baseline Gasoline Taxi Parameters

Parameter	Value	Source
Gasoline usage	7.7 l/100km	PNUD[7]
Maintenance cost	0.039 USD/km	Alcaldía Mayor de Bogotá, 2016 excludes tyres
CAPEX	14,000 USD	Kia Motors Colombia, 2021; Auto Koreana, 2021; Chevrolet, 2021
Lifespan	7 years	Sanchez, 2021
Loan conditions	80% 8.8% 6 years	Scotiabank

Table 19: E-Taxi Parameters

Parameter	Value	Source
Specific electricity usage	0.16 kWh/km	Nissan LEAF or BAIC taxi
Maintenance cost	0.02 USD/km	40% below fossil excl. tyres
Lifespan	7 years	Idem fossil
Lifespan battery @ 70% SOH	7 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	30,000 USD	Nissan LEAF large battery or BAIC
CAPEX home charger 7.4kW	2,000 USD	Includes wall-box installation
Lifetime charger	10 years	standard value based on ABB
Loan conditions	80% 7.5% 6 years	BBVA Colombia

[6] Based on Sanchez, 2021 with 220km daily mileage and 330 operating days
[7] https://www.minambiente.gov.co/images/cambioclimatico/pdf/estudios_de_costos_de_abatimiento/capitulos_sectoriales_/Transporte_Anx.pdf

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	14,000	30,000
CAPEX charging infrastructure	0	2,000
Total CAPEX	**14,000**	**32,000**
Energy cost	3,239	2,248
Maintenance cost	2,831	1,133
Finance cost average p.a. during loan term	543	980
Economic costs of emissions year 1	640	60
Lifespan in years	7	7
TCO financial per km	**0.12**	**0.12**
TCO economic per km	**0.13**	**0.12**

Source: Grutter Consulting

Comparing total costs over the taxi lifetime of 7 years 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	18,000	129%
Additional loan requirement	12,800	114%
Additional equity requirement	5,200	186%

Source: Grutter Consulting

E-taxis require a capital investment factor 2 of a gasoline unit. The required equity increases by the factor 3. 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 2% and below the WACC of 7%.
- The EIRR is 9%.

The investment in e-taxis is thus not profitable.

4.3.5. Discounted Payback

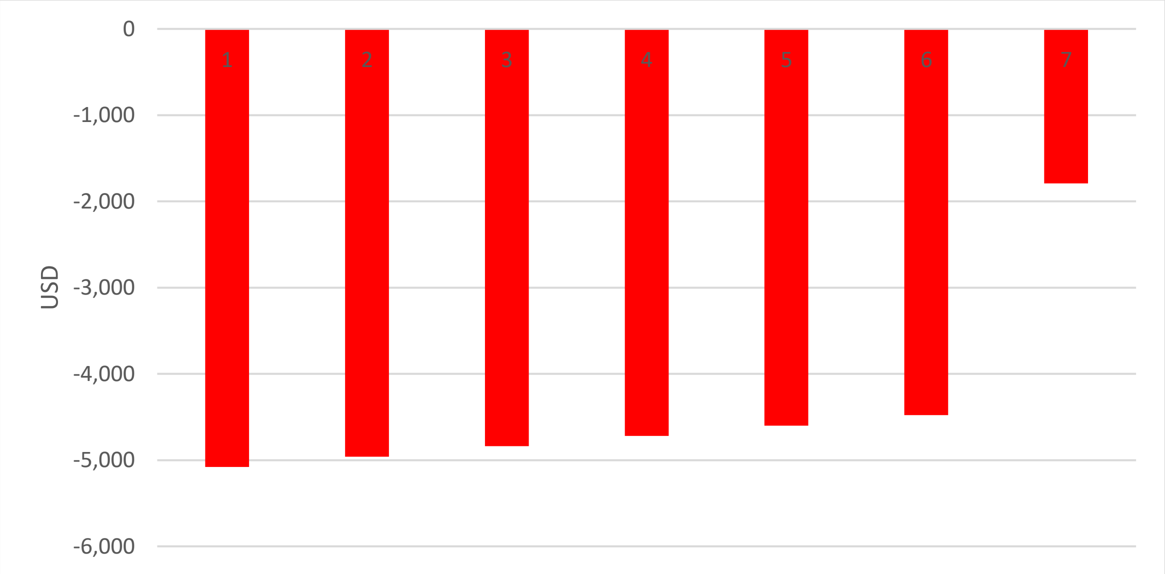
The discounted payback looks at the number of years required to recover the initial incremental investment from savings of e-taxis relative to gasoline units. Annual incremental savings of using an e-taxi versus a fossil taxi are discounted. The discounted payback gives a good indication of the risk 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 only turns positive in year 7.

Figure 8: Cumulative Differential Cash Flow Electric and Fossil 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	Comparable for e-taxis to gasoline units	Non-discounted the cumulated lifetime costs for e-taxis are comparable to gasoline units.
Capital investment	2x of a conventional taxi	Significantly higher capital requirement incl. higher loan demand
Equity investment	3x of a conventional taxi	Significantly higher equity demand which might overstretch the capabilities of taxi owners
Profitability	2%	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	Positive in year 7 (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 not profitable and commercially not viable. A 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	6 years	6 years
Interest rate	7.5%	5.2%
Lending rate	80% of CAPEX	80% of CAPEXincl. 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% 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	0.12
TCO financial new	0.12
FIRR old	2%
FIRR new	2%
Additional equity old	186%
Additional equity new	129%
Discounted Payback in years old	never
Discounted Payback in years new	never

Source: Grutter Consulting

The concessional loan improves the liquidity but is not sufficient to make the investment financially attractive.

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	0.12
TCO financial new	0.11
FIRR old	2%
FIRR new	20.2%
Additional equity old	186%
Additional equity new	0%
Discounted Payback in years old	never
Discounted Payback in years new	6

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces marginally.
2. The FIRR increases and investments are now profitable.
3. Owners capital requirements are 0.
4. The risk and the capital exposure of the entrepreneur is reduced significantly with a dynamic payback time discounted with the new WACC adjusted to the new loan conditions of 6 years.

It can be concluded that the grant is interesting and has a positive impact. However, it does not resolve the issue of potentially reduced revenues due to lack of a fast-charging infrastructure. Grants and concessional finance are however important for the establishment of fast-charging taxi infrastructure.

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 Colombia. The annual assumed mileage is 33,000 km[8].

Photo: LCV Assessed for Colombia

Source: [JAC lanza vehículos para la última milla - Alianza Flotillera]

[8] Fajardo, 2021 based on 100km/day

Table 26: Baseline Diesel LCV Parameters

Parameter	Value	Source
Diesel consumption	11 l/100km	Review reports of JAC 250
Maintenance	0.03 USD/km	Review reports
CAPEX	23,300 USD	JAC X250, 3.7 ton; https://jacmotors.com.co/camiones/jkr-largo-power/
Lifespan	20 years	Redacción digital CM&, 2017
Interest rate	8.8%	Same assumed as for taxis; loan tenure 6 years; 80% of CAPEX

Table 27: E-LCV Parameters

Parameter	Value	Source
Specific electricity usage	0.36 kWh/km	https://www.autecomobility.com/camion-electrico-stark-e-cargo/p
Maintenance	0.02 USD/km	50% of fossil version
Lifespan	20 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	56,800 USD	https://www.autecomobility.com/camion-electrico-stark-e-cargo/p
CAPEX home charger 7.4kW	2,000 USD	Wall-box installation
Lifetime charger	10 years	ABB
Battery size	81 kWh	https://www.autecomobility.com/camion-electrico-stark-e-cargo/p
Drive range electric (maximum)	180 km	https://www.autecomobility.com/camion-electrico-stark-e-cargo/p

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	23,300	56,800
CAPEX charging infrastructure	0	2,000
Replacement battery cost in year 7	0	16,200
Total CAPEX	**23,300**	**58,800**
Energy cost	2,142	2,073
Maintenance cost	990	495
Finance cost average p.a. during loan term	903	1,855
Economic costs of emissions year 1	1,000	62
Lifespan in years	20	20
TCO financial per km	**0.14**	**0.22**
TCO economic per km	**0.18**	**0.22**

Source: Grutter Consulting

Comparing total costs over the LCV lifetime of 20 years e-LCVs have significantly 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	35,500	152%
Additional loan	26,800	144%
Additional equity	8,700	187%

Source: Grutter Consulting

E-LCVs require 2.5x 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 -16%
- 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.

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	Clearly higher TCOs of e-LCVs	
Capital investment	2.5 higher than a conventional LCV	Higher capital requirement incl. higher loan demand
Equity investment	3x 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	6 years	6 years
Interest rate	7.5%	5.2%
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 plus 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% 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	0.22
TCO financial new	0.22
FIRR old	-16%
FIRR new	-16%
Additional equity old	187%
Additional equity new	152%
Discounted Payback in years old	never
Discounted Payback in years new	never

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	0.22
TCO financial new	0.20
FIRR old	-16%
FIRR new	-15%
Additional equity old	187%
Additional equity new	none
Discounted Payback in years old	never
Discounted Payback in years new	12

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO is now marginally lower but still above the value of diesel units;
2. The FIRR is still negative;
3. The risk and the capital exposure of the entrepreneur is reduced with a dynamic payback time (discounted with the new WACC) at 12 years which is however still long.

It can be concluded that the grant does not resolve the major commercial investment problems. E-LCVs might be competitive more in smaller versions comparing them to gasoline units. Diesel units are however very energy efficient and diesel fuel prices are very low in Colombia. Also, as of today only few commercial brands offer e-LCVs in Colombia thus resulting in high prices and models with limited efficiency. The EV program will thus have to work still more on TA to change these barriers as well as focus on electric LCVs which are potentially more profitable.

5. Possible Business Models Investment Projects

5.1. Urban Buses

5.1.1. Barriers and Interventions Options

The following table summarizes main barriers towards massive e-bus deployment in Colombia. 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 Colombia

Barrier Type	Concrete Aspects
Atomized market structure of bus operators	Although the Government of Colombia is working on the implementation of Integrated Mass Transit Systems (SITM) and Strategic Public Transportation Systems (SETP), there are still many small operators in the country, especially outside the largest cities.
Financially weak operators	Operators have a fragile balance sheet. Commercial banks have expressed their disinterest in financing vehicle fleets due to the instability of the transportation systems and their difficulties. In most cities there is no injection of additional resources to compensate for the differences between technical and social tariffs.
Financial barriers	BEBs are not profitable. The FIRR is equal to the WACC but the repayment period for the incremental investment in electric buses is more than 15 years. The investor needs to invest up to 1.5x the owners capital required for fossil buses, increases significantly his debt levels and suffers from a negative cash flow at least for the loan period.
COVID-19 effect	Transport systems in Colombia have difficult financial conditions due to the differential between the technical fare and the social fare, although in some cities municipal governments contribute resources to cover it. Demand for the

	systems has been reduced due to the COVID-19 effect, which has further weakened the systems. As a result, e-bus deployment will face more difficult financial conditions in which the cost differential in technologies, additional investments and training needs will take on greater weight.
Institutional capacity	The restructuring of transport systems has strengthened the capacities of operators and the sector in general, however, this process has advanced in large cities while medium and small cities still have difficulties in planning, structuring and evaluation of transport projects as well as in the knowledge of technology, business models, generation of contracts, distribution of responsibilities, among others.

Source: Grutter Consulting

E-buses have major environmental and societal advantages expressed in large positive environmental and health impacts. Whilst the TCO of e-buses is slightly lower than of diesel units, the capital exposure, risks and lack of profitability make it an non-attractive investment. This combined with market conditions (atomized bus ownership) and a political/contractual framework which hampers e-bus deployment result in e-buses not being deployed in cities other than Bogota, Medellin and Cali.

The **atomized market structure** results in very small amounts of buses being purchased. This results in high purchase and maintenance/repair costs and potentially sub-optimal technology solutions. Also, operators lack the know-how on e-bus technologies and are thus dependent on claims of suppliers. Bulk purchase would resolve these problems. This can be based on different organizational models:

- Group purchase based on (ad-hoc) associations;
- Bulk purchase of buses through leading enterprises which thereafter sell buses to smaller companies. However, it has disadvantages as smaller companies might feel that they are being pushed out of the market by depending on larger operators and financing of such fleets is complex as assets are given along to 3rd parties and operators might not have sufficient solvency for such operations;
- Purchase of buses through a 3rd party and delivery for operations either credit- or leasing-based by operators.

Technical assistance can be useful to further develop appropriate bulk-purchase business models and link them with concessional financial instruments.

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 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 including Medellin. This operation scheme can be replicated in intermediate cities and accelerate the transition to electromobility. Technical assistance can help structure these new systems in intermediate cities that do not have the institutional capacities of large cities. To rely on financial assistance alone would be inefficient as this would require far more support resources and would maintain a non-efficient public transport system.

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.

5.1.2. Asset Separation Model

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.

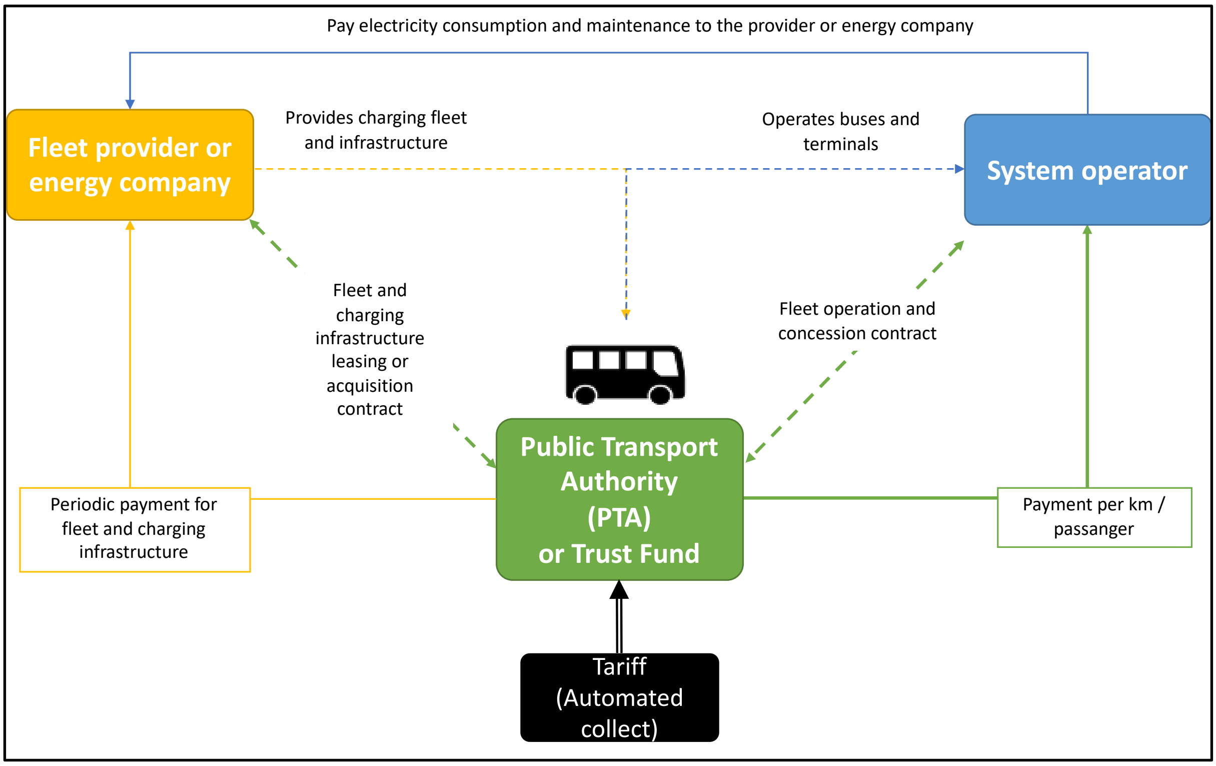
1. **Fleet provider (for example energy company):** is responsible for acquiring the vehicle fleet, the charging infrastructure and its installation. The fleet provider may enter into a lease contract with the transport authority and, if necessary, an asset care and maintenance contract with the operator. 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 9: Business Models Based on Asset Separation



Source: Grutter Consulting

5.1.3. Potential Investment Projects

The following table lists potential bus investment projects for Colombia.

Table 35: Potential Investment Projects e-Buses Colombia

ID	Ownership	Project	Nu. of units 2023 to 2027	Estimated CAPEX	Estimated GHG impact[9]	Timeline
1	Public	Technological upgrading of the fleet in 14 cities of Colombia[10]	89 18m buses, 199 12m buses, 493 10m buses and 306 7m units	290 MUSD	1,300,000 tCO_{2e} reduced	60% in 2022/2023 and 40% 2024 to 2026
2	Public	TransMilenio trunk route electrification	432 26m buses, 253 18m units and 350 12m units	710 MUSD	1,600,000 tCO_{2e} reduced	2025-2026

Source: Grutter Consulting: Details see Excel sheet

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 Colombia:

[9] Cumulative lifespan of units
[10] Armenia, Barranquilla, Bucaramanga, Cali, Cartagena, Medellin, Monteria, Neiva, Pasto, Pereira, Popayan, Santa Marta, Sincelejo, Valledupar

- Grant facility covering up to 20% of the initial total CAPEX (bus, charging infrastructure, grid connection and bus depot upgrade);
- 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%.

5.1.3. 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. Multiple models are available which need to be assessed to resolve the problem of an atomized bus ownership structure with weak credit subjects.
- Assessment of optimal e-bus technology and charging systems to enable a robust and cost-effective e-bus deployment.
- Roadmap for e-bus deployment for medium sized cities.
- Capacity building for planning, operation and maintenance in local authorities and operators.

5.2. Taxis and LCVs

5.2.1. Barriers and Intervention Options

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

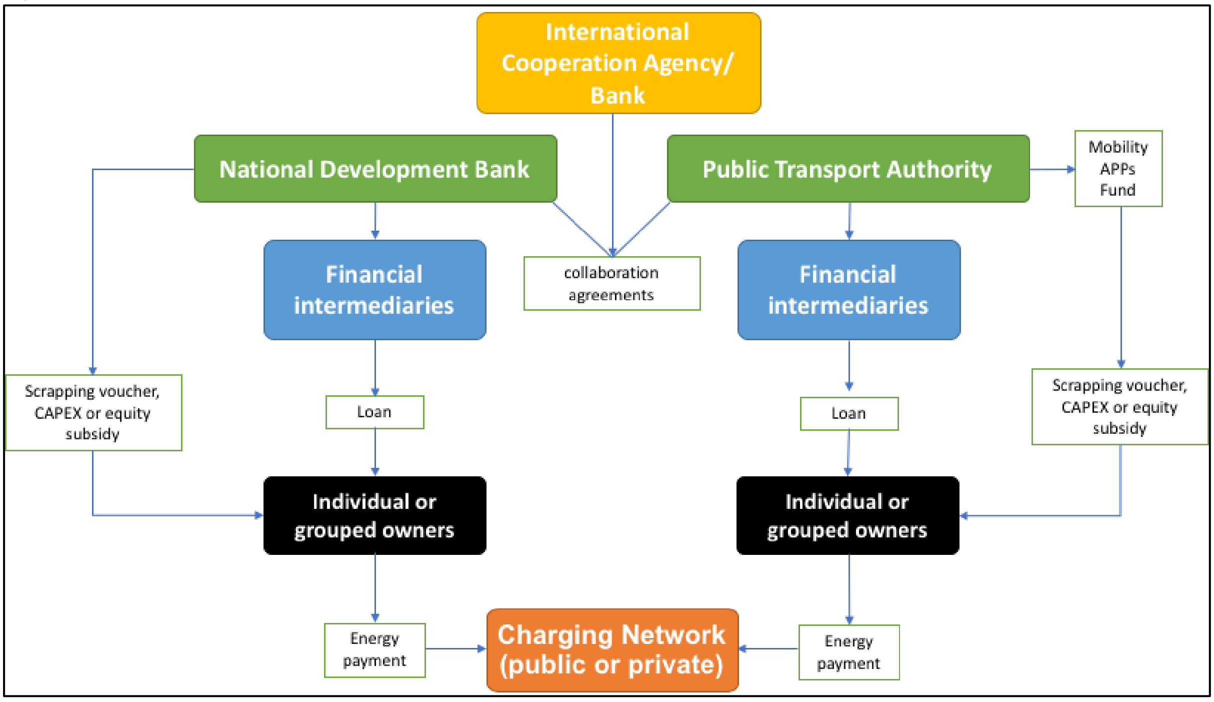
- E-taxis require a capital investment factor 2.5 of a gasoline unit. The investor could opt for purchasing 2 gasoline units instead of 1 electric one thus increasing considerably his revenue and profit base.
- Investments in e-LCVs are financially risky and not profitable.
- Lack of an urban fast-charging network in case of necessity. The same fast-charging network could be potentially used by taxis, cars as well as LCVs.
- For LCVs 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 for electric LCVs as vehicles are owned by individual drivers and not by the logistics companies or by the cargo company.

5.2.2. Possible Business Model

The traditional model for the acquisition of Taxis and LCVs has been characterized as being entirely the responsibility of the individual owner or the entrepreneur grouping more than one vehicle. In this case, the traditional financial sector, or even vehicle sales agencies, are the ones who directly finance the owners. However, for the massification of electromobility in this market segment, additional incentives are needed to reduce the difference in the cost of gasoline or gas vehicles compared to electric vehicles.

The proposed model consists of the generation of Taxis or LCVs renewal programs with support to the owner to reduce the difference in CAPEX and stimulate the acquisition of electric vehicles. Here it is important the role that local development banks and transport authorities can play, as institutions that lead the structuring of this type of vehicle renewal programs, coordinating financing from banks or international cooperation agencies, and focusing the programs, in coordination with national and international development banks, to individual users or informal micro-entrepreneurs, who are usually considered by financial institutions as not creditworthy.

Figure 10: Possible Business Model for e-Taxis and LCVs



Source: Grutter Consulting

These would be the main roles played by each of the actors involved:

1. **International Cooperation Agency or Bank:** contributes with funding mechanisms or lines of credit to national development banks with favorable credit conditions compared to commercial banks. They can also collaborate in the design of vehicle fleet renewal programs (Taxis, LCVs, and even public transport) and in the identification of transport authorities that may be interested.

2. **National Development Bank:** creates lines of credit and establishes cooperation agreements with local transportation authorities to carry out the renovation programs. It is also in charge of selecting and contracting the intermediary financial entities that will operate the program and establish direct links with the atomized owners. Depending on the availability of resources, development banks may also offer direct incentives to vehicle owners through vouchers for scrapping or through subsidies for the payment of equity or CAPEX.

3. **Public Transport Authority:** creates lines of credit and establishes cooperation agreements with local transportation authorities to carry out the renovation programs and make the rules and credit conditions clear to individual operators. It is also in charge of selecting and contracting the intermediary financial entities that will operate the program, and of setting specific criteria on the users that can be part of the project.

4. **Financial intermediaries:** receive resources from both the development banks and the transportation authority, and place loans directly to the atomized owners. These intermediaries are directly responsible for the collection of loans.

This business model necessarily requires the creation of a public or taxi-preferential fast charging infrastructure network, so that individual owners have sufficient incentive to ensure continuous operation throughout the day without resorting to long empty trips to look for charging stations. This is mentioned because failed projects have already been identified in Latin America (Chile, Mexico), where the charging network was minimal and generated many inconveniences for Taxi drivers.

LCVs are very diverse with most operated by private entities but also many public or semi-public units such as for the postal service, utilities or municipal services. The financing structure above would be basically for the private sector. Whilst large companies not necessarily need loans, smaller companies and individual vehicle owners do require that.

The practical experience with LCVs is still very limited. Initial pilot projects with different vehicle categories and types will be required to eliminate the information barrier and know-how on EV possibilities. The design of complementary programs can contribute to accelerate the entry of electric vehicles in urban areas. For example, the creation of 0-Emissions zones, e.g. within historical centers, can encourage the purchase of LCVs by the private sector.

5.2.3. Potential Investment Projects

The following table lists potential taxi/LCV investment projects for Colombia.

Table 36: Potential Investment Projects e-Taxis Colombia

ID	Ownership	Project	Nu. of units 2023 to 2027	Estimated CAPEX	Estimated GHG impact[11]	Timeline
1	public	Secretary of mobility; Taxi replacement program Medellin	150 taxis	6 MUSD of which 5 MUSD vehicles + home chargers and 1 MUSD fast charging infrastructure	14,000 tCO_{2e} reduced	2022-2024
2	public	Secretary of mobility; Taxi replacement program Bogota (total 48,000 units)	17,000 taxis in initial 5 years	570 MUSD of which 540 MUSD vehicles + home chargers and 30 MUSD fast charging infrastructure	1,600,000 tCO_{2e} reduced	2022-2027

[11] Cumulative lifespan of units

In report 3 a taxi program will be structured around the pipeline project with concessional loans for taxis (no grants) and grants/concessional loan for the charging infrastructure.

Table 37: Potential Investment Project e-LCVs Colombia

ID	Ownership	Project	Nu. of units 2023 to 2027	Estimated CAPEX	Estimated GHG impact[12]	Timeline
2	public	Secretary of mobility; LCV replacement program Bogota (total 1,200 units)	650 e-LCVs in initial 5 years	33 MUSD	150,000 tCO_{2e} reduced	2022-2026

The following financial intervention instruments are proposed for e-taxi and e-LCV deployment in Colombia:

- Grant facility covering up to 50% of the CAPEX of urban fast charging infrastructure designed for taxis and LCVs;
- Highly concessional loans for urban fast charging infrastructure with participation from the GCF blended with loans from AFD.
- For vehicles concessional loans from the GCF @ 0.75% which are blended with AFD and co-finance, a long tenure, and a high loan share (80% of total investment). Together with the entrance of financially stronger players this should be capable to cut interest rates by more than 50%.
- Financial incentives of local and national governments e.g. based on scrapping fees.

In report 3 the BAU price development of e-taxis and e-LCVs will be matched with the financial profitability of units and the actions of the program to improve market access and reduce entry barriers related e.g. to performance risks. This will allow to identify the market potential and the appropriate timing for interventions to not only have a one-time batch of EVs but a sustainable influx of this technology.

6. TA intervention Areas and Instruments

6.1. TA Actors in E-Mobility

German Cooperation Agency GIZ

GIZ conducted the study *Economic and Financial Evaluation of E-Buses in Colombia*, which aims to: (i) perform a financial exercise to estimate the impact (costs) of several bus technologies (diesel, electric, natural gas vehicles) in a real transportation operation; (ii) perform an economic analysis to help identify the project scheme that best contributes to the welfare of the country; and (iii) propose a financing mechanism that allows the mobilization of resources (public and/or private) in an efficient manner, in order to implement a fleet electrification program for public transportation (GIZ, 2019). In addition, the *Design of a Measurement System for the National Electric Bus Program*, which estimates GHG emission mitigation indicators and co-benefits in $PM_{2.5}$ emissions of the national electric bus program (GIZ & Hill, 2020) and support to establish governance structure for e-mobility with SITM. They are currently working on the design of an investment fund to promote the upgrade of public transportation systems to electric technologies.

[12] Cumulative lifespan of units

Inter-American Development Bank IDB

The Inter-American Development Bank has conducted regional studies to promote electromobility, such as the *Analysis of Technology, Industry, and Market for Electric Vehicles in Latin America and the Caribbean*; *How to get to zero net emissions: Lessons from Latin America and the Caribbean* and *Green Transportation: The outlook for electric vehicles in Latin America*. In addition, through the *Sustainable Urban Transport in Colombian Cities* project, IDB seeks to accelerate electric buses deployment in Colombian cities through: (i) the study for the structuring of a public transport operator for the operation of electric buses in Bogotá Phase V Stages 1, 2 and 3; (ii) development of technical guidelines for the purchase of low emission vehicles for up to 50 passengers in Colombian cities; (iii) support in the structuring, design and implementation of urban electromobility projects in 2 cities in Colombia; (iv) standards study to promote the safe deployment of electric vehicles in the country; (v) support for the strengthening of the National Electromobility Policy focused on urban public transportation; (vi) development of mechanisms to promote electromobility in Colombia and (vii) technical workshops to strengthen the Management Entities in charge of the implementation of electromobility projects in public transportation (IDB, 2020).

World Wildlife Fund WWF

WWF is working together with the Ministry of Transportation, the National Planning Department (DNP), the Mining and Energy Planning Unit (UPME), the Ministry of Environment and Sustainable Development (MADS) and the Territorial Development Finance (FINDETER) in the development of the *NAMA MovE - Electric Mobility and Low Emissions* (IDEAM, PNUD, MADS, DNP, CANCILLERÍA, 2018). This project will build a regulatory and financial enabling environment that will allow for the massification of electric vehicles. It will establish the regulatory and technical standards for commercialization and operation, implement a large-scale communications and capacity building strategy, define an electricity tariff scheme for transportation and establish quotas for the governmental fleet to showcase the benefits of electric vehicles, and thus stimulate market demand. plans to introduce two financial mechanisms: a cross subsidy scheme, based on energy efficiency and GHG emission rates, and a mix of dedicated financing tools to facilitate private financing through credit lines, with preferential interest rates (NAMA Facility, 2021).

Cities Finance Facility CFF

The C40 Cities Finance Facility and the International Council on Clean Transportation (ICCT) with funding from P4G have developed the Zero Emission Bus Rapid-Deployment Accelerator (ZEBRA). This initiative involves the participation of vehicle manufacturers, distributors and investors. BYD, Creatti EV/Zhongtong, Foton, Sunwin and Yutong committed to commercialize a zero-emission bus model in Medellín within 12 months and to guarantee the commercial availability of a model throughout the country within a maximum of 18 months. This initiative provides technical assistance in the generation of business models that facilitate electromobility (Posada, Delgado, Xie, & Maltese, 2020). ZEBRA has also developed the E-bus radar platform that monitors electric bus fleets in public transportation systems in Latin America, quantifying the avoided CO_2 emissions. In Colombia are monitored 260 e-buses in Bogota, 69 in Medellin and 26 in Cali (LABMOB; UFRJ, 2021).

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 (UNEP, 2021). This program collaborated in the development of the National Electric Mobility Strategy (Ministerio de Ambiente y Desarrollo Sostenible, 2020).

6.2. Possible TA Interventions within the E-Motion Program

The recent massive purchase of more than 1,000 e-buses by Transmilenio under an innovative business model, as well as the inclusion of e-buses in Cali and Medellín shows that Colombia has been taking important steps towards a massive deployment of e-buses. To share this experience among other intermediate cities in Colombia is an important component of a TA Project. Further activities include an ongoing training of stakeholders regarding technologies, operation and improvement of charging facilities.

La reciente compra masiva de más de 1.000 e-buses por parte de Transmilenio bajo un modelo de negocio innovador, así como la inclusión de e-buses en Cali y Medellín muestra que Colombia ha estado dando pasos importantes hacia un despliegue masivo de e-buses. Compartir esta experiencia entre otras ciudades intermedias de Colombia es un componente importante de un proyecto de AT.

- Support in the structuring and knowledge of the actors involved in the operation contracts that allow the inclusion of third parties.
- Support for the acceleration of the development and implementation of SETPs.
- Institutional training in the different sectors involved in electromobility for an adequate adoption of the technology.
- Colombia has not yet deployed electric buses on trunk routes. Different technological alternatives are available for such services and usage of overnight charged BEBs might be a sub-optimal solution. Technical assistance could be provided on optimal system design independent of interest of specific bus providers.
- Training on the appropriate operating conditions based on the durability of battery autonomy, recharging and maintenance services.
- Technical assistance for the appropriate deployment of electric vehicles in the cabs service, including the design of charging infrastructure, the generation of financial mechanisms and business models that facilitate access to e-vehicles.
- Technical assistance for the generation of guidelines for the correct deployment of recharging infrastructure, considering the particularities of the distribution network.
- Training in the financial sector for capacity building focused on financing mechanisms for electromobility in the framework of the international mechanisms that have been generated for environmental finance and green finance.
- Technical assistance for the generation of recharging infrastructure standards.
- Support in the structuring and implementation of pilot programmes focused on the second life of batteries used in electromobility[13].
- Business models for adequate stakeholder participation in the energy supply chain and the establishment of the electricity supply market for electromobility.

[13] Colombian Institute of Technical Standards and Certification (ICONTEC) is developing standards for the regulation of electric vehicles as well as the second life and disposal of batteries used in electromobility (Charry Ruiz & Pinilla Rodríguez, 2021).

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Annex: Details of Calculations

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

Electricity Prices

Parameter	**Value**	**Unit**
Electricity price home charging	0.165	USD/kWh
Electricity price fast chargers	0.26	USD/kWh
peak consumption price	0.123	USD/kWh
off'peak consumption price	0.123	USD/kWh
Power charge night per month		USD/kW
Power charge day off-peak per month		USD/kW
https://www.epm.com.co/site/home/sala-de-prensa/boletines-estamos-ahi/epm-lanzo-su-servicio-de-carga-para-vehiculos-electricos		
official price minus 10% for negotiation		
Calculation for buses		
Average electricity price overnight charged buses	0.12	USD/kWh
Average electricity price fast charged buses	0.12	USD/kWh

TCO 12m Bus

Parameter	Value	Unit	Source
Distance driven per bus per annum	59,000	km	Transmilenio
Workday distance driven daily	198	km	calculated
Specific electicity usage	1.1	kWh/km	Chinese average; ADB, 2018; includes AC; includes charger efficeincy loss
Diesel usage	42	l/100km	Monitoring TransMilenio 12m buses padron all operators average
Maintenance cost diesel bus incl. labor excl. Tyres	0.13	USD/km	sumatorio for GIZ
Lifespan bus diesel	10	years	concession contract
Lifespan bus electric	15	years	concession contract
Lifespan battery @ 80% SOC	8	years	current guarantee levels
Interest rate BEB	7.4%		Bancoldex, 2015.Special credit line; spread needs to be added; see also Findeter
Loan duration BEB	12	years	80% concession period

Financial defaults

Parameter	Value	Unit	Source
CAPEX diesel bus	190,000	USD	Euro V, sumatorio
CAPEX overnight charged e-bus	274,000	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	240,000	USD	Based on standard fast-charged bus with 200 kWh set
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	198
Energy usage day	kWh	217
Risk ratio (higher energy consumption)		10%
Reserve ratio		20%
SOC loss year 8		20%
Battery size required year 8	**kWh**	**370**
Charging required at bus depot overnight		
Parameter	**Unit**	**Value**
Battery capacity	kWh	370
Average daily consumption workday	kWh	217
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	57
Average share of day electricity		26%
Fast-charger	kW	300
Power conversion efficiency of chargers		90%
Average required re-charge day with 300 kW charger	minutes	13
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	190,000	274,000	240,000
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	190,000	320,000	289,613
Battery replacement yr 8	0	37,000	25,000
Energy cost yr 1	14,620	7,983	7,983
Maintenance cost bus yr 1	7,670	5,369	5,369
Maintenance cost infra yr 1	0	920	992
Finance cost average per year	4,118	9,348	8,188
Economic costs yr 1	4,937	992	992
TCO financial per km	0.76	0.78	0.72
TCO economic per km	0.86	0.80	0.74

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	60	kWh	Nissan Leaf 2020; idem BAIC
Battery lifespan	7	years	idem to vehicle lifespan
Vehicle lifespan	7	years	sanchez, 2021
Annual mileage	72,600	km	
Daily mileage	220	km	sanchez, 2021
Charging at home average	70%		Assumption; only re-charge if above-average mileage or night shifts
Charging fast-chargers	30%		
CAPEX gasoline taxis	14,000		Kia Motors Colombia, 2021; Auto Koreana, 2021; Chevrolet, 2021
CAPEX e-taxi	30,000		Nissan LEAF large battery or BAIC
Capex home charger 7.4kW	2,000	USD	Nissan LEAF large battery or BAIC
Gasoline consumption	7.7	l/100km	PNUD; https://www.minambiente.gov.co/images/cambioclimatico/pdf/estudios_de_costos_de_abatimiento/c
Electricity consumption	0.16	kWh/km	Nissan LEAF https://ev-database.org/car/1106/Nissan-Leaf
Charger lifespan	10	years	
Maintenance cost gasoline	0.039	USD/km	Alcaldía Mayor de Bogotá, 2016 excludes tyres
Maintenance cost total e-taxi	0.0156	USD/km	40% lower than gasoline
Loan tenure taxi	6	years	Bank conditions
Loan share taxi	80%		
Interest rate fossil	8.8%		Scotiabank Conozca las entidades bancarias que manejan las tasas de interés más bajas para crédito de vehículo (larepublica.co)
Interst rate e-taxi	7.5%		BBVA Colombia, 2021

gasoline versus e-taxi

Parameter	gasoline	e-taxi
CAPEX vehicle	14,000	30,000
CAPEX charger	0	2,000
Total CAPEX	14,000	32,000
Energy cost	3,239	2,248
Maintenance cost	2,831	1,133
Finance cost average per loan year	543	980
Economic costs yr 1	640	60
Lifespan in years	7	7
TCO financial per km	0.12	0.12
TCO economic per km	0.13	0.12

LCVs

1. Diesel Van

Parameter	Value	Unit	explanation
CAPEX van	23,300	USD	JAC X250, 3.7 ton; https://jacmotors.com.co/camiones/jkr-largo-power/
Diesel fuel consumption	11.0	l/100km	JAC 250 reports
Maintenance cost	0.03	USD/km	value mexico
Lifespan	20	years	Redacción digital CM&, 2017
Daily distance driven	100	km	Fajardo 2021
Annual distance	33,000	km	based on daily distance

2. E-Van

Parameter	Value	Unit	explanation
CAPEX e-van	56,800	USD	https://www.autecomobility.com/camion-electrico-stark-e-cargo/p
Range WLTP	180	km	https://www.autecomobility.com/camion-electrico-stark-e-cargo/p
Battery size	81	kWh	
Cost battery	16,200	USD	Based on 200 USD/kWh per battery
electricity consumption	0.36	kWh/km	WLTP
Maintenance cost	0.02	USD/m	50% of fossil (as only engine maintenance is included; no tyres, no repairs)
Lifespan van	20	years	assumed same as fossil
Lifespan battery	8	years	
Capex home charger 7.4kW	2,000	USD	
Lifespan charger	20	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	23,300	56,800
CAPEX charger	0	2,000
Replacement battery cost	0	16,200
Total CAPEX	23,300	58,800
Energy cost	2,142	2,073
Maintenance cost	990	495
Finance cost average per year	903	1,855
Economic costs yr 1	1,000	62
Lifespan in years	20	20
TCO financial per km	0.14	0.22
TCO economic per km	0.18	0.22