grütter consulting

Assessment of Commercial EV Demand in Mexico

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Abbreviations

AC	Air Conditioning
AFD	French Development Agency
AMIA	Mexican Automotive Industry Association
BAU	Business As Usual
BEB	Battery Electric Buses
BN	Banco Nacional
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CF	Cash Flow
CANAME	National Chamber for Electric Manufacturers
CONUEE	National Commission for the Efficient Use of Energy
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
EIRR	Economic Internal Rate of Return
EV	Electric Vehicle
FA	Financial Assistance
FIRR	the Financial Internal Rate of Return
GHG	Greenhouse Gases
GIZ	German International Cooperation
IEA	International Energy Agency
INEEL	National Institute of Electricity and Clean Energy
ITDP	Institute for Transportation and Development Policy
KfW	State Development Bank of the Federal Republic of Germany
LCV	Light Commercial Vehicle
SEDEMA	Secretariat for Environment
SEMARNAT	Secretariat of Environment and Natural Resources
SENER	Secretariat of Energy
TA	Technical Assistance
TCO	Total cost of ownership
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 Mexico from materializing the market potential.

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

Electric transport has been operating in Mexico since the 1950s using trolleybuses. Recently, cities like Mexico City, Guadalajara and Monterrey have introduced electric transportation through subway lines, light rail, cable cars and electric cabs. The country's public charging network began with the installation of the first fast charging station in 2011 in Mexico City. The number of EVs sold in Mexico is marginal (200-300 units per year) without a trend towards increasing numbers.

A special credit line for electric cars or LCVs is since 2021 available from HSBC with a slightly lower interest rate - 12% instead of 13.5% for electric compared to fossil cars.

3. Commercial EV Market Potential in Mexico

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	5,800	51,000
Market share (% of stock)	6%	26%
Sales share (% of new registrations)	22%	100%

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

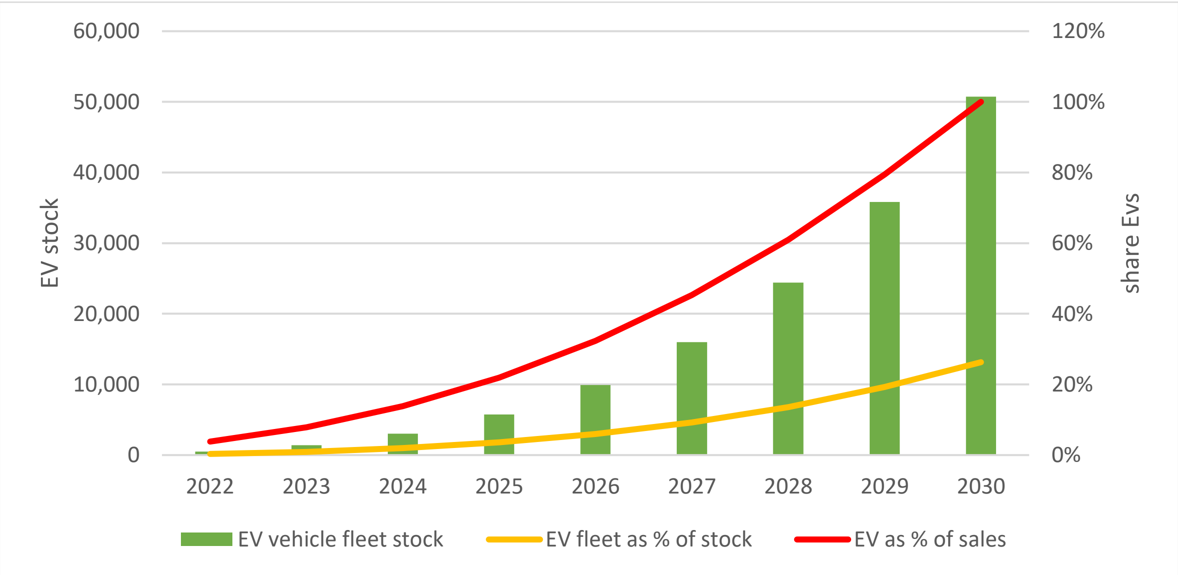
With a high growth scenario a market share of around 26% is targeted by 2030 equivalent to 51,000 electric buses operating in the country. The main parameters for the high growth market potential are outlined in the following table.

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

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock buses	143,838	149,219	154,801	160,591	166,599	172,831	179,296	186,004	192,962
New registered BEBs	425	910	1,657	2,721	4,163	6,047	8,441	11,420	14,907
Stock BEBs	475	1,385	3,042	5,764	9,927	15,974	24,415	35,834	50,741
Share BEBs of stock	0%	1%	2%	4%	6%	9%	14%	19%	26%

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

Figure 1: Urban Electric Bus High Growth Scenario

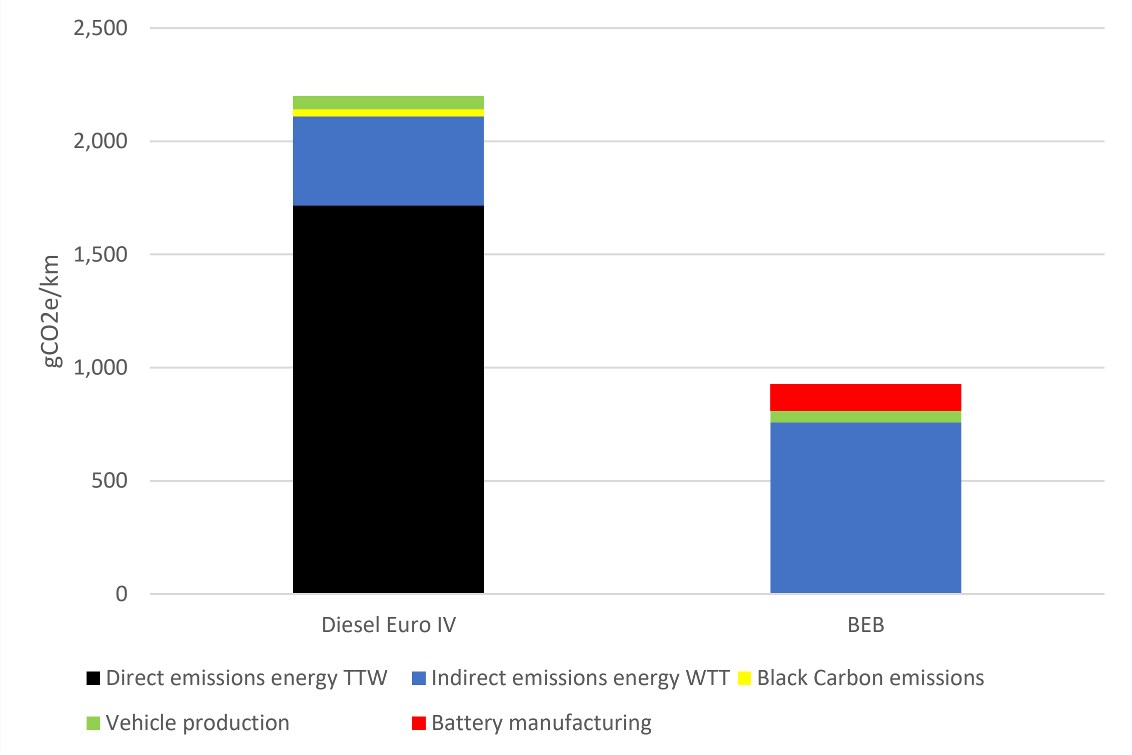


Source: Grutter Consulting

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

A BEB can reduce well-to-wheel (WTW) Greenhouse Gas (GHG) emissions in Mexico by 65% and cradle to grave emissions by 58% 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 Mexico

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	52,000	460,000
Market share (% of stock)	6%	43%
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.

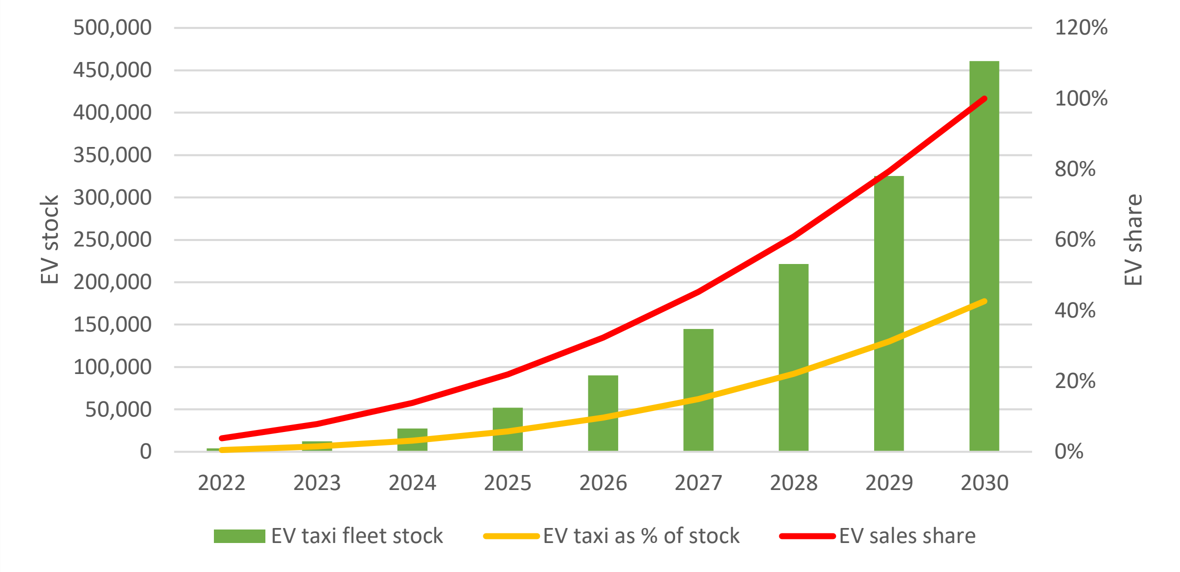
Table 4: High Growth Scenario Electric Taxis 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock taxis	805,984	836,134	867,413	899,861	933,523	968,445	1,004,673	1,042,256	1,081,245
Sales e-taxis	3,863	8,273	15,060	24,736	37,843	54,963	76,723	103,796	135,494
Stock e-taxis	4,063	12,336	27,396	52,132	89,975	144,937	221,660	325,457	460,951
Share e-taxis of stock	1%	1%	3%	6%	10%	15%	22%	31%	43%

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

As of 2030 460,000 e-taxis would be electric with this scenario.

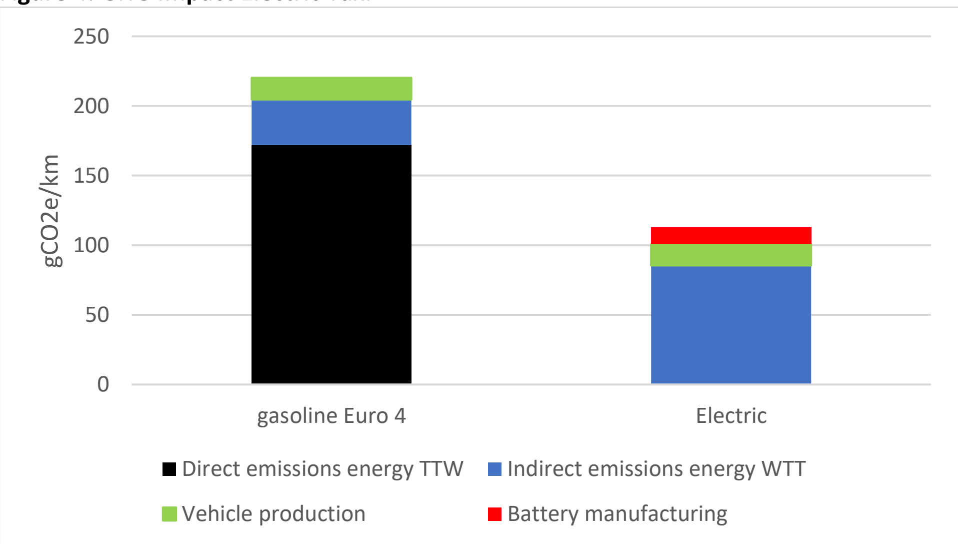
Figure 3: Electric Taxi High Growth Scenario



Source: Grutter Consulting

An electric taxi can reduce WTW emissions in Mexico by 58% and cradle to grave emissions by 51% (see figure below).

Figure 4: GHG Impact Electric Taxi



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

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	110,000	900,000
Market share (% of stock)	2%	18%
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.

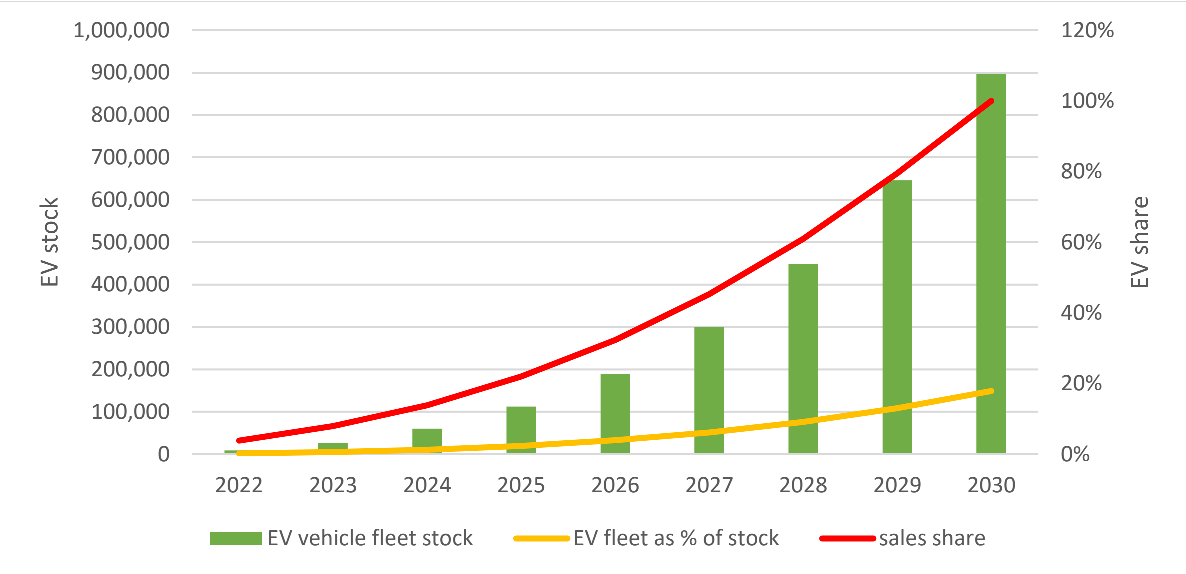
Table 6: High Growth Scenario Electric LCVs 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock LCVs	4,606,095	4,655,749	4,705,938	4,756,668	4,807,945	4,859,775	4,912,163	4,965,116	5,018,640
Sales e-LCVs	8,794	18,353	32,552	52,092	77,648	109,882	149,447	196,994	250,552
Stock e-LCVs	8,844	27,197	59,749	111,841	189,489	299,371	448,818	645,812	896,364
Share e-LCVs of stock	0%	1%	1%	2%	4%	6%	9%	13%	18%

Source: Grutter Consulting, report 1

As of 2030 nearly 900,000 e-LCVs would operate in Mexico with this scenario.

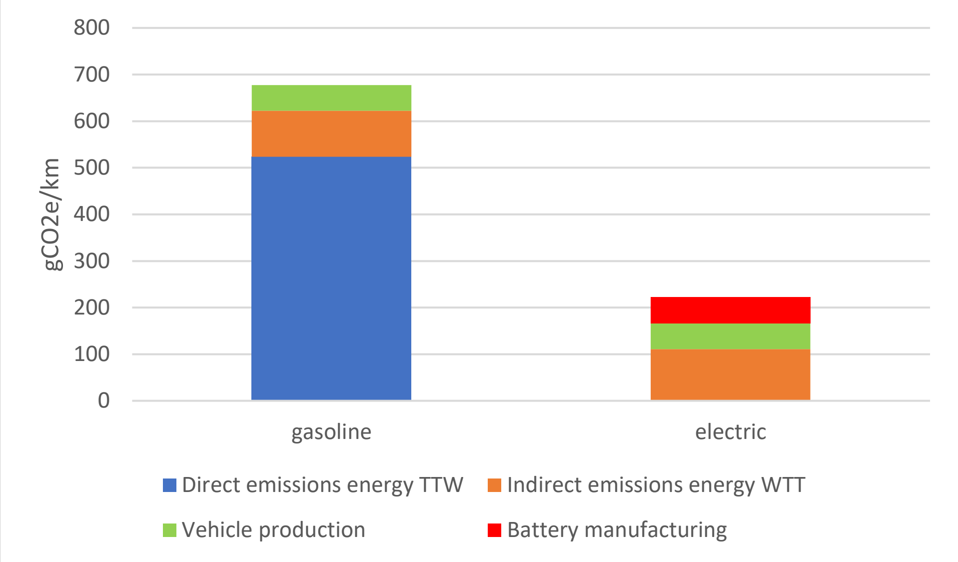
Figure 5: LCV High Growth Scenario



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 Mexico by 82% and cradle to grave emissions by 67% (see figure below).

Figure 6: GHG Impact Electric LCV



Source: Grutter Consulting; mileage and energy consumption based on values for Mexico based on JAC X250/EX350 gasoline/electric version; major assumptions include 22,500km annual mileage; 23 l/100km and 0.21 kWh/km e-LCV; 17 year lifespan; 8-year lifespan of battery; battery set of 92kWh; 110kg CO_2/kWh battery (ICCT, 2018); grid factor 0.529 kgCO_2/kWh

4. Financial Assessment of Commercial EVs in Mexico

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 Mexico;
- 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. Costs are based on national values and include applicable taxes including preferential tax regimes for EVs.

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 Mexico for the transport sector.

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

Parameter	Value	Source
Cost of equity	10.3%	(UNFCCC, 2019); value for transport sector of Mexico
Share of equity financing	20%	Banks are willing to finance 80% with loans
Cost of debt	12.5%	Current average rate of FIs[2]
Share of debt financing	80%	Banks are willing to finance 80% with loans
Corporate tax rate	30%	Deloitte, 2020
WACC	9.1%	Calculated

[2] Based on http://documents1.worldbank.org/curated/en/410331548180859451/pdf/133929-WP-PUBLIC-P164403-Summary-Report-Green-Your-Bus-Ride.pdf; https://www.nafin.com/portalnf/content/financiamiento/empresa-transportista.html; https://www.financiatrucks.com.mx/; https://www.hsbc.com.mx/creditos/auto/verde/;

4.2. Financial Analysis E-Buses

4.2.1. General Data

Calculations are realized for the standard bus as used in Mexico 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 430 kWh[3];
- A BEB with batteries capable of fast-charging and a battery set of 250 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 78,000 km[4].

Table 8: Baseline Fossil Bus Parameters

Parameter	Value	Source
Diesel usage	54 l/100km	World Bank, 2019[5]
Maintenance cost diesel bus	0.28 USD/km	Values from Metrobus
Cost of diesel	0.95 USD/l	https://www.globalpetrolprices.com/
CAPEX diesel bus	153,000 USD	Diesel Euro V bus based on 90% of value estimated by World Bank, 2019[6]
Lifespan fossil bus	9 years	SEDEMA for concessioned buses

Table 9: BEBs Common Parameters

Parameter	Value	Source
Specific electricity usage	1.1 kWh/km	Chinese average; (ADB, 2018); includes AC usage
Maintenance cost	0.20 USD/km	(ADB, 2018) based on 70% of diesel bus cost
Lifespan bus	9 years	Due to concession same as for diesel bus
Lifespan battery @ 70% SOH	9 years	current guarantee levels of BEBs is 8 years but batteries could be used for 9 years with a SOH of 70% (guarantee 8 years is 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

[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] Source: Based on SEMARNAT, 2016 as cited in https://theicct.org/sites/default/files/presentacioi%cc%80n%20roadmap%20taller%20ICCT%20copiar%202%20(2).pdf

[5] http://documents1.worldbank.org/curated/en/410331548180859451/pdf/133929-WP-PUBLIC-P164403-Summary-Report-Green-Your-Bus-Ride.pdf

[6] 90% as Euro V diesel bus prices have decreased since the database 2018 of the World Bank

		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

Table 10: BEB Overnight Charged Bus

Parameter	Value	Source
CAPEX bus	286,000 USD	Based on bus with 350 kWh battery set and sur-cost for battery size of 430 kWh as required in Mexico
CAPEX batteries	200 USD/kWh	LFP batteries
Battery capacity	430 kWh	Calculated based on workday range with sufficient battery size to cater for risks (20% reserve rate, 10% risk ratio due to higher than expected energy consumption related to driving conditions, climate, driver) and 20% SOH loss in year 8)
Charger power	60 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	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	153,000	286,000	250,000
CAPEX charging infrastructure	0	9,700	12,113
CAPEX grid connection	0	30,000	30,000
CAPEX depot upgrade	0	7,500	7,500
Total CAPEX	**153,000**	**333,200**	**299,613**
Battery replacement yr 8	0	43,000	31,250
Energy cost yr 1	31,629	18,524	14,924
Maintenance cost bus yr 1	21,845	15,292	15,292
Maintenance cost infra yr 1	0	944	992
Finance cost average per year	8,699	16,260	14,213
Economic costs yr 1	6,432	1,312	1,312
TCO financial per km	**0.98**	**1.05**	**0.94**
TCO economic per km	**1.07**	**1.07**	**0.96**

Source: Grutter Consulting

Following conclusions are drawn:

- Comparing total costs over the bus lifetime of 9 years BEBs have a comparable TCO to diesel;
- The TCO of fast-charged BEBs is far 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	180,000	118%	147,000	96%
Additional loan demand	106,000	87%	78,000	63%
Additional equity requirement	74,000	241%	69,000	226%

Source: Grutter Consulting

BEBs require a 2x higher capital investment than diesel buses[7]. Loans are currently only available for the bus component and limited to 80% of the capital. This means loans will increase by around factor 1.5. If other than bus collateral is demanded this can cause a problem to the company. Also company debt levels might go beyond tolerable levels. 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. With the same amount of equity the bus owner could opt to purchase 20-25 diesel buses instead of 10 e-buses thus increasing his absolute profits by increasing service levels (one BEB will deliver the same level of revenues as one fossil bus).

[7] 2x higher capital investment is identical to incremental 100%

4.2.4. Relative Profitability

The relative profitability assesses the FIRR of the incremental investment for BEBs (relative to a Diesel bus) based on the operational savings of BEBs versus diesel units:

- The FIRR of overnight charged BEBs is -1% and of fast-charged BEBs of 9%.
- The EIRR is 6% respectively 17%.

The investment in BEBs is thus not profitable enough to reach the WACC level and not commensurate with the risks associated with investing in a new technology with many unknown performance factors and costs (e.g. concerning maintenance cost savings which represent the second largest cost-saving block in OPEX).

4.2.5. Discounted Payback

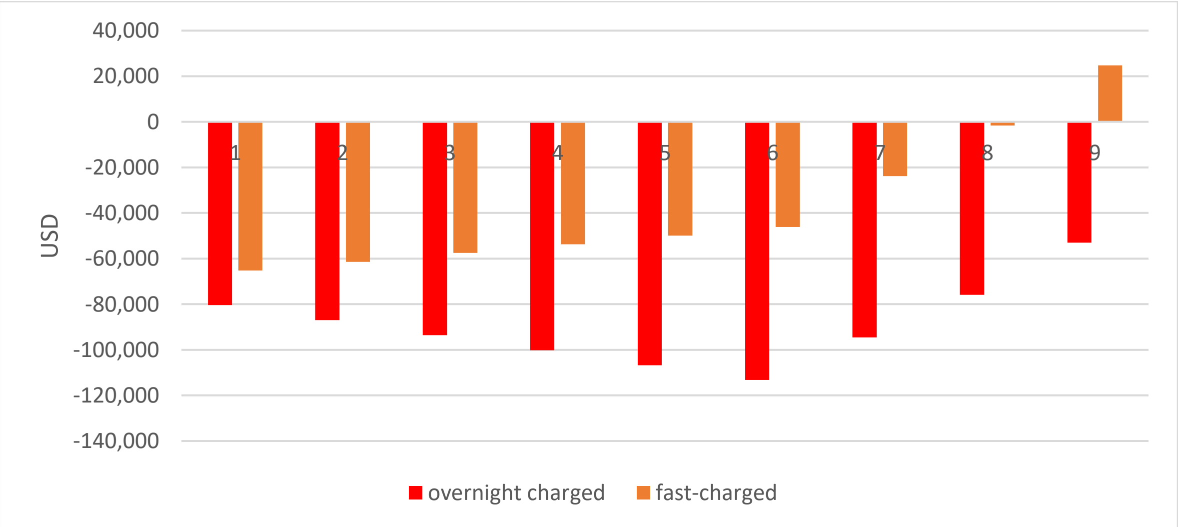
The discounted payback looks at the number of years required to recover the initial incremental investment from savings of BEBs relative to diesel buses. Annual incremental savings of using a BEB versus a diesel bus are discounted. The discounted payback gives a good indication of the risk the entrepreneur 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 9 years.

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 for fast-charged units in year 9 and remains negative for overnight charged units over the lifetime of the asset.

Figure 7: Cumulative Differential Cash Flow Diesel and BEB



Source: Grutter Consulting

The cumulative differential CF continues to drop for slow charged BEBs as the outlays for loan repayment are a very significant component.

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	2.5x of a conventional bus	Significantly higher equity demand which might overstretch the capabilities of small and medium enterprises
Profitability	FIRR below WACC	Investment in e-buses is not profitable.
Discounted Payback	Incremental investment is not recovered with savings during asset lifetime (9 yrs)	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 Mexico.

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	7 years	9 years
Interest rate	12.5%	3.1%
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 3.5% 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	1.07	0.96
TCO financial new	0.97	0.87
FIRR old	-1%	9%
FIRR new	-1%	9%
Additional equity old	241%	226%
Additional equity new	218%	196%
Discounted Payback in years old	Not recovered	Not recovered
Discounted Payback in years new	Not recovered	7

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces by around 0.1 USD/km and is now below the diesel buses (0.98 USD/km) for both e-bus options.
2. The concessional loan does not change the FIRR by logic (the FIRR is calculated without financial costs).
3. Owners capital requirements are reduced with the concessional loan (due to not only financing the bus but all investment components including bus, charging infrastructure, grid connection and bus depot upgrade for e-buses). Owners capital is however still factor 2 above the amount required for fossil buses.
4. The risk and the capital exposure of the entrepreneur can be reduced significantly. With fast-charged BEBs the investment can be recovered within 7 years.

It can be concluded that 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 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	1.07	0.96
TCO financial new	0.86	0.78
FIRR old	-1.0%	9%
FIRR new	12%	31%
Additional equity old	240%	230%
Additional equity new	70%	60%
Discounted Payback in years old	NEVER	NEVER
Discounted Payback in years new	6	4

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 positive and 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 4-6 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 Mexico. 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 65,500 km[8]. The loan conditions for fossil and electric taxis are 12.5% interest rate and 6 year tenure.

Table 18: Baseline Gasoline Taxi Parameters

Parameter	Value	Source
Gasoline usage	8.0 l/100km	https://manufactura.mx/automotriz/2013/09/27/cual-es-el-taxi-ideal-para-mexico
Maintenance cost	0.02 USD/km	Transconsult, 2018
CAPEX	15,800 USD	Average value of 10 cities in Mexico; Transconsult, 2018
Lifespan	6 years	INECC, 2017[9]

Table 19: E-Taxi Parameters

Parameter	Value	Source
Specific electricity usage	0.16 kWh/km	Nissan LEAF or BAIC taxi[10]
Maintenance cost	0.01 USD/km	30% below fossil (higher repair costs and potentially tyre costs have been factored into a reduction of only 30%
Lifespan	6 years	Idem fossil taxi due to concession
Lifespan battery @ 70% SOH	6 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

4.3.2. TCO

The following table shows the results of the TCO calculation.

[8] Based on Transconsult, 2018: https://www.gob.mx/cms/uploads/attachment/file/395996/CGMCC_ES_06.pdf

[9] https://datos.abiertos.inecc.gob.mx/Datos_abiertos_INECC/CGMCC/C_MexicoDinamarca/CatalogoTransporte_vff_Esp.pdf

[10] Transconsult (2018), compared their estimates of TCOs by using a BYD E1. However this car has very limited power and a small battery (30 kWh). If the car is used with load or AC it will have a limited range estimated at less than the daily driving range – at the same time it can only be charged at maximum with a load of 50kW which is not considered as sufficient for taxis for fast charging during the day with time availability of 30 minutes or less.

Table 20: TCO Calculations (USD of 2020)

Parameter	gasoline	e-taxi
CAPEX taxi	15,800	30,000
CAPEX charging infrastructure	0	2,000
Total CAPEX	**15,800**	**32,000**
Energy cost	4,821	2,117
Maintenance cost	1,507	753
Finance cost average p.a. during loan term	898	1,706
Economic costs of emissions year 1	601	222
Lifespan in years	6	6
TCO financial per km	**0.15**	**0.15**
TCO economic per km	**0.16**	**0.15**

Source: Grutter Consulting

Comparing total costs over the taxi lifetime of 6 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	16,000	103%
Additional loan requirement	11,000	90%
Additional equity requirement	5,000	153%

Source: Grutter Consulting

E-taxis require a capital investment factor 2 of a gasoline unit. The required equity increases by the factor 2.5. This can place a serious problem for taxi owners. The investor could opt for purchasing 2 gasoline units instead of 1 electric one thus increasing considerably his revenue and profit base.

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 11% and above the WACC of 9%.
- The EIRR is 17%.

The investment in e-taxis is thus profitable.

4.3.5. Discounted Payback

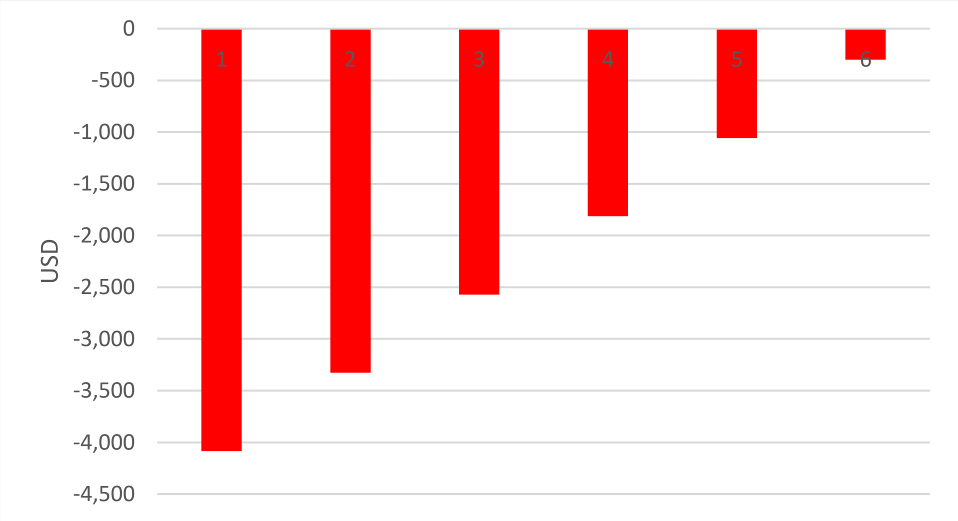
The discounted payback looks at the number of years required to recover the initial incremental investment from savings of e-taxis relative to gasoline units. Annual incremental savings of using an e-taxi versus a fossil taxi are discounted. The discounted payback gives a good indication of the risk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

Figure 8: Cumulative Differential Cash Flow Fossil versus 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	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	2.5x of a conventional taxi	Significantly higher equity demand which might overstretch the capabilities of taxi owners
Profitability	11%	Investment in e-taxis is profitable
Discounted Payback	Incremental investment is not recovered	This indicates a high risk profile of the investment.
Cash Flow	Negative cumulative CF entire period	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	6 years	6 years
Interest rate	12.5%	5.1%
Lending rate	80% of CAPEX	80% of CAPEX

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 3.5% 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	0.15
TCO financial new	0.14
FIRR old	11%
FIRR new	11%
Additional equity old	153%
Additional equity new	103%
Discounted Payback in years old	never
Discounted Payback in years new	5

Source: Grutter Consulting

The concessional loan improves the liquidity and is 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	0.15
TCO financial new	0.14
FIRR old	11%
FIRR new	11%
Additional equity old	153%
Additional equity new	No equity
Discounted Payback in years old	never
Discounted Payback in years new	3

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces marginally.
2. The FIRR remains at the same rate.
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 3 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. The concessional loan would be sufficient to resolve the problems at the level of the taxi investor and no grants are deemed as necessary for taxi purchase. 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 Mexico. The annual assumed mileage is 22,500km[11].

Photo: LCV Assessed for Mexico

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

11 http://ri.uaemex.mx/bitstream/handle/20.500.11799/71061/Teisis%20ITR%20Buendia%20Pe%C3%B1aloza.pdf?sequence=1&isAllowed=y

Table 26: Baseline Gasoline LCV Parameters

Parameter	Value	Source
Gasoline consumption	23 l/100km	Instituto Mexicano del Transporte, 2018
Maintenance	0.03 USD/km	Instituto Mexicano del Transporte, 2018; excludes tyres and repairs
CAPEX	28,400 USD	JAC X250
Lifespan	17 years	300,000 km lifespan mileage
Interest rate	13.5%	NAFIN, 2020[12]

Table 27: E-LCV Parameters

Parameter	Value	Source
Specific electricity usage	0.21 kWh/km	WLTP for JAC EX350
Maintenance	0.01 USD/km	50% of fossil version
Lifespan	17 years	Same as gasoline version; 1x exchange batteries
Lifespan battery @ 70% SOC	8 years	Replacement assumed in year 8 (middle of lifespan)
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	73,600 USD	JAC EX350 with 3.7t load capacity [13]
CAPEX home charger 7.4kW	2,000 USD	Wall-box installation
Lifetime charger	17 years	Above guarantee level
Battery size	92 kWh	https://www.alianzaflotillera.com/jac-lanza-vehiculos-para-la-ultima-milla/
Drive range electric (maximum)	440 km	https://www.alianzaflotillera.com/jac-lanza-vehiculos-para-la-ultima-milla/

4.4.2. TCO

The following table shows the results of the TCO calculation.

Table 28: TCO Calculations (USD of 2020)

Parameter	Gasoline	e-LCV
CAPEX LCV	28,400	73,600
CAPEX charging infrastructure	0	2,000
Replacement battery cost in year 7	0	18,400
Total CAPEX	**28,400**	**75,600**
Energy cost	4,761	822
Maintenance cost	563	281
Finance cost average p.a. during loan term	1,789	4,061
Economic costs of emissions year 1	572	100
Lifespan in years	17	17
TCO financial per km	**0.34**	**0.37**
TCO economic per km	**0.37**	**0.37**

Source: Grutter Consulting

Comparing total costs over the LCV lifetime of 17 years e-LCVs have slightly higher financial and economic TCOs than gasoline units.

[12] https://www.nafin.com/portalnf/content/financiamiento/empresa-transportista.html
[13] https://www.eleconomista.com.mx/empresas/JAC-le-apuesta-al-mercado-de-camiones-electricos-20201022-0010.html

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	47,000	170%
Additional loan	36,000	160%
Additional equity	11,000	190%

Source: Grutter Consulting

E-LCVs require nearly triple the capital investment compared to gasoline units.

4.4.4. Relative Profitability

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

- The FIRR is 2% and clearly below the WACC.
- The EIRR is 4%.

The investment in e-LCVs is thus not profitable.

4.4.5. Discounted Payback

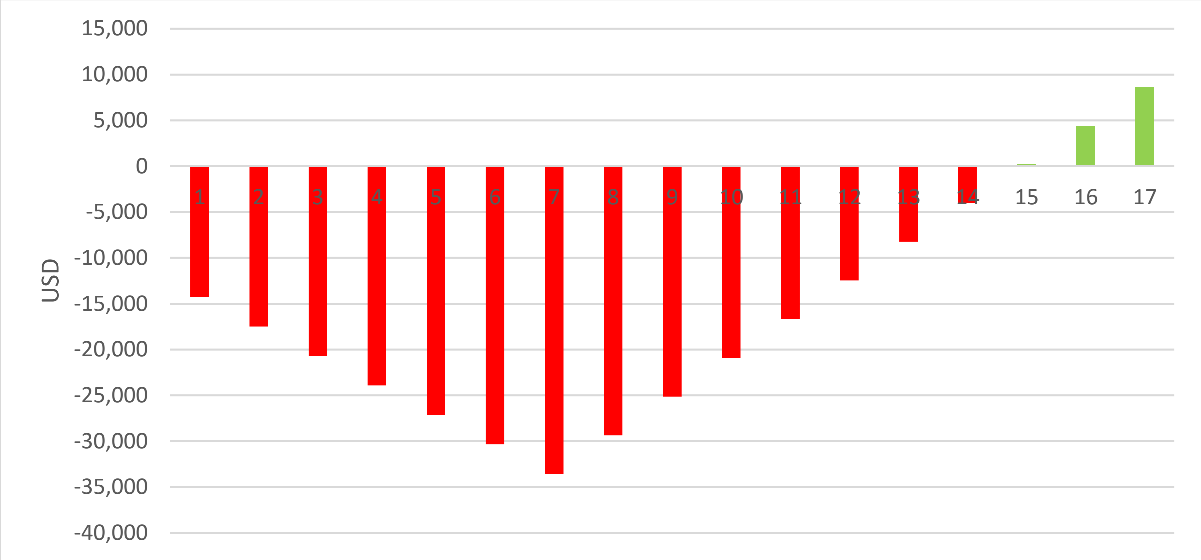
The discounted payback looks at the number of years required to recover the initial incremental investment from savings of e-LCVs relative to gasoline units. Annual incremental savings of using an e-LCV versus a gasoline LCV are discounted. The discounted payback gives a good indication of the risk the 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 gasoline unit. Only cash outflows are considered as revenues (cash inflows) are identical between an e-LCV and a gasoline unit. The cumulative CF is positive from year 5 onwards. This means that the company will have a positive liquidity impact from year 15 onwards due to savings on maintenance and energy sufficient to cover the additional finance outlays and initial equity injection.

Figure 9: Differential Cumulative Cash Flow Fossil and Electric LCV



Source: Grutter Consulting

The cumulative differential CF continues to decline until year 8 due to loan repayments.

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	Slightly higher TCOs of e-LCVs	
Capital investment	170% higher than a conventional LCV	Higher capital requirement incl. higher loan demand
Equity investment	190% higher than a conventional LCV	Higher equity demand
Profitability	2%	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	Positive from year 15	The investment in e-LCVs has during a long period 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	7 years	7 years
Interest rate	12%	5.1%
Lending rate	80% of CAPEX	80% of CAPEX

The concessional interest rate is based on a 1.25% rate from the GCF (commissions fees factored into the interest rate) for 30% of the loan and 70% of the investment from AFD/co-financers at 3.5% 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	0.37
TCO financial new	0.32
FIRR old	2%
FIRR new	2%
Additional equity old	194%
Additional equity new	194%
Discounted Payback in years old	never
Discounted Payback in years new	16

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 of vehicle investment including charger 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	0.37
TCO financial new	0.28
FIRR old	2%
FIRR new	7%
Additional equity old	194%
Additional equity new	-72%[14]
Discounted Payback in years old	never
Discounted Payback in years new	10

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO is now significantly lower than for gasoline units;
2. The FIRR is higher and above the WACC including concessional finance i.e. the investment is now profitable;
3. Owners capital requirements are lower than with a gasoline unit;
4. The risk and the capital exposure of the entrepreneur is reduced significantly with a dynamic payback time (discounted with the new WACC) at 10 years which is however still long.

[14] Less equity required than for fossil vehicle

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

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

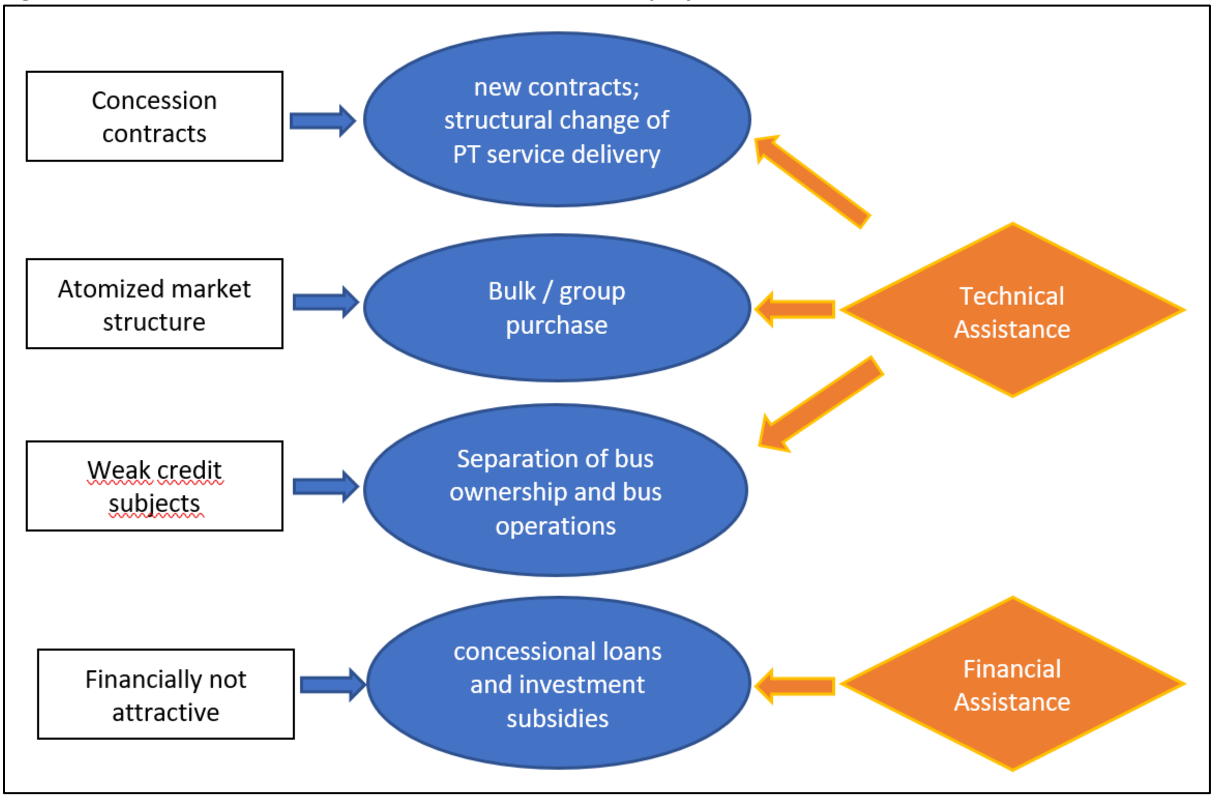
Table 34: Barriers towards e-Bus Deployment in Mexico

Barrier Type	Concrete Aspects
Concession contracts	The variability in concession contracts in the different states makes the financing processes difficult. 9 year concession contracts limit the loan tenure which is for e-buses very short considering investments in batteries in year 8. Concession contracts also do not offer to creditors guarantees that assets are kept and operated by another transport operator in case of default or loss of concession. With the exception of structured mass transportation systems, payments are fixed per route and go directly to the operator i.e. the creditor has no guaranteed direct payment from the fare box.
Atomized market structure of bus operators	Many small and some medium-sized operators exist in Mexico.
Financially weak operators	Operators have a fragile balance sheet. To access loans they need to provide real guarantees beyond vehicles. As they only take relatively small loans and are considered a high risk, the resultant interest rate is high and loaning levels are low.
Financial barriers	BEBs are not profitable. The FIRR is below the WACC and the repayment period for the incremental investment in electric buses is more than 9 years. The investor needs to invest up to 2.5x the owners capital required for fossil buses, increases significantly his debt levels and suffers from a negative cash flow with the current market offer for e-buses prevalent in Mexico. To reduce operational costs operators also do not insure vehicles against collision damage and full loss. This again makes it impossible to accept vehicles as loan guarantee to banks.

Source: Grutter Consulting

E-buses have major environmental and societal advantages expressed in large positive environmental and health impacts. However, reasons such as 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. The following figure shows intervention instruments which can overcome these barriers.

Figure 10: Intervention Instruments to Overcome E-Bus Deployment Barriers



Source: Grutter Consulting

Concession contracts can be updated and changed to incorporate longer periods (e.g. 15 years) and with asset turn-over in case of default or concession loss. In the medium term a structural change to the system how public transport is delivered will be required to increase system efficiency and convenience for the customer at it has been developing in some cities. This will imply a change of ownership structure and potentially of service delivery structures. However, at first instance the major barrier is to increase the length of concession contracts as a standard for all states.

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 dependant 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;
- Purchase of buses through a 3rd party and delivery for operations either credit- or leasing-based by operators. This model is used in structured systems as Metrobus.

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 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. To overcome the problem of guarantees and costly financial conditions a separation of ownership and operations is an important condition, especially in market conditions such as Mexico with many individual small and weak operators. Technical assistance can help to overcome these barriers and structure financially more viable solutions. 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 favors 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 or energy company:** is responsible for acquiring the vehicle fleet, the recharging infrastructure and its installation in the yard. 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.

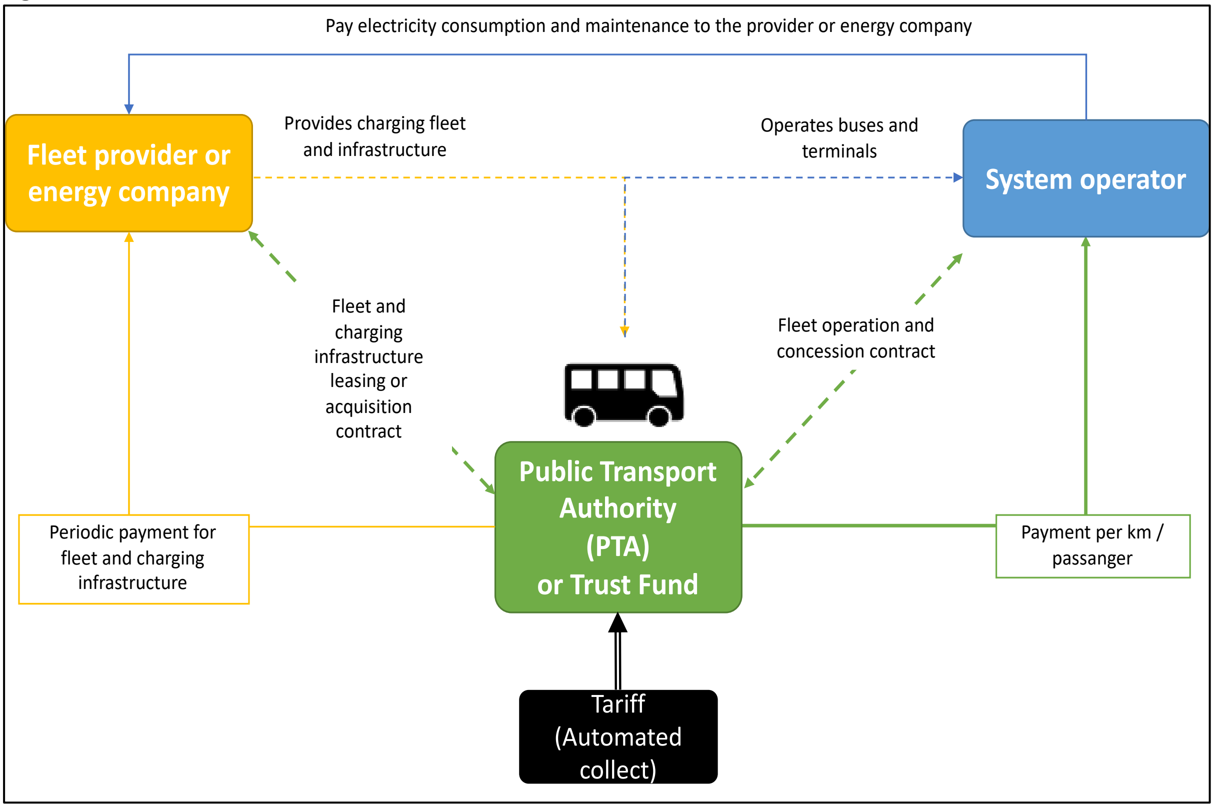
2. **Vehicle fleet operator:** is responsible for the operation of the service and will have a legal relationship with the transport authority, or managing company, through a service provision contract during the concession period, which could eventually be 15 years.

The operator may be responsible for paying other operating expenses such as personnel, energy consumption and other services associated with the operation. It is worth mentioning that in this 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 11: Possible business models for urban buses



Source: Grutter Consulting

5.1.3. Potential Investment Projects

The following table lists potential bus investment projects for Mexico.

Table 35: Potential Investment Projects e-Buses Mexico

ID	Ownership	Project	Nu. of units 2023 to 2027	Estimated CAPEX	Estimated GHG impact[15]	Timeline
1	public	Metrobus BRT fleet renewal plan 2020 - 2030: Acquisition of BEBs to operate in new peripheral trunk corridors	480 18m buses and 30 24m units	380 MUSD	430,000 tCO_{2e} reduced	70% in 2023/2024 and rest 2025 to 2027
2	public	STE operator of trolleybuses	150 18m and 150 12m units	160 MUSD	220,000 tCO_{2e} reduced	2022-2025
3	Public	Gov. Of the State of Nuevo Leon for buses in Monterrey	130 12m units	40 MUSD	80,000 tCO_{2e} reduced	2023
4	mixed	Public transport in Guadalajara	33 10m buses	8 MUSD	17,000 tCO_{2e} reduced	2022
5	mixed	Public transport in Hermosillo	51 12m buses	16 MUSD	32,000 tCO_{2e} reduced	2025-2027
6	Public	Government of the State of Sinaloa	200 12m buses	63 MUSD	127,000 tCO_{2e} reduced	2022

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 Mexico:

- 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) and the ability to take vehicles as loan guarantee[16]. Together with the entrance of financially stronger players this should be capable to cut interest rates by more than 60%.

5.1.4. 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 including 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 and formalization of small transporters into formal companies.
- 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 prevalent in the country.

[15] Cumulative lifespan of units
[16] This will require vehicles to be insured against loss.

- Assessment of optimal e-bus technology and charging systems to enable a robust and cost-effective e-bus deployment considering the particularities of the transportation system.
- 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.

5.2. Taxis and LCVs

5.2.1. Barriers and Intervention Options

The following table summarizes major barriers towards the deployment of e-taxis and e-LCVs in Mexico. 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 36: Barriers towards e-taxis and e-LCVs Deployment in Mexico

Barrier Type	Concrete Aspects
Financial barriers	Investments in e-LCVs are financially risky and not profitable. Serious financial problems of the sector: official taxis struggle under intense competition from ride-hailing services and latter are subject to legal intervention in certain states. The taxi sector is considered to be over-indebted and many loans have gone sour in this area. Not surprisingly bank managers ask for blanket guarantees which is an indicator that the sector is not creditworthy. Uber or related services lack a proper legal framework and operations are potentially financially not feasible if all costs are paid (e.g. appropriate vehicle and passenger insurance, tax and licence payments). It is expected that the market will undergo serious re-structuring. Investing in this area in the next few years thus entails a potential default risk which would need to be well managed
Urban fast-charging network	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
Know-how	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
Success of cab pilot schemes	Cab service, being individually owned, is a voice-to-voice market lacking technical knowledge. In this type of market, the reputation of the pilot programs takes on great importance. The program developed by Mexico City was not successful and demonstrated the need for appropriate support for e-taxis generating a lack of interest due to investment conditions and operating difficulties. In addition to the rapid obsolescence of the technology[17]
Ownership structures	Ownership structures are often a barrier as vehicles are owned by individual drivers and not by the logistics companies or by the cargo company

Source: Grutter Consulting

Considering the barriers, the following can be considered as areas of intervention:

- Development of roadmaps from the federal level that involve the particularities of this technology and facilitate the adoption by the federal entities. Issues such as costs, charging infrastructure, vehicle standards, batteries and charging infrastructure, energy supply, among others, can be considered.

[17] According with STE Interview who is in charge of this fleet

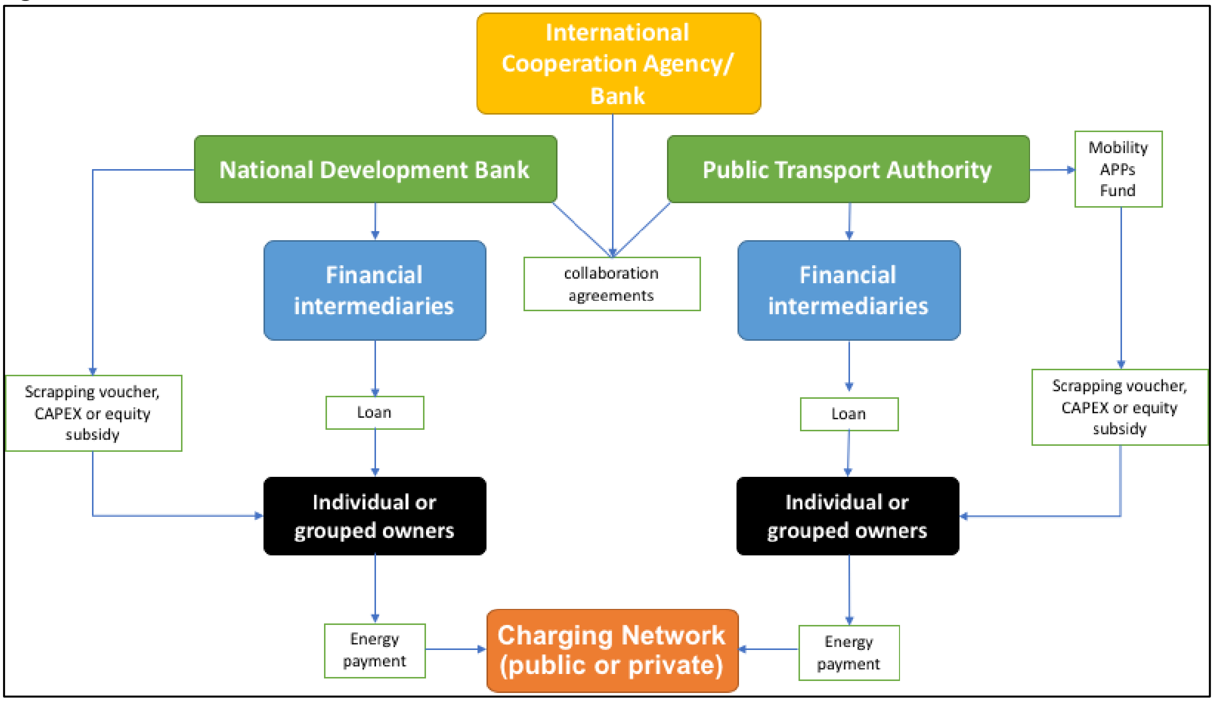
- Generation of innovative business models that facilitate access to credit, while respecting individual operations. Leasing schemes may be considered, where the fleet is acquired by a third party or a municipal authority, which makes it available for operation for a period of time. This allows the risks to be distributed and facilitates technological adoption.
- Support for the development of a public recharging infrastructure system considering its acquisition and operation. This allows the development of a network with easy access for vehicles.

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 12: Possible business models for 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 Mexico.

Table 37: Potential Investment Projects e-Buses Mexico

ID	Ownership	Project	Nu. of units 2023 to 2027	Estimated CAPEX	Estimated GHG impact[18]	Timeline
1	public	Secretary of mobility for DF; Taxi replacement program for 26,000 units until 2030	20% estimated from 2023 to 2027 i.e. 5,200 units	180 MUSD of which 170 MUSD vehicles + home chargers and 20 MUSD fast charging infrastructure	180,000 tCO_{2e} reduced	Fast charging infrastructure 2023; taxis gradual
2	public	Government of the State of Sinaloa	100 special taxis	3.5 MUSD of which 3.2 MUSD vehicles + home chargers and 0.3 MUSD fast charging infrastructure	5,000 tCO_{2e} reduced	2023
3	Mixed	KFW-NAFIN Phase 2 Vehicle Renewal Program for taxi, LCV and public transportation bus	Not defined			

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. For LCVs a proposal will be realized around the KFW-NAFIN program. The following financial intervention instruments are proposed for e-taxi and e-LCV deployment in Mexico:

- 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, a high loan share (80% of total investment) and the ability to take vehicles as loan guarantee[19]. 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.

[18] Cumulative lifespan of units
[19] This will require vehicles to be insured against loss.

6. TA intervention Areas and Instruments

6.1. TA Actors in E-Mobility

Various actors are engaged currently in electric mobility in Mexico. The coordination between each of these parts is crucial in order to not duplicate efforts.

Cities Finance Facility CFF

The C40 Cities Finance Facility is supporting the cities of Mexico City, Guadalajara, Monterrey and Hermosillo by developing the necessary feasibility studies for a new bus corridor project called *Eje 8*, a feeder route of *Mi Macro Periférico*, three feeders of the new line 3 of Monterrey's subway system and the BRT line along *Bulevar Solidaridad*, respectively. All these projects are focused on electric buses. The CFF aims to deliver a replicable model of how to finance clean buses in developing countries and emerging economies (C40 Cities Finance Facility, 2021).

C40 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, Foton, Yutong and Sunwin committed to commercialize a zero-emission bus model in Mexico City 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 Mexico are monitored trolleybuses in Mexico City and 25 e-buses in Guadalajara (LABMOB; UFRJ, 2021).

Carbon Trust

Carbon Trust have developed studies for the implementation of electromobility in Mexico such as the *Mexico City: Carbon Trust Initiative to Form a Public Policy and Promote Electric Transportation*, a public policy guidance document, with the aim of developing a sectoral program, finding areas of opportunity and designing schemes to meet climate change objectives (WRI Mexico, 2018).

They have also collaborated with C40 CFF in the generation of the *Mexico City Electromobility Strategy 2018-2030* (C40 Cities Finance Facility; Carbon Trust Mexico, 2018).

German Cooperation Agency GIZ

GIZ is in charge of implementing the C40 Cities Finance Facility program in Mexico. Also, GIZ worked with CEPAL in the generation of the document *Towards public electromobility in Mexico*, within the framework of the *CEPAL-BMZ/GIZ Cooperation Program* and the project *Sustainable Development Pathways for Middle Income Countries in the framework of the 2030 Agenda for Sustainable Development in Latin America and the Caribbean*. This publication presents proposals for the implementation of electromobility, including suggestions focused on an industrial policy for electromobility, the evaluation of Mexico's current automotive industrial policy and the identification of strategies to promote the development of the national industry of electric public transportation vehicles, especially electric buses (CEPAL, 2020).

State Development Bank of the Federal Republic of Germany KfW

KfW is developing a vehicle renewal program with the support of National Financial (NAFIN). This program grants a scrapping bonus and favorable financial conditions, especially for the "man-truck". It has a counterpart of resources from the participating states and its target public are buses, cabs and LCVs. Although the scope of the technical assistance component of the program is still in the definition phase, some of the topics being considered are vehicle emissions verification systems, development of recharging infrastructure, strengthening of institutional capacity, structuring of scrappage schemes, dissemination of the benefits of fleet renewal, management of vehicle fleet information with emphasis on identifying opportunities, and intersectoral collaboration.

World Resources Institute WRI

WRI has provided technical assistance to the Secretariat of Environment and Natural Resources (SEMARNAT) in the development of the *National Electric Mobility Strategy* (WRI Mexico, 2019). WRI has also worked in cities evaluating alternatives for the implementation of low-carbon fleets and the comparison of technologies as in the *Monterrey project: Analysis for the introduction of low-carbon vehicles in the Transmetro system* (WRI México, 2018). It also collaborates with International Cooper Association Mexico in the *Alliance for Electromobility in Mexico*, an initiative in which entities such as SEMARNAT, Secretariat of Energy (SENER), National Comission for the Efficient Use of Energy (CONUEE), Secretariat for Environment (SEDEMA), Mexican Automotive Industry Association (AMIA), National Institute of Electricity and Clean Energy (INEEL) and National Chamber for Electric Manufacturers (CANAME) participate (International Copper Association Mexico, 2019).

Inter-American Development Bank (IDB)

IDB has worked in technical cooperation in the public transportation sector in Mexico. Under the project *Knowledge Exchange in the Implementation of Dual Concessions for Public Transportation*, an exchange was granted for the knowledge of the operation segmentation models used in Santiago de Chile and Bogota (IDB, 2019). In addition, the *Program to Support the Expansion of Public Transportation in Mexico City* included among its objectives the analysis of electric buses in the design of a system to renew the fleet of concessioned buses in this city; this program is in the implementation phase (IDB, 2020).

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).

Others

The Federal Electricity Commission (CFE) in conjunction with SENER, the government of Mexico City, AMIA, NISSAN, BMW I and TESLA has developed the *Program for the Promotion of Electro-mobility through Investment in Recharging Infrastructure (PEII).* The program is focused on expanding the existing charging infrastructure in Mexico City, Guadalajara and Monterrey, is expected to connect 10 Mexican states with fast charging stations.

6.2. Possible TA Interventions within the E-Motion Program

The areas of intervention in electromobility are mainly focused on financing, charging infrastructure and knowledge of the technology. Considering the projects and with the objective of facilitating the structure of electromobility in the country, the following are defined as focal points:

- Homologation of federal incentives that promote the acquisition of vehicle fleet and auto parts, contributing to the reduction of cost differentials with respect to other technologies. It is important to consider not only the reduction of tariffs or taxes at the time of purchase, but also the reduction of taxes on income tax returns to facilitate the conditions for operators of this type of technology.
- Considering the Mexican context and project evaluation methodologies, it is necessary to provide assistance for the adequate inclusion of the benefits, especially environmental, that electromobility generates and that generally makes it a competitive option compared to others. This is especially important in mass public transportation systems and allows for a more equitable vision for decision making.
- Technical assistance for the generation of a differential electricity tariff policy for the recharging of e-vehicles. This type of incentive contributes to the compensation of the investment in recharging infrastructure.
- Training for drivers and maintenance personnel for the proper operation of the vehicles. Driving patterns, battery recharging and unit maintenance directly influence the durability of the vehicles, especially the batteries.
- Support in the legal and financial structuring of innovative business models along with their dissemination to stakeholders. This facilitates the financing of units, the control processes of the authorities and the involvement of the stakeholders.
- Technical assistance to the government in re-structuring public transport sector that would result in stronger and fewer operators e.g. in direction of separation of bus ownership and bus operations. This works to remove barriers to financing for small carriers.
- Policies for the proper disposal and secondary uses of batteries. These batteries can later be used in other production sectors.
- Policy advice including the establishment of concrete sub-sector specific roadmaps on electrification of urban public transport buses, electrification of LCVs and public charging infrastructure.
- Information and knowledge dissemination as well as advisory services to companies and public entities interested in investing in LCVs.
- On-going TA on specific conditions to improve the enabling conditions for e-mobility deployment such as capacity building for insurance companies and firefighters allowing insurance companies to better assess the risk and costs of insuring an electric vehicle and by training specialized fire fighters and vehicle maintenance personnel (mechanics and depot managers) on how to cope with the particular hazards of EVs.
- Technical support for the generation of standards and requirements for electric vehicles and charging infrastructure.
- Dissemination of knowledge and technical assistance to local authorities on the particularities of electromobility, the proper structuring of projects, as well as the analysis of the legal framework of transport for the correct adoption and control of the implementation.
- Support for impact studies on the national energy matrix and the stability of the local distribution network in the adoption of electromobility.

- Support for the structuring of the national electromobility committee, in charge of centralising and coordinating public policy initiatives and activities on electromobility at both national and local level.
- Technical assistance for designing an appropriate fast-charging infrastructure catering to the demands of taxis and ride-hailing vehicles.

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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 3 gasoline passenger car and LCV	15%		EEA, 2020, tabla 3-92
BC fraction Euro 4 gasoline passenger car and LCV	15%		
BC fraction Euro 3 diesel passenger car and LCV	85%		
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	0.16	USD/kWh
Electricity price fast chargers	0.3	USD/kWh
Electricity price consumption medium tension	0.09	USD/kWh
Electricity price consumption medium tension	0.09	USD/kWh
Power charge	15	USD/kW
Power charge	15	USD/kW

https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/Tarifas/tarifas_negocio.asp; chargers assumed

Calculation for buses

Average electricity price overnight charged buses	0.22	USD/kWh
Average electricity price fast charged buses	0.17	USD/kWh

TCO 12m Bus

Parameter	Value	Unit	Source
Distance driven per bus per annum	78,019	km	225km per day with 330 days; SEMARNAT, 2016. Concessioned buses
Workday distance driven daily	225	km	SEMARNAT
Specific electicity usage	1.1	kWh/km	Chinese average; ADB, 2018; includes AC
Diesel usage	54	l/100km	mexico BM
Maintenance diesel bus	0.28	USD/km	http://documents1.worldbank.org/curated/en/410331548180859451/pdf/133929-WP-PUBLIC-
maintenance e-bus	0.20	USD/km	70% of diesel bus
Lifespan bus diesel	9	years	SEDEMA concessioned buses
Lifespan bus electric	9	years	SEDEMA concessioned buses
Lifespan battery @ 80% SOC	8	years	current guarantee levels

Financial defaults

Parameter	Value	Unit	Source
CAPEX diesel bus	153,000	USD	90% of estimate of Diesel Euro V,
CAPEX overnight charged e-bus	286,000	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
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	225
Energy usage day	kWh	248
Risk ratio (higher energy consumption)		10%
Reserve ratio		20%
SOC loss year 8		20%
Battery size required year 8	**kWh**	**430**

Charging required at bus depot overnight

Parameter	Unit	Value
Battery capacity	kWh	430
Average daily consumption workday	kWh	248
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	60

Option B: Fast Charging

Parameter	Unit	Value
Battery size	kWh	250
C-rate		0.65
Charging in 30 minutes	kWh	81
Average re-charge during day required with 20% reserve ratio	kWh	48
Average share of day electricity		19%
Fast-charger	kW	300
Power conversion efficiency of chargers		90%
Average required re-charge day with 300 kW charger	minutes	11
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	153,000		286,000	250,000
CAPEX charging infrastructure	0		9,700	12,113
CAPEX grid connection	0		30,000	30,000
CAPEX depot upgrade	0		7,500	7,500
Total CAPEX	153,000		333,200	299,613
Battery replacement yr 8	0		43,000	31,250
Energy cost yr 1	31,629		18,524	14,924
Maintenance cost bus yr 1	21,845		15,292	15,292
Maintenance cost infra yr 1	0		944	992
Finance cost average per year	8,699		16,260	14,213
Economic costs yr 1	6,432		1,312	1,312
TCO financial per km	0.98		1.05	0.94
TCO economic per km	1.07		1.07	0.96

TCO Taxis

Parameter	Value	Unit	Source
Average battery size	60	kWh	Nissan LEAF large battery or BAIC
Battery lifespan	6	years	idem vehicle
Vehicle lifespan	6	years	INECC, 2017
Annual mileage	65,500	km	
Daily mileage	211	km	Based on 310 working days
Charging at home average	70%		Assumption; only re-charge if above-average mileage or night shifts
Charging fast-chargers	30%		
CAPEX gasoline taxis	15,800		Valor promedio 10 ciudades de México. Transconsult, 2018
CAPEX e-taxi	30,000		Transconsult, 2018, calculates with BYD E1 but small battery; thus Nissan Leaf large battery or BAIC
Capex home charger 7.4kW	2,000	USD	Nissan LEAF large battery or BAIC
Gasoline consumption	8.0	l/100km	https://manufactura.mx/automotriz/2013/09/27/cual-es-el-taxi-ideal-para-mexico
Electricity consumption	0.16	kWh/km	Nissan LEAF large battery or BAIC
Charger lifespan	6	years	
Maintenance cost gasoline excl. Tyres	0.02	USD/km	https://www.gob.mx/cms/uploads/attachment/file/395996/CGMCC_ES_06.pdf
Maintenance cost total e-taxi	0.01	USD/km	30 % lower cost (tyres the same or higher; higher spare costs; less maintenance of engine

Transconsult compared with BYD E1. However this car has very limited power, a small battery (30 kWh), as soon as used with load or AC a limited range (in practice less than 200km) and can oinly be charged with 50kW

gasoline versus e-taxi

Parameter	gasoline	e-taxi
CAPEX vehicle	15,800	30,000
CAPEX charger	0	2,000
Total CAPEX	15,800	32,000
Energy cost	4,821	2,117
Maintenance cost	1,507	753
Finance cost average per loan year	898	1,706
Economic costs yr 1	601	222
Lifespan in years	6	6
TCO financial per km	0.15	0.15
TCO economic per km	0.16	0.15

LCVs

1. Petrol Van

Parameter	Value	Unit	explanation
CAPEX van	28,400	USD	JAC X250
Petrol fuel consumption	23.0	l/100km	Instituto Mexicano del Transporte, 2018. Valores para 2017
Maintenance cost	0.03	USD/km	Instituto Mexicano del Transporte, 2018. Valores para 2017
Lifespan	17	years	INECC 2017
Daily distance driven	68	km	commensurate with annual mileage
Annual distance	22,500	km	Buendía, José Luis; Peñaloza, Pedro Abraham. 2016
Interst rate e-LCV	12%		HSBC, 2021. For passenger cars with 80% loan share and 72 month financing
Interst rate commercial LCV	13.5%		NAFIN, 2020
Tenure	7	years	

2. E-Van

Parameter	Value	Unit	explanation
CAPEX e-van	73,600	USD	JAC EX350 3.7t load
Range WLTP	440	km	https://www.alianzaflotillera.com/jac-lanza-vehiculos-para-la-ultima-milla/
Battery size	92	kWh	
Cost battery	18,400	USD	Based on 200 USD/kWh per battery
electricity consumption	0.21	kWh/km	WLTP
Maintenance cost	0.01	USD/m	50% of fossil (as only engine maintenance is included; no tyres, no repairs)
Lifespan van	17	years	assumed same as fossil
Lifespan battery	8	years	
Capex home charger 7.4kW	2,000	USD	
Lifespan charger	17	years	
Charging at home average	90%		Assumption
Charging fast-chargers	10%		Exceptional if long distances were made

fossil versus e-van

Parameter	petrol	e-van
CAPEX vehicle	28,400	73,600
CAPEX charger	0	2,000
Replacement battery cost	0	18,400
Total CAPEX	28,400	75,600
Energy cost	4,761	822
Maintenance cost	563	281
Finance cost average per year	1,789	4,061
Economic costs yr 1	572	100
Lifespan in years	17	17
TCO financial per km	0.34	0.37
TCO economic per km	0.37	0.37