Assessment of Commercial EV Demand in Peru

Client	AFD
Version	02
Date	20/03/2021
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Abbreviations

AC	Air Conditioning
AFD	French Development Agency (Agence Française de Développement)
APN	National Port Authority
ATU	Urban Transportation Authority for Lima and Callao
BAU	Business As Usual
BCRP	Central Reserve Bank of Peru - (Banco Central de Reserva del Perú)
BEB	Battery Electric Buses
BEV	Battery electric vehicle
CAF	Andean Development Corporation (Corporación Andina de Fomento)
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CF	Cash Flow
CORPAC S. A.	Corporación Peruana de Aeropuertos y Aviación Comercial S.A.
DGEE	Directorate General of Energy Efficiency
EIRR	Economic Internal Rate of Return
ENAPU S. A.	Empresa Nacional de Puertos S.A.
EU	Executing Units
EV	Electric Vehicle
FA	Financial Assistance
FIRR	the Financial Internal Rate of Return
GHG	Greenhouse Gases
GIZ	German Cooperation Agency - GmbH (Deutsche Gesellschaft für Internationale Zusammenarbeit - GmbH)
GPAE	Policy and Economic Analysis Management
HEV	Plug-in hybrid electric vehicle
IADB	Inter-American Development Bank
IEA	International Energy Agency
INEI	National Institute of Statistics and Informatics
ISC	Selective Consumption Tax
KfW	Reconstruction Loan Corporation (Kreditanstalt für Wiederaufbau)
LCV	Light Commercial Vehicle
MINAM	Ministry of Environment
MINEM	Ministry of Energy and Mines - (Ministerio de Energía y Minas)
MINSA	Ministry of Health
NDC	Nationally Determined Contributions
NGV	Natural Gas Vehicles
OPEX	Operational Expenditure
OPI	Programming and Investment Offices
OSITRÁ	Supervisory Body for Public Transportation Infrastructure Investment
PHEV	Hybrid electric vehicle
PNA	National Environmental Policy
PROPARCO	Promotion and Participation for Economic Cooperation, part of AFD (Promotion et de Participation pour la Coopération Economique)
SERPOST S. A.	Postal Services of Peru S.A. (Servicios Postales del Perú S. A.)
SETACA	Cab Service in Callao
SETAMETA	Metropolitan Taxi Service
SUTRANS	Superintendencia de Transporte Terrestre de Personas, Carga y Mercancías (Superintendence of Land Transportation of People, Cargo and Merchandise)
TA	Technical Assistance

TCO	Total cost of ownership
TTW	tank-to-wheel
UF	Formulation Units
UNEP	United Nations Environment Programme
WACC	Weighted Average Capital Cost
WB	World Bank
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 Peru from materializing the market potential.

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

It is important to mention that national mobility statistics in Peru are somewhat deficient, especially for urban contexts, the reader will find in this document that many of the conceptual and numerical references in this field could be insufficient.

2. Current Commercial EV Market in Peru

Currently the EV market in Peru is incipient. No fleets of commercial EVs are operating. With only one exceptional case, there are no special credit lines for electric vehicles[1]. The current loan conditions for vehicle finance are 10.5% USD interest rate with a 7-year loan tenor covering 80% of the investment.

2.1. Peruvian Fleet in Numbers

According to data from the Peruvian Ministry of Transport and Communications, for 2018 Peru has 2,894,327 vehicles.

Table 1. Estimated National Vehicle Fleet, According to Vehicle Class - 2018

Class of Vehicle	Vehicle Units
Total	2,894,327
Automobile	1,254,803
Station Wagon	472,955
Pick Up Truck	305,855
Rural Van	391,591
Panel Van	44,349
Bus	90,315
Truck	217,931
Trailer	47,074
Trailer and Semi trailer	69,454

Source: National Superintendence of Public Registries - MTC - OGPP - Statistical Office.

[1] The exception is COFIDE, which has approved a credit line of USD 30M (with IDB resources) for electric buses for the SIT of Arequipa.

Peru does not (yet) have a roadmap for the use of electric vehicles. In total only some 20 BEVs have been registered in 2019 and 22 in 2020 (AAP, 2020)

Table 2. Sales of Light and Heavy Electric and Hybrid Vehicles (2019 - Oct 2020)

	2019	2020	Total
BEV	20	22	42
PHEV	7	6	13
HEV	339	388	727
TOTAL	366	416	782

Source: Automotive Statistics (Edition- November 2020, page N° 12)

On the other hand Table 3 shows fragmentary data on passenger vehicles operating at the national level, with no figures for urban vehicles to be found.

Table 3. Passenger vehicles operating nationally - 2018

Fuel Type	Vehicle category			Sum
	M1	M2	M3	
Bi-Fuel LPG	86	131		217
Bi-Fuel NGV	9	17		26
Diesel	44	4,612	12,676	17,332
Petrol	166	250	2	418
LPG	9			9
NGV			158	158
Hybrid (diesel / batteries)			3	3
Sum	**314**	**5,010**	**12,839**	**18,163**

M1: up to 9 seats (including driver)
M2: With more than 9 seats (including driver) and GVW up to 5 tonnes.
M3: More than 9 seats (including driver) and GVW greater than 5 tonnes.
Source: http://portal.mtc.gob.pe/estadisticas/transportes.html

Between January 2019 and October 2020, Peru had 782 electrified vehicles on the road. The register shows that 765,152 new vehicles have been registered in Peru in this same period.

2.2. Main National Transport Policies

As described in the diagnosis, in Peru, Supreme Decree Nº 064-2010-EM created the General Directorate of Energy Efficiency as an entity of the Ministry of Energy and Mines with the aim of coordinating national development policies, including the energy sector. It approves the National Energy Policy of Peru 2010-2040.

In 2018 the peruvian government's Supreme Decree No. 019-2018-MTC updated the National Vehicle Regulation in order to include vehicles with new technologies such as electric vehicles, Additionally, the Supreme Decree No. 094-2018-EF increased taxes on fuels according to their degree of harmfulness. The purpose of the decree is to encourage consumers to choose less polluting options and thus reduce carbon emissions.

The Supreme Decree N°012-2019 approved the Urban Transport Policy, Supreme Decree N° 027-2019-MTC that creates PROMOVILIDAD, Supreme Decree No. 181-2019-EF increased and standardized the Selective Consumption Tax rate for imported used vehicles to 40%, in order to have new and clean technologies, Supreme Decree No. 022-2020-EM approved the provisions to implement charging and energy supply infrastructure for electric mobility in order to encourage an alternative transportation system that is environmentally and public health friendly.

Finally the Directorial Resolution No. 266-2020-MTC/16 approve the Guide "Climate Change, Air Quality and Transport: Guide to quantify emissions of Greenhouse Gases (GHG) and Short-Lived Climate Pollutants (SLCP) in the transport sector".

2.3. EV Demand

Through Supreme Decree N° 022-2020-EM, the Minem proposes that by 2030, 5% of all light vehicles and buses operating in the country will use electric energy, and to this end the regulation will allow recharging infrastructure establishments to access the free electricity market, obtaining competitive prices for their investment.

When considering public policies, tax incentives, specifically the reduction of the consumption tax, Peru's targets in the global emissions reduction agendas, it is clear that there is a real demand for migration of the energy matrix related to the transport sector with petroleum derivatives to electric power. Potentially, all cars in Peru could be electric, mainly in public transport, but also in last mile freight transport, private passenger vehicles, taxis, motorbikes and scooters. However, the real demand for electric vehicles will only be confirmed when there is technical, economic and financial feasibility to migrate the technology, as well as a network of vehicle suppliers, maintenance and recharging.

2.4. Incentives for Electric Mobility in Peru

It is highlighted that the market for electric and hybrid vehicles in Peru is still incipient compared to the electric vehicle market in the world. Some consumer incentives for the purchase of electric vehicles are summarised here, such as:

- Exemption from excise tax for the commercialisation of electric and hybrid vehicles.
- Exemption or reduction of taxes on imports of electric and hybrid vehicles.
- Tax reduction on the import of auto parts and parts and equipment for the production of electric and hybrid buses in the country.
- Better financing conditions for electric or hybrid vehicles with lower rates and longer terms than those available for traditional buses.

3. Commercial EV Market Potential in Peru

3.1. Scenarios

Scenarios assessed in Report 1 were the IEA 15@30[2], IEA 30@30[3], EV targets based on MINEM and a high growth 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

[2] 15% of EVs as share of vehicle sales in 2030
[3] 30% of EVs as share of vehicle sales in 2030

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[4].

Report 3 will also include 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 4: Urban E-Buses: High Growth Scenario 2025 and 2030

Parameter	2025	2030
Cumulative e-buses	500	3,700
Market share (% of stock)	3%	21%
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 20% is targeted by 2030 equivalent to 3,700 electric buses operating in the country. The main parameters for the high growth market potential are outlined in the following table.

Table 5: High Growth Scenario Electric Urban Buses 2022-2030

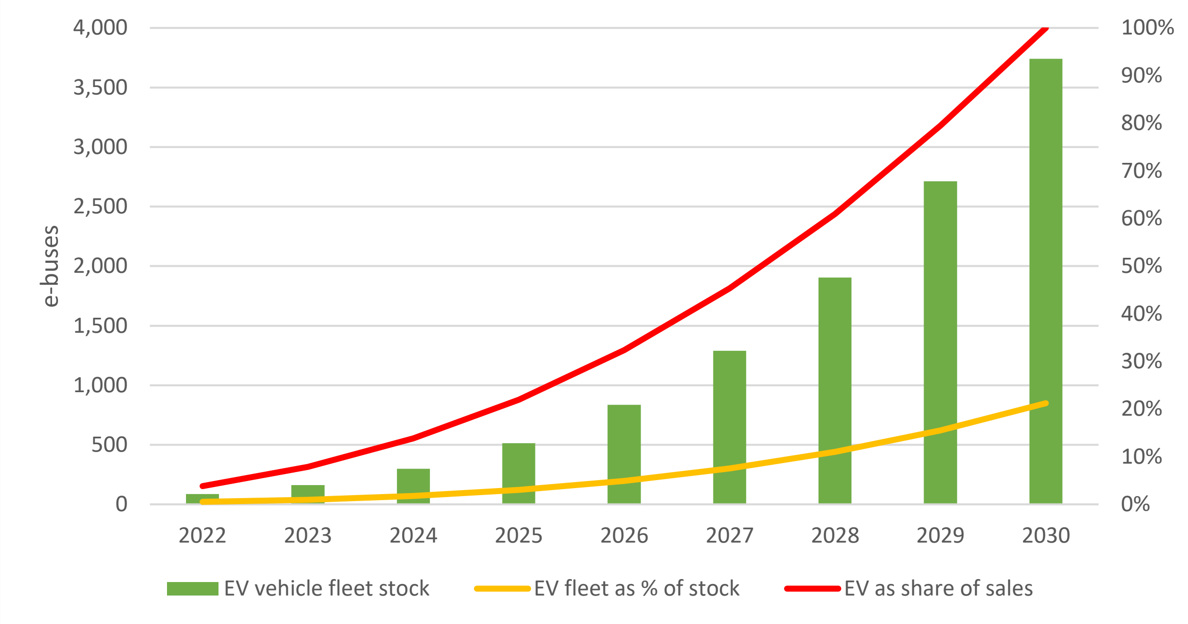
Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock buses	16,428	16,573	16,719	16,867	17,016	17,166	17,317	17,470	17,625
Market of new buses[5]	814	821	829	836	843	851	858	866	874
New registered BEBs	37	76	135	216	321	453	615	810	1,028
Stock BEBs	87	163	298	514	835	1,288	1,904	2,713	3,741
Share BEBs of stock	1%	1%	2%	3%	5%	8%	11%	16%	21%

Source: Grutter Consulting; report 1

[4] For details on scenarios see Country Diagnostic Report Peru

[5] Replacement plus additional vehicles

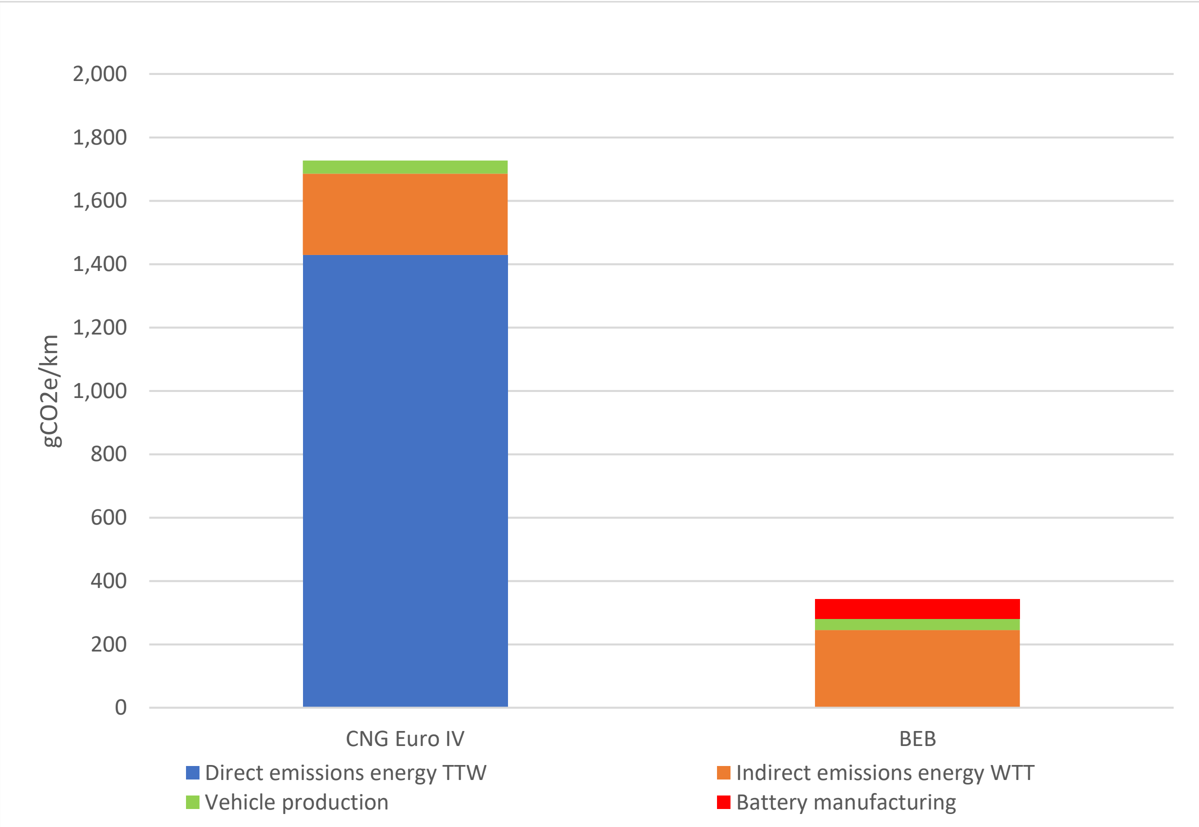
Figure 1: Urban Electric Bus High Growth Scenario



Source: Grutter Consulting

A BEB can reduce well-to-wheel (WTW) Greenhouse Gas (GHG) emissions in Peru by 85% and cradle to grave emissions by 80% compared to a CNG unit (see figure below).

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



Source: Grutter Consulting; mileage and energy consumption based on values for Peru; major assumptions include 57,000km annual mileage; 48 kg/100km CNG and 1.1 kWh/km BEB; 14-year lifespan CNG and 16-year BEB; 8-year lifespan of battery; battery set of average 260 kWh; 110kg CO_2/kWh battery (ICCT, 2018); grid factor 0.223 $kgCO_2$/kWh (IEA data)

3.3. Electric Taxis

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

Table 6: Electric Taxis: High Growth Scenario 2025 and 2030

Parameter	2025	2030
Cumulative e-taxis	17,000	155,000
Market share (% of stock)	6%	47%
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.

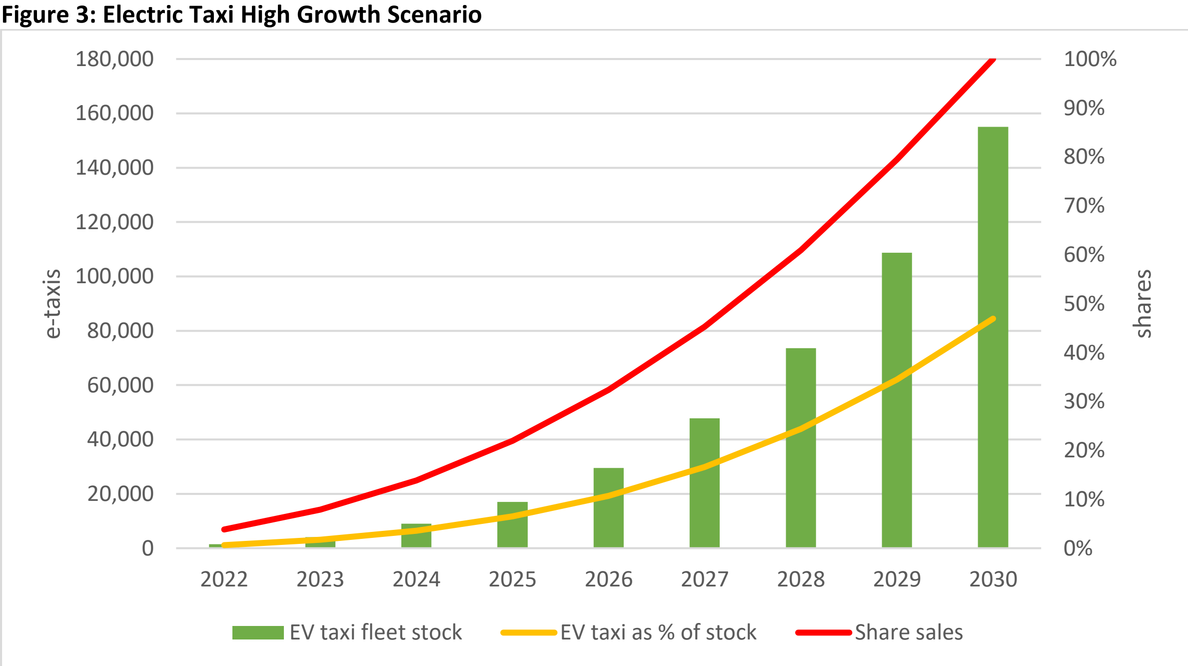
Table 7: High Growth Scenario Electric Taxis 2022-2030

Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock taxis	229,358	240,073	251,288	263,026	275,313	288,175	301,636	315,727	330,476
New sales taxis[6]	21,912	22,936	24,007	25,129	26,303	27,531	28,817	30,164	31,573
Target rate e-taxis of sales	10,236	10,714	11,215	11,739	12,287	12,861	13,462	14,091	14,749
New e-taxis	1,229	2,657	4,880	8,087	12,483	18,294	25,765	35,170	46,322
Stock e-taxis	1,429	4,086	8,967	17,054	29,537	47,831	73,596	108,765	155,087
Share e-taxis of stock	1%	2%	4%	6%	11%	17%	24%	34%	47%

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

As of 2030 155,000 e-taxis would be electric with this scenario.

Figure 3: Electric Taxi High Growth Scenario

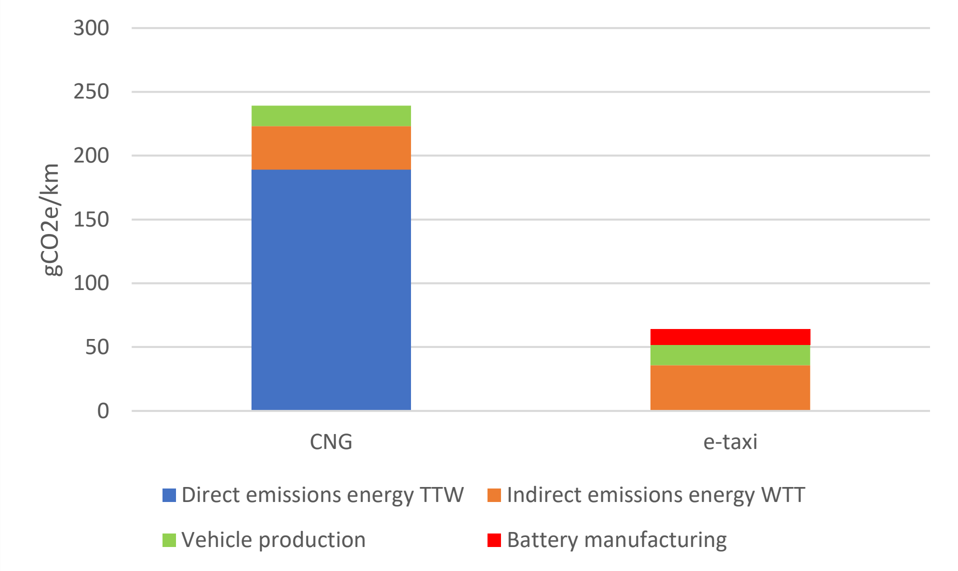


Source: Grutter Consulting

[6] Replacement plus additional vehicles

An electric taxi can reduce WTW emissions in Peru by 84% and cradle to grave emissions by 73% (see figure below).

Figure 4: GHG Impact Electric Taxi



Source: Grutter Consulting; mileage and energy consumption based on values for Peru; major assumptions include 53,000km annual mileage; 6.3 kg/100km CNG and 0.16 kWh/km e-taxi; 10-year lifespan CNG and e-taxi; 10-year lifespan of battery; battery set of 60 kWh; 110kg CO_2/kWh battery (ICCT, 2018); grid factor 0.223 kgCO_2/kWh (IEA)

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 8: Electric LCVs: High Growth Scenario 2025 and 2030

Parameter	2025	2030
Cumulative e-LCVs	3,300	29,000
Market share (% of stock)	4%	33%
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 9: High Growth Scenario Electric LCVs 2022-2030

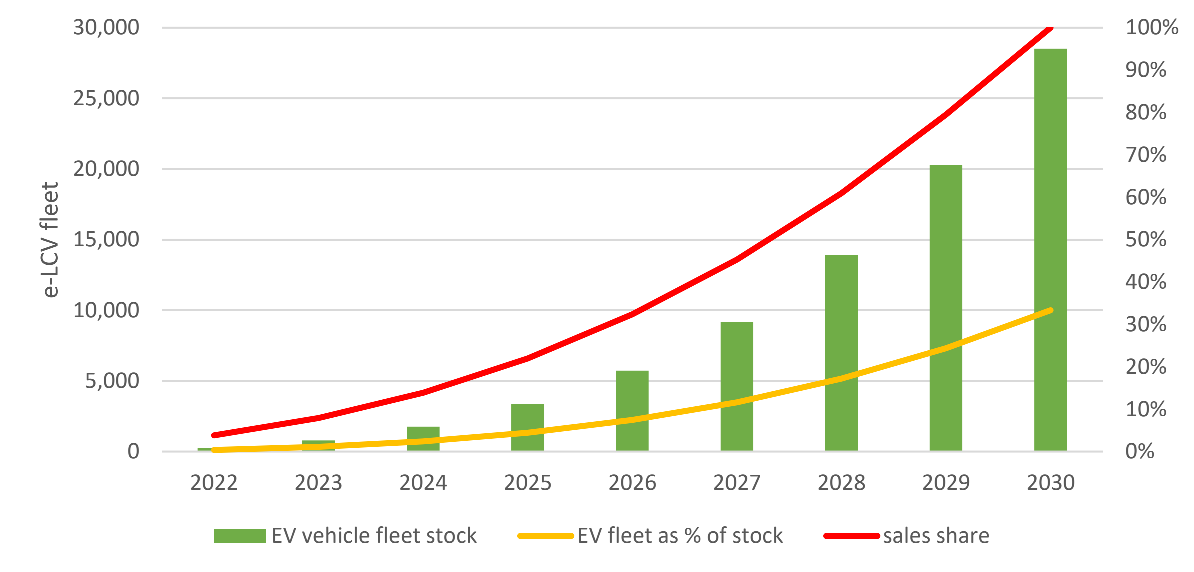
Parameter	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock LCVs	68,869	70,759	72,700	74,695	76,745	78,851	81,014	83,237	85,521
new LCVs[7]	4,788	4,919	5,054	5,193	5,335	5,482	5,632	5,787	5,946
Target rate e-LCVs of new sales	1,839	1,890	1,942	1,995	2,050	2,106	2,164	2,223	2,284
New sales e-LCVs	253	538	969	1,577	2,389	3,436	4,751	6,365	8,230
Stock e-LCVs	257	795	1,764	3,341	5,730	9,166	13,917	20,282	28,512
Share e-LCVs of stock	0%	1%	2%	4%	7%	12%	17%	24%	33%

Source: Grutter Consulting, report 1

As of 2030 nearly 30,000 e-LCVs would operate in Peru with this scenario.

[7] Replacement plus additional vehicles

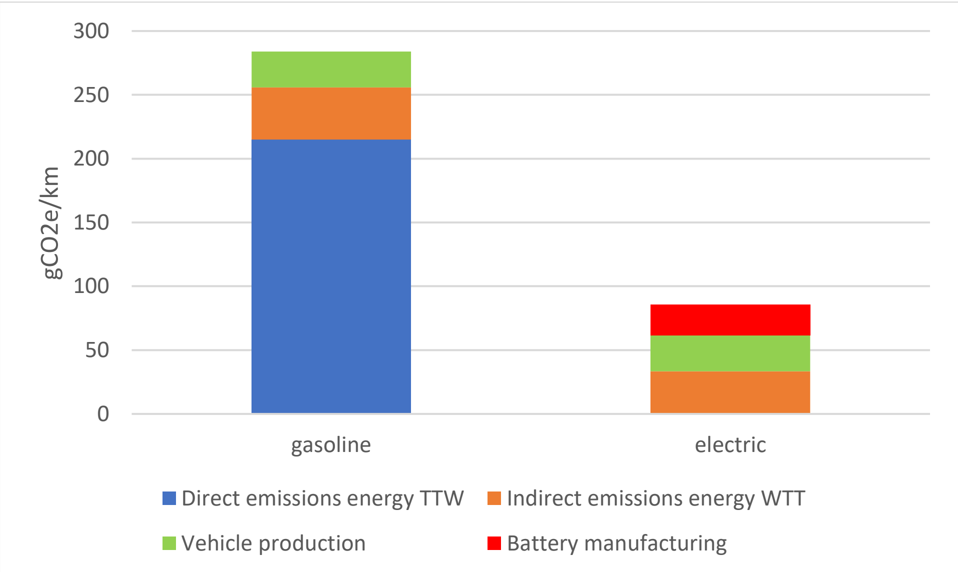
Figure 5: LCV High Growth Scenario



Source: Grutter Consulting

LCVs are a remarkably diverse segment of vehicles with different vehicle sizes and very different usage patterns and therefore also very different mileage as well as lifespan of usage. Based on an LCV as used by many delivery services (500-800kg carrying capacity) an electric LCV can reduce WTW emissions in Peru by 87% and cradle to grave emissions by 70% (see figure below).

Figure 6: GHG Impact Electric LCV



Source: Grutter Consulting; mileage and energy consumption based on values for Peru based on Suzuki APV gasoline versus Maxus E-Deliver; major assumptions include 20,000km annual mileage; 8.5 l/100km and 0.15 kWh/km e-LCV; 15 year lifespan gasoline and e-LCV; 8-year lifespan of battery; battery set of 35kWh; 110kg CO_2/kWh battery (ICCT, 2018); grid factor 0.223 kgCO_2/kWh; see for details Annex

4. Financial Assessment of Commercial EVs in Peru

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 Peru[8];
- 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

[8] The WACC is different due to differential loan terms.

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 Peru for the transport sector.

Table 10: WACC Transport Sector Peru (all rates in USD)

Parameter	Value	Source
Cost of equity	10.3%	(UNFCCC, 2019); value for transport sector of Peru
Share of equity financing	20%	Banks are willing to finance 80% with loans
Cost of debt	10.5%	Current average rate of FIs
Share of debt financing	80%	Banks are willing to finance 80% with loans
Corporate tax rate	30%	Deloitte, 2020
WACC	8.0%	Calculated

4.2. Financial Analysis E-Buses

4.2.1. General Data

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

- An overnight charged BEB with a battery set of 310 kWh[9];
- 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 general parameters, the diesel bus specific values, the overnight BEB and the fast-charged BEB specific values.

[9] 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.

Table 11: General Bus Parameters

Parameter	Value	Source
Distance driven per bus per annum	57,000 km	IDB, 2020

Table 12: Baseline Fossil Bus Parameters

Parameter	Value	Source
Diesel usage	50 l/100km	(IDB, 2020)
CNG usage	48 kg/100km	(IDB, 2020)
Maintenance cost diesel bus	0.25 USD/km	(IDB, 2020)
Maintenance cost CNG bus	0.38 USD/km	(IDB, 2020)
Cost of diesel	0.81 USD/l	https://www.globalpetrolprices.com/
Cost of CNG	0.29 USD/kg	(IDB, 2020)
Insurance cost as % of CAPEX	1.4%	(IDB, 2020)
CAPEX diesel bus	118,000 USD	(IDB, 2020) includes taxes
CAPEX CNG bus	147,000 USD	(IDB, 2020) includes taxes
Lifespan fossil bus	14 years	(IDB, 2020)

Table 13: BEBs Common Parameters

Parameter	Value	Source
Specific electricity usage	1.1 kWh/km	Chinese average; (ADB, 2018); includes AC usage
Maintenance cost	0.15 USD/km	(ADB, 2018)
Insurance cost as % or CAPEX	2.2%	(IDB, 2020)
Lifespan bus	16 years	Maximum based on battery age (1x replacement)
Lifespan battery @ 80% SOH	8 years	current guarantee levels of BEBs
Reduction battery cost in 8 years	50%	US DOE projections, 2017 have a decrease of 12% per annum; applied to 5 years[10];
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

Table 14: BEB Overnight Charged Bus

Parameter	Value	Source
CAPEX bus	378,000 USD	IDB, 2020, based on Yutong with 320 kWh battery base price plus 16% IGV and 2% ISC tax
CAPEX batteries	200 USD/kWh	LFP batteries
Battery capacity	310 kWh	Calculated based on workday range with sufficient
Charger power	40 kW	Calculated based on available charging time and daily average electricity usage

[10] https://energy.gov/sites/prod/files/2017/02/f34/67089%20EERE%20LIB%20cost%20vs%20price%20metrics%20r9.pdf

Table 15: BEB Fast Charged Bus

Parameter	Value	Source
CAPEX bus	295,000 USD	Includes taxes
CAPEX batteries	250 USD/kWh	NMC batteries
Battery size	200 kWh	Calculated based on workday range with sufficient margins and battery sets cum C-rates as offered in the market (see Annex)
Night charger power	40 kW	Calculated based on available charging time and daily average electricity usage
Fast-charger power	300 kW	Calculated for additional 100km in 20 minutes
Number of buses per fast charger	10 buses / charger	Calculated for small fleets (average in PR China 6-10 buses)

For e-buses, in principle, it is important to recognise that a sound financial scheme has as its benchmark a sound debtor and, to that extent, well-structured PPP schemes, with tariffs and contractual indemnities that appropriately consider the risks in the concession contracts, are what make an attractive programme for direct private investment and for DFI banks such as Proparco and commercial debt.

4.2.2. TCO

The following table shows the results of the TCO calculation.

Table 16: TCO Calculations (USD of 2020)

Parameter	Diesel	CNG	BEB overnight	BEB fast
CAPEX bus	118,000	157,000	377,600	295,000
CAPEX charging infrastructure	0	0	7,300	11,150
CAPEX grid connection	0	0	30,000	30,000
CAPEX depot upgrade	0	0	7,500	7,500
Total CAPEX	**118,000**	**157,000**	**422,400**	**343,650**
Battery replacement yr. 8	0	0	31,000	25,000
Energy cost yr. 1	21,577	7,749	10,629	10,629
Maintenance cost bus yr. 1	14,250	21,660	8,436	8,436
Insurance cost average	974	1,295	4,413	3,448
Maintenance cost infra yr. 1	0	0	896	973
Finance cost average per year	2,807	3,735	10,048	8,175
Economic costs yr. 1	5,187	4,906	959	959
Total OPEX (financial) yr 1	**39,607**	**34,439**	**34,422**	**31,661**
TCO financial per km	**0.82**	**0.77**	**1.10**	**0.96**
TCO economic per km	**0.93**	**0.87**	**1.12**	**0.98**

Source: Grutter Consulting

Following conclusions are drawn:

- Comparing total costs over the bus lifetime of 16 years BEBs have a significantly higher TCO than diesel or CNG buses.
- 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 17: Capital Demand (USD of 2020)

Capital investment BEB relative to CNG bus (per unit)	BEB overnight		BEB fast charged	
	Absolute	%	Absolute	%
Additional capital investment	265,000	169%	187,000	119%
Additional loan demand	176,000	141%	110,000	88%
Additional equity requirement	89,000	283%	76,000	243%

Source: Grutter Consulting

BEBs require a 2-3x higher capital investment than diesel buses[11]. Loans are currently only available for the bus component and limited to 80% of the capital. This means loans will increase by around factor 2. 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 2.5 to 3. 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 30 instead of 10 diesel or CNG buses thus increasing his absolute profits by increasing service levels (one BEB will deliver the same level of revenues as one fossil bus).

4.2.4. Relative Profitability

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

- The FIRR of overnight charged BEBs is -13% and of fast-charged BEBs of -6%.
- The EIRR is -5% respectively 0%.

The investment in BEBs is thus not profitable 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.

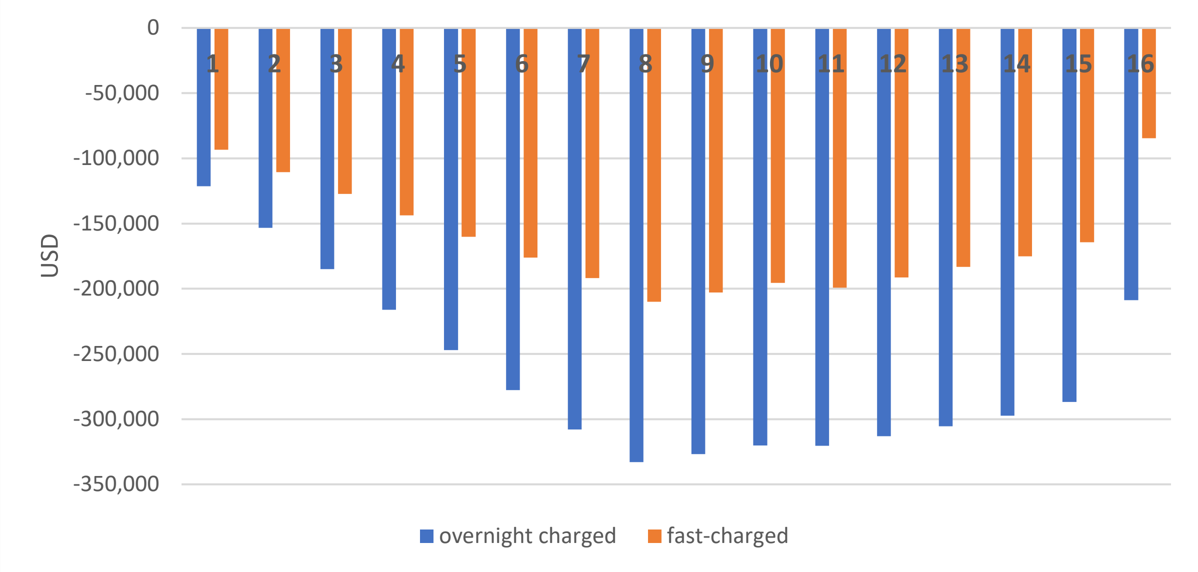
In both cases the discounted payback shows that the initial incremental investment is not recovered i.e. the payback period is longer than the lifetime of the equipment. This points to a non-profitable and high-risk investment.

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 CNG bus. Only cash outflows are considered as revenues (cash inflows) are identical between a BEB and a CNG bus. The cumulative CF remains negative in the 16 years.

[11] 2x higher capital investment is identical to incremental 100%

Figure 7: Cumulative Differential CF CNG and BEB (USD)



Source: Grutter Consulting

Cumulative CF initially drops due to higher loan repayments for BEBs than for CNG buses.

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 18: Summary Financial Assessment BEBs

Criteria	Result	Assessment
TCO	30% higher for BEBs	Non-discounted the cumulated lifetime costs for BEBs are higher than for fossil buses, especially against CNG units
Capital investment	2.5x of a conventional bus	Significantly higher capital requirement incl. higher loan demand; negative impact on debt-to-equity ratio
Equity investment	3x of a conventional bus	Significantly higher equity demand which might overstretch the capabilities of small and medium enterprises
Profitability	FIRR negative	Investment in e-buses is not profitable.
Discounted Payback	Incremental investment is not recovered with savings during asset lifetime (16yrs)	The investment in e-buses is not profitable and the payback time is extremely 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 Peru.

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 in USD.

Table 19: Concessional Loan Parameters

Parameter	Current conditions	Concessional conditions
Loan tenure	7 years	12 years
Interest rate	7%	4.2%
Lending rate	80% of bus investment	80% of total investment

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 5.5% interest rate.

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

Table 20: Impact of Concessional Loan Conditions

Parameter	overnight charged BEB	fast charged BEB
TCO financial old	1.12	0.98
TCO financial new	1.02	0.90
FIRR old	-12.8%	-6.1%
FIRR new	-12.8%	-6.1%
Additional equity old	283%	243%
Additional equity new	169%	119%
Discounted Payback in years old	never	never
Discounted Payback in years new	never	never

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces by around 0.1 USD/km but remains above the TCO of CNG buses.
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). Owners capital is however still 120-170% above the amount required for fossil buses.
4. The risk and the capital exposure of the entrepreneur can be reduced the investment is not recovered in the asset lifespan.

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 21: Impact of 20% Upfront Grant + Concessional Loan Conditions

Parameter	overnight charged BEB	fast charged BEB
TCO financial old	1.12	0.98
TCO financial new	0.85	0.79
FIRR old	negative	negative
FIRR new	negative	4.0%
Additional equity old	283%	243%
Additional equity new	88%	53%
Discounted Payback in years old	never	never
Discounted Payback in years new	never	never

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces considerably with values now comparable to that of fossil buses.
2. The FIRR increases and is now positive of fast-charged buses.
3. Owners capital requirements are reduced significantly.
4. The risk and the capital exposure of the entrepreneur is reduced. However, this incremental investment is, compared to a CNG bus, still not recovered during the lifespan of the asset.

It can be concluded that the grant resolves partially the profitability and risk issue. The payback period is still too long i.e. additional incentives are required. This means that for e-bus deployment in areas with CNG availability either the authorities would need to force bus owners to use BEBs (which would entail eiterh deficits of operators or would require (higher) subsidies of the government or would result in higher user tariffs and thus a reduction of public transport demand) or additional subsidies would be required.

4.3. Financial Analysis E-Taxis

4.3.1. General Data

Calculations are realized for the standard taxi as used in Peru. The following tables indicate the general parameters, the CNG taxi specific values, and the e-taxi specific values. The average mileage assumed of taxis is 53,000 km.

Table 22: Baseline CNG Taxi Parameters

Parameter	Value	Source
CNG usage	6.3 kg/100km	Average for Euro 4 unit based on EEA, 2019
Maintenance cost	0.03 USD/km	For CNG taxi, excludes tyres and repairs
CAPEX	14,000 USD	1,000 USD additional to gasoline unit
Lifespan	10 years	Average usage time as taxi

Table 23: E-Taxi Parameters

Parameter	Value	Source
Specific electricity usage	0.16 kWh/km	Nissan LEAF or BAIC taxi
Maintenance cost	0.02 USD/km	50% below fossil
Lifespan	10 years	Max. based on battery age (commensurate with concession period)
Lifespan battery @ 70% SOH	10 years	
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.

Table 24: TCO Calculations (USD of 2020)

Parameter	CNG	e-taxi
CAPEX taxi	14,000	30,000
CAPEX charging infrastructure	0	2,000
Total CAPEX	**14,000**	**32,000**
Energy cost	954	1,654
Maintenance cost	1,749	875
Finance cost average p.a. during loan term	333	761
Economic costs of emissions year 1	492	76
Lifespan in years	10	10
TCO financial per km	**0.08**	**0.12**
TCO economic per km	**0.09**	**0.12**

Source: Grutter Consulting

Comparing total costs over the taxi lifetime of 10 years e-taxis have higher financial and economic TCO than CNG 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 25: Capital Demand (USD of 2020)

Comparison e-taxi to CNG taxis	Absolute	%
Additional capital investment	18,000	129%
Additional loan requirement	14,400	129%
Additional equity requirement	3,600	129%

Source: Grutter Consulting

E-taxis require a capital investment factor 2 of a CNG unit. The required equity increases by the same rate. 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 CNG units:

- The FIRR is -32% and below the WACC of 8%.
- The EIRR is -18%.

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 CNG 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 CNG unit. Only cash outflows are considered as revenues (cash inflows) are identical between an e-taxi and a CNG unit. The cumulative CF remains negative over the asset lifetime.

4.3.7. Summary Financial Assessment

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

Table 26: Summary Financial Assessment E-Taxis

Criteria	Result	Assessment
TCO	Higher for e-taxis than for CNG units	Non-discounted the cumulated lifetime costs for e-taxis are higher than for CNG units.
Capital investment	2x of a conventional taxi	Significantly higher capital requirement incl. higher loan demand
Equity investment	2x of a conventional taxi	Significantly higher equity demand which might overstretch the capabilities of taxi owners
Profitability	Negative	Investment in e-taxis is not profitable
Discounted Payback	Incremental investment is not recovered	This indicates a high risk profile of the investment.
Cash Flow	Negative cumulative CF 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 not profitable and 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 27: Concessional Loan Parameters

Parameter	Current conditions	Concessional conditions
Loan tenure	7 years	7 years
Interest rate	10.5%	5.7%
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 5.5% interest rate plus 1.5% spread of the national banking system.

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

Table 28: Impact of Concessional Loan Conditions

Parameter	e-taxi
TCO financial old	0.12
TCO financial new	0.12
FIRR old	Negative
FIRR new	Negative
Additional equity old	129%
Additional equity new	129%
Discounted Payback in years old	Not recovered
Discounted Payback in years new	Not recovered

Source: Grutter Consulting

The concessional loan improves the liquidity but is insufficient to change other parameters in a significant manner.

Investment Grant

An upfront grant of 20% on the total initial investment with standard (i.e. not concessional finance) is modelled. The following table shows the impact of an upfront grant.

Table 29: Impact of 20% Upfront Grant (standard financial conditions)

Parameter	e-taxi
TCO financial old	0.12
TCO financial new	0.11
FIRR old	Negative
FIRR new	Negative
Additional equity old	129%
Additional equity new	no equity
Discounted Payback in years old	Not recovered
Discounted Payback in years new	Not recovered

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO reduces marginally.
2. The FIRR remains negative.
3. Owners capital requirements are 0.
4. The risk and the capital exposure of the entrepreneur is reduced but not significantly.

It can be concluded that the grant does not resolve the problems. The cost of energy of the CNG taxis is lower than of e-taxis. The lower maintenance costs of e-taxis cannot offset this.

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 tables indicates the gasoline LCV specific values, and the e-LCV specific values. The annual assumed mileage is thereby 20,000km.

Table 30: Baseline Gasoline LCV Parameters

Parameter	Value	Source
Gasoline consumption	8.5 l/100km	https://www.carsguide.com.au/suzuki/apv
Maintenance	0.04 USD/km	Vehicle manufacturer
CAPEX	17,500 USD	https://autos.suzuki.com.pe/auto/apv-van
Lifespan	15 years	300,000 km lifespan mileage

Table 31: E-LCV Parameters

Parameter	Value	Source
Specific electricity usage	0.15 kWh/km	WLTP for Maxus E-Deliver
Maintenance	0.02 USD/km	50% of fossil version
Lifespan	15 years	Same as gasoline version; 1x exchange batteries
Lifespan battery @ 70% SOC	10 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	31,000 USD	Maxus E-Deliver with 4.8m³ cargo volume; short-wheel base; small battery version[12]
CAPEX home charger 7.4kW	2,000 USD	Wall-box installation
Lifetime charger	10 years	Based on ABB

4.4.2. TCO

The following table shows the results of the TCO calculation.

Table 32: TCO Calculations (USD of 2020)

Parameter	Gasoline	e-LCV
CAPEX LCV	17,500	31,000
CAPEX charging infrastructure	0	2,000
Replacement battery cost in year 7	0	3,500
Total CAPEX	**17,500**	**33,000**
Energy cost	1,615	495
Maintenance cost	850	425
Finance cost average p.a. during loan term	833	1,570
Economic costs of emissions year 1	187	27
Lifespan in years	15	15
TCO financial per km	**0.20**	**0.21**
TCO economic per km	**0.21**	**0.21**

Source: Grutter Consulting

Comparing total costs over the LCV lifetime of 15 years e-LCVs have comparable financial and economic TCOs as gasoline 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 33: Capital Demand (USD of 2020)

Comparison e-LCV to gasoline LCV	Absolute	%
Additional capital investment	16,000	89%
Additional loan	12,000	89%
Additional equity	3,000	89%

Source: Grutter Consulting

[12] https://saicmaxus.co.uk/edeliver3/

E-LCVs require nearly double the capital investment than gasoline units. The required equity increases by the same rate.

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 3% and clearly below the WACC of 8%.
- The EIRR is 5%.

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 5 onwards due to savings on maintenance and energy sufficient to cover the additional finance outlays and initial equity injection.

4.4.7. Summary Financial Assessment

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

Table 34: Summary Financial Assessment e-LCVs

Criteria	Result	Assessment
TCO	Comparable e-LCV and gasoline unit	
Capital investment	90% higher than a conventional LCV	Higher capital requirement incl. higher loan demand
Equity investment	90% higher than a conventional LCV	Higher equity demand
Profitability	3%	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 5	The investment in e-LCVs has no large negative liquidity impact in initial years

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. Also electric LCVs are not common in the market and are not offered by vehicle suppliers in Peru.

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 35: Concessional Loan Parameters

Parameter	Current conditions	Concessional conditions
Loan tenure	7 years	7 years
Interest rate	10.5%	5.7%
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 5.5% interest rate plus 1.5% spread of the national banking system.

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

Table 36: Impact of Concessional Loan Conditions

Parameter	e-LCV
TCO financial old	0.21
TCO financial new	0.19
FIRR old	3%
FIRR new	3%
Additional equity old	89%
Additional equity new	89%
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 with standard (i.e. not concessional finance) is modelled. The following table shows the impact of an upfront grant.

Table 37: Impact of 20% Upfront Grant (standard financial conditions)

Parameter	e-LCV
TCO financial old	0.21
TCO financial new	0.17
FIRR old	3%
FIRR new	14%
Additional equity old	89%
Additional equity new	no equity
Discounted Payback in years old	never
Discounted Payback in years new	none

Source: Grutter Consulting

Following impacts can be observed:

1. The TCO is now significantly lower than for gasoline units.
2. The FIRR is above the WACC i.e. the investment is now profitable.
3. Owners capital requirements are 0.
4. The risk and the capital exposure of the entrepreneur is not reduced significantly.

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 Perú:

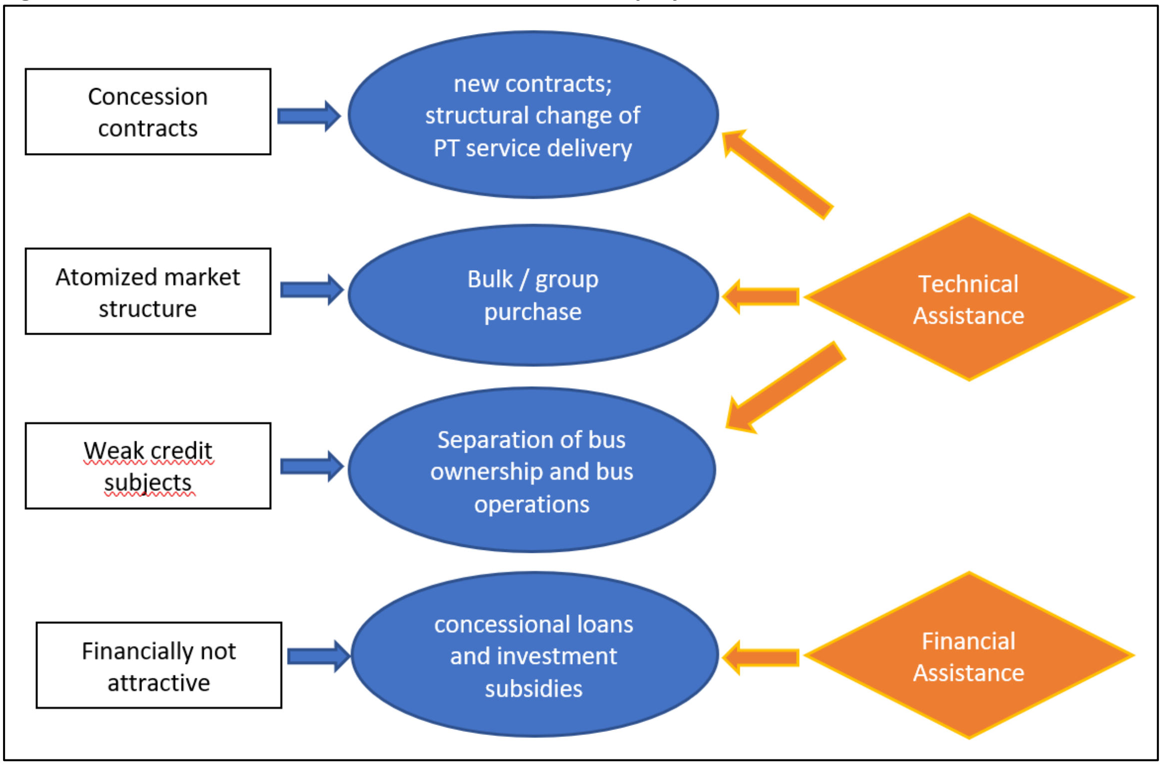
Table 38. Main barriers to commercial EVs

Barrier Type	Concrete Aspects
Loans	No special credit lines for EVs are in operation. Loans are currently only available for the bus component and limited to 80% of the capital. The most important impact is on the required equity: this increases by the factor 2.5 to 3.
Political situation	There is not currently a national policy on electric mobility. °· Atomized transport sector which hinders capital investment. Public transport structures in Peru need to be consolidated/formalised and reformed. This also inhibits viable business models and therefore higher CAPEX is an even greater challenge. °· Production of cheaply priced gas for vehicle use
Technical capacity	Public institutions in charge of leading and encouraging the electrification of transportation in each of the cities fall short in terms of knowledge (Osinergmin, 2019). The transition to electric transportation systems will be slowed down with the lack of trained staff.
Procurement policies	Procurement policies are not in line with e-mobility requirements with more focus on initial investment costs and with too short concession contract periods in relation to the long payback periods of EVs.
Lack of domestic supply chain	Currently there is no local supply chain for the manufacture and assembly of electric vehicles, which generates a lack of availability of spare parts in the country. This results in higher maintenance and repair costs of EVs (Osinergmin, 2019).
Economic issues	the cost of electric energy compared to CNG.
Regulatory framework to exploit lithium	Peru does not have a regulatory framework for the exploitation and export of lithium and uranium (Osinergmin, 2019).
Financial	BEBs are not profitable and not commensurate with the risks associated with investing in a new technology with many unknown performance factors and costs. The FIRR is negative and the discounted payback shows that the initial incremental investment is not recovered i.e. the payback period is longer than the lifetime of the equipment.
Technical	Being a major gas-producing country makes it consider this option as a priority to be used as a mobility technology, rather than electricity, in the same sense that electricity production plants operate with gas, which leads to consider the energy balance of using electricity in cars produced from a fossil fuel rather than the greater efficiency of electric vehicles.

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 a 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 8: 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 extendable by 9 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 in Mexico.

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 of Pakistan or in Medellin. To overcome the problem of guarantees and costly financial conditions a separation of ownership and operations is an important condition, especially in Peru's domestic market conditions 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. However, in the case of Peru this is not sufficientfor E-buses if they compete with CNG units. In report 3 it will be shown that it is however of interest in the case of a competition with diesel buses for cities without gas pipelines.

5.1.2. Potential Investment Project

The following table list identified potential investment project for Peru.

Table 39: Potential Investment Projects e-Buses Peru

ID	Ownership	Project	Nu. of units	Estimated CAPEX	Estimated GHG impact[13]	Timeline
1	public	Public bidding for 12 route packages in Lima/Callao; implemented by private operators;	3,400 buses of which 400 18m, 2,400 12m and 500 9m units	580 MUSD	2,370,000 tCO_{2e} reduced	50% in 2023 and 50% in 2024
2	private	Transporte Cruz de Sur/ BRT El Metropolitano for Lima	100 12m buses of bidding package listed under 1	34 MUSD	140,000 tCO_{2e} reduced	2023
3	private	Lima Bus / BRT El Metropolitano for Lima	150 12m buses and 110 18m buses of bidding package listed under 1	133 MUSD	420,000 tCO_{2e} reduced	2023
4	public	e-bus project for Trujillo with a private operator	46 18m units	36 MUSD	90,000 tCO_{2e} reduced	2024
5	private	e-buses for Arequipa	76 12m units	26 MUSD	110,000 tCO_{2e} reduced	2022
6	private	Lima vías / BRT El Metropolitano for Lima	100 12m buses and 90 18m buses of bidding package listed under 1	101 MUSD	310,000 tCO_{2e} reduced	2023

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.

5.1.2. Asset separation model

This 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

[13] Cumulative lifespan of units

can invest in one or more components of the project: vehicle fleet, recharging infrastructure or even the adaptation of yards 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 asset separation 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.

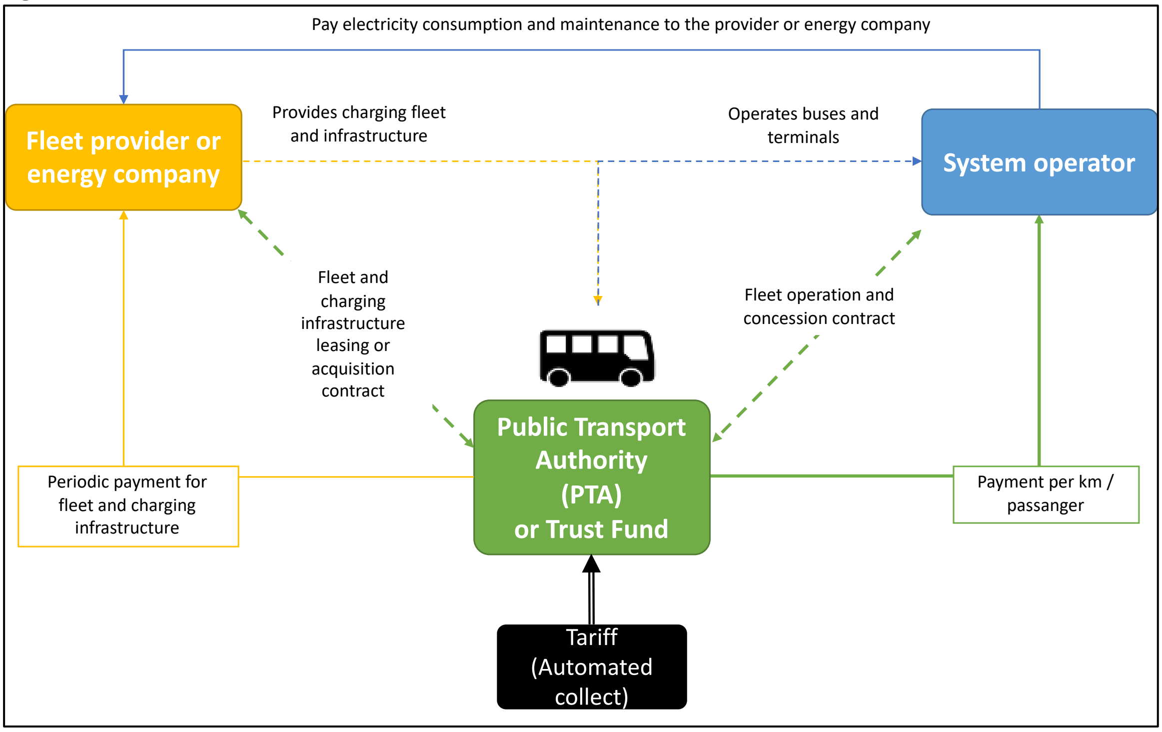
2. **Vehicle fleet operator:** is responsible for the operation of the service and will have a legal relationship with the transport authority, or managing company, through a service provision contract during the concession period, which could eventually be 15 years.

   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. An alternative to the latter option could be for a public entity to own the equipment and, directly, for that entity to provide a guarantee of repayment to lending agencies, thus providing a higher level of lender confidence.

Figure 9: Possible business models for urban buses



Source: Grutter Consulting

5.1.3. Technical Assistance

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

- Design and implementation of a roadmap for e-bus deployment that includes concrete steps and goes beyond target setting.
- Policy development aimed at encouraging electromobility.
- Development of national regulatory schemes that allow for standardised and reliable statistical information on the urban transport sector.
- Structuring of appropriate tenders and concession contracts with conditions that favour e-bus deployment, including the duration of the concession, the structuring of fares, guarantees, their requirements, etc.
- Structuring of public transport models leading to stronger and fewer operators, e.g. in the sense of separating fleet ownership and operation.
- Development of technical skills in personnel from different areas and specialties such as: public officials, potential private investors, bankers and insurance company executives, drivers and mechanics, first responders: firefighters, paramedics, law enforcement personnel, among the most significant.
- Structuring of favourable conditions to encourage the entry of financially strong players into the public transport business, e.g. as bus owners. This could be private companies or a special-purpose municipal entity, a public-private partnership, or a municipality or government-led bus procurement. There are multiple models that need to be evaluated to address the problem of atomised ownership and weak creditworthy subjects.
- Evaluation of optimal e-bus technology and charging systems to enable a robust and cost-effective deployment of e-buses.

- To counteract the imaginary benefits of gas vehicle consumption, it is necessary to disseminate the benefits, especially environmental, generated by electromobility.
- Technical assistance to generate a policy of differential electricity tariffs for e-vehicle recharging to offset the cost of recharging infrastructure.
- Policies for the second life of batteries and their correct disposal.
- Dissemination of information and knowledge, as well as advisory services to companies and public entities interested in investing in taxis and light commercial vehicles.

The following financial intervention instruments are proposed for e-bus deployment in Peru, with a focus only on regions where no gas pipelines exist (asee report 3 for details)

- 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 (12 years or longer), a high loan share (80% of total investment) and the ability to take vehicles as loan guarantee[14]. Together with the entrance of financially stronger players this should be capable to cut interest rates by 50%.

Low-cost CNG makes investments in e-buses unattractive. Concessional loans and initial investment grants can tease initial investors. However a closer cost parity will be important to make e-buses commercially viable without subsidies in the case of Peru. In report 3 the BAU price development of e-buses 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 e-buses but a sustainable influx of this technology.

5.2. Taxis and LCVs

5.2.1. Barriers and Intervention Options

The deployment of e-taxis faces two technology related barriers and one generic barrier to the sector:

- Investments in e-taxis or LCVs are financially risky and not profitable.
- Lack of urban fast-charging network catering to the needs of taxi and LCVs drivers. This makes the deployment of electric units a potential financial risk as drivers could lose considerable potential income and profit due to range limitations of e-taxis and lack of public fast-charging facilities.
- The taxi sector is not regulated in Peru with a huge number of eventual taxi drivers and large numbers of old vehicles operating with very low tariffs. Entering this market except for specialized services is not considered to be a viable business option at the moment.
- Lack of information and know-how of options and possibilities of e-mobility in this area. Some companies are interested in EVs but do not have access to information on available models. Vehicle importers are not actively engaging in the business as they have higher profits selling fossil vehicles and their spare parts. In the urban cargo area also vehicles and customer demands vary widely.
- Ownership structures are often a barrier as vehicles are owned by individual drivers and not by the logistics companies or by the cargo company.

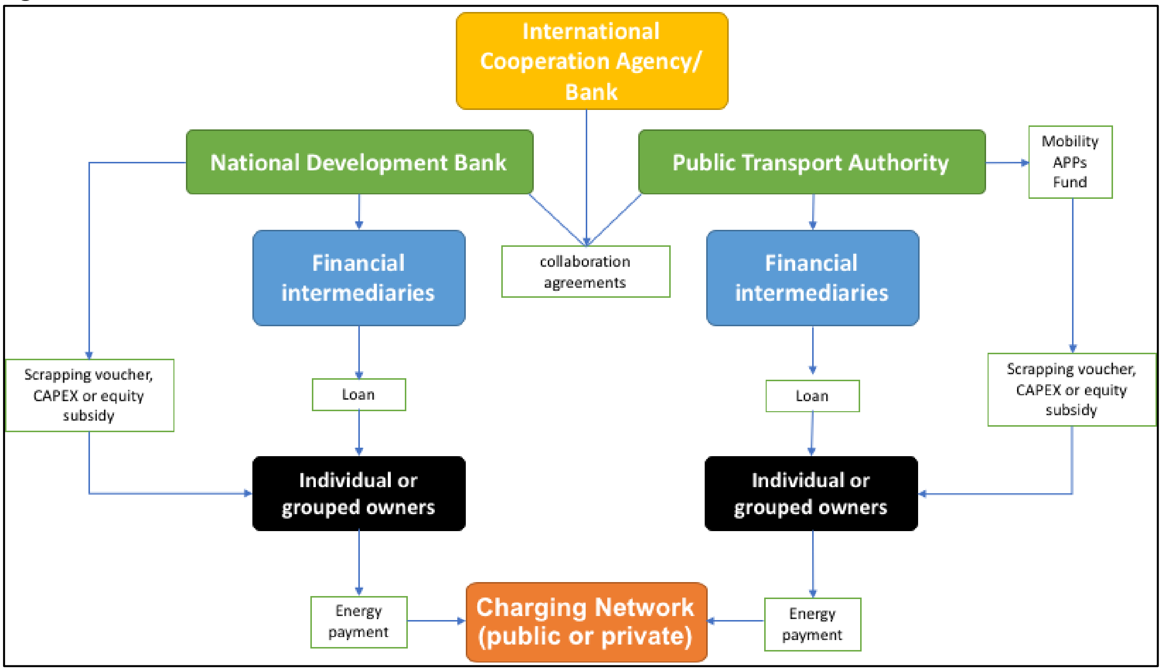
[14] This will require vehicles to be insured against loss.

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 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 - COFIDE:** 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, this development bank 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 – PROMOVILIDAD:** On a national level this entity channels national resources to the cities 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.

Important notes:

1. This business model necessarily requires the creation of a charging infrastructure network, public, private or mixed, 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 recharging network was minimal and generated many inconveniences for Taxi drivers.

2. It is necessary for this model to generate a fast charging network, preferably with 100Kw chargers, focused on Taxis and LCVs. Even 50 kW chargers are not enough to meet the potential demand of vehicles that require fast charging to continue operating efficiently.

3. It has been identified that the private sector that has invested in LCVs, as in the case of Bimbo (Mexico), does not require additional sources of financing because they have sufficient budgetary autonomy to even pay for the acquisition of fleets without the need for credit.

5.2.3. Potential Investment Projects

No taxis operator has mentioned interest in participating in the program. In the short and medium term an investment is not considered to be attractive.

Currently companies are not interested in investing and the profitability is not given with EVs. It is suggested to realize basically technical assistance and potentially at a later stage an investment project. Report 3 will look at the BAU deployment curve for LCVs in Peru and assess if a possible investment project towards year 5 could make sense.

6. TA intervention Areas and Instruments

6.1. TA Actors in E-Mobility

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

German Cooperation Agency – GIZ

The project "Sustainable Urban Transport in Intermediate Cities (DKTI)", implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, works together with with the Ministry of Transport and Communications (MTC) and selected local municipalities. It includes the creation of the National Program for Sustainable Urban Transport 2019 (Promovilidad), which supports medium-sized cities in the development of sustainable and lower-emission urban transport systems. The project offers expert advice on mobility planning and works closely with Peruvian and German universities.

On the other hand, the Peruvian government, under the leadership of the Ministry of Transport and Communications (MTC), developed TRANSPerú, a set of Nationally Appropriate Mitigation Actions (NAMA) consisting of more than 50 measures aimed at reducing GHG emissions related to transport and urban mobility. The project, funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the UK Department for Business, Energy and Industrial Strategies (BEIS), supports these measures within the framework of the Nationally Appropriate Mitigation Action (NAMA) Facility. Through this project, GIZ supports the Ministry of Transport and Communications in the consolidation of structures for the implementation of an efficient public transport system as well as in providing technical assistance to various partners.

GIZ also supports Peru through the TRANSfer Project in the cargo sector. It seeks to reduce GHG emissions through different measures such as eco-driving and the fleet renewal through scrapping programs.

World Resources Institute WRI

In 2014, Peru was awarded an allocation of more than $11 million to finance Peru's urban transport NAMA, known as T-NAMA, an ambitious package of infrastructure investments, new climate-friendly regulations and institutional reforms that will reduce Peruvian greenhouse gas emissions from the transport sector by four million tons of carbon dioxide equivalent over the next decade and improve quality of life. This is equivalent to the emission reductions of taking 760,000 cars off the road for one year. Peru's T-NAMA has been jointly developed by the Peruvian Ministries of Environment and Transport, with the support of GIZ-Transfer, the World Resources Institute (WRI), the Global Alliance for Low Emission Development Strategies (LEDS-GP), the Pontificia Universidad Católica del Perú (PUC), Transitemos and other local partners.

This award reflects Peru's leadership in the fight against climate change through the transport sector. As national leaders at COP20 look for ways to reduce greenhouse gas emissions, Peru's efforts highlight the role of sustainable and integrated urban transport in curbing emissions at the country and city level and demonstrate the potential of NAMAs and climate finance in general to complement large-scale investments in low-carbon infrastructure.

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.

Inter-American Development Bank - IADB

Lima is currently implementing a pilot-test to evaluate different variables to consider when adapting a fleet of electric buses. This program is a joint effort between the Inter-American Development Bank (IADB), the government and the private sector. In 2020, the IDB published a study, coordinated with the Ministry of Energy, in which it analyzes the business models and financing mechanisms for electric buses in Lima. The study showed that it is feasible to adopt financial schemes that encourage investment in clean public transport systems. The project is financed with US$40 million, of which US$20 million is from the Clean Technology Fund (CTF) and the other US$20 million from the IDB loan. The program will have access to long-term financing for private EV projects (replacement of internal combustion engine vehicles with EVs and electric stations preferably powered by renewable energy) and the resources will be provided by the National Development Bank of Peru (COFIDE). This financial approach will have funds not only for EV investment, but also for complementary EV activities such as: awareness raising and capacity building, development of financial models and improvement of the regulatory framework.

COFIDE

COFIDE has a credit line of 30 MUSD, from IDB, for the purchase 20 of 77 electric buses for the SIT of Arequipa. Through this entity, funds can be channeled for the development of electric mobility projects in other cities.

6.2. Possible TA Interventions within the E-Motion Program

The main TA interventions are around capacity building, policies and business models to promote electromobility in the country. It is important that companies such as IDB, ENGIE and Enel X, due to their experience in the sector, generate more agreements with both national and international institutions. The main areas of intervention are presented below:

- Advice on business models, mainly for institutions and public entities interested in investing in LVCs, allowing the integration of these with other actors that have greater capacity and financial experience in transport electrification.
- Advice on procurement policies, with the development of roadmaps for the selection of electric vehicles whose lifetime cost of ownership is the most profitable. This purpose is especially valid and should be oriented in the short term in cities such as Arequipa, Cusco, Ayacucho, among others, which do not have pipeline supplies of this fuel. It is noted that Arequipa plans to acquire 77 electric buses.
- Dissemination of information and advice to companies interested in manufacturing and/or assembling electric vehicles, with potential support for pilot projects.
- Tightening of climate cost policies for greenhouse gases, generation of political, technical, and economic scenarios where the use of electric vehicles can be promoted.
- Clarification of the regulatory framework for the exploitation of lithium and uranium in the country, allowing the manufacture of batteries. In addition, complementation with accurate and sufficient policies and regulations for battery recycling and disposal.

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Annex: Data

General Parameters

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

Electricity Prices

Parameter	Value	Unit
Electricity price home charging	0.15	USD/kWh
Electricity price fast chargers	0.3	USD/kWh
Electricity price medium tension peak	0.09	USD/kWh
Electricity price consumption medium tension off peak	0.07	USD/kWh
Power charge off-peak per month	13	USD/kW
Power charge peak per month	21	USD/kW

Enel; for fast chargers no price yet: thus assumed at double residential
Peak hours 18-23

Calculation for buses

Parameter	Value	Unit
Average electricity price overnight charged buses	0.170	USD/kWh
Average electricity price fast charged buses	0.170	USD/kWh

peak hours can be avoided by both bus types

Finance Costs

Parameter	Value	Unit
Loan term	7	years
Commercial interest rate	10.5%	
concessional interest rate	10.5%	
loan spread	2%	

in USD

WACC

Cost equity	10.3%		UNFCCC, CDM Methodological Tool Investment Analysis Version 10.0, 2019; value for transport sector
Share equity	20%		offers banks, see IDB, 2020 figura 71
Cost bank loan EV	10.5%		see above
Cost bank loan fossil	10.5%		see above
Share bank loan	80%		offers banks
Corporate tax rate	30%		Deloitte, 2020
WACC EV	8.0%		calculated
WACC fossil	8.0%		

TCO 12m Bus

Parameter	Value	Unit	Source
Distance driven per bus per annum	57,000	km	Corredores complementarios; BID, 2020, figure 34
Workday distance driven daily	163	km	calcualted based on 95% availability and 10% above average for workday
Specific electicity usage	1.1	kWh/km	Chinese average; ADB, 2018; includes AC but not heating
Diesel usage	50	l/100km	operator value reported in IDB, 2020, figure 50
CNG usage	48	kg/100km	operator value reported in IDB, 2020, figure 50
maintenance cost CNG bus incl. labor and tyres	0.38	USD/km	operator value reported in IDB, 2020, figure 50
Maintenance cost diesel bus incl. labor and tyres	0.25	USD/km	operator value reported in IDB, 2020, figure 50
CNG cost	0.29	USD/kg	operator value reported in IDB, 2020, figure 50
Insurance diesel / CNG as % of CAPEX	1.4%		operator value reported in IDB, 2020, figure 50
insurance e-bus as % of CAPEX	2.2%		operator value reported in IDB, 2020, figure 50
Lifespan bus diesel	14	years	IDB, 2020 see e.g. Figure 71
Lifespan bus electric	16	years	max based on battery age; can be 20% more than diesel
Lifespan battery @ 80% SOC	8	years	current guarantee levels

Financial defaults

Parameter	Value	Unit	Source
CAPEX diesel bus	118,000	USD	IDB, 2020, figure 44 incl. taxes
CAPEX CNG bus	157,000	USD	IDB, 2020, figure 44 incl. taxes
CAPEX overnight charged e-bus	377,600	USD	IDB, 2020, figure 27 based on Yutong with 320 kWh battery base price plus 16% IGV and 2% ISC tax;
CAPEX slow-charged batteries	200	USD/kWh	LFP batteries
CAPEX fast-charged BEB	295,000	USD	Based on standard fast-charged bus incl. taxes
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 incl. labour	0.15	USD/km	Based on experience in PR China; ADB, 2018; 10% higher tyre costs; 40% lower maintenance staff and
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	163
Energy usage day	kWh	180
Risk ratio (higher energy consumption)		10%
Reserve ratio		20%
SOC loss year 8		20%
Battery size required year 8	**kWh**	**310**

Charging required at bus depot overnight

Parameter	Unit	Value
Battery capacity	kWh	310
Average daily consumption workday	kWh	180
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	40

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	20
Average share of day electricity		11%
Fast-charger	kW	300
Power conversion efficiency of chargers		90%
Average required re-charge day with 300 kW charger	minutes	4
Number of buses per fast-charger	buses / charger	10
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	CNG	BEB overnight	BEB fast
CAPEX bus	118,000	157,000	377,600	295,000
CAPEX charging infrastructure	0	0	7,300	11,150
CAPEX grid connection	0	0	30,000	30,000
CAPEX depot upgrade	0	0	7,500	7,500
Total CAPEX	118,000	157,000	422,400	343,650
Battery replacement yr 8	0	0	31,000	25,000
Energy cost yr 1	21,577	7,749	10,629	10,629
Maintenance cost bus yr 1	14,250	21,660	8,436	8,436
Insurance cost average	974	1,295	4,413	3,448
Maintenance cost infra yr 1	0	0	896	973
Finance cost average per year	2,807	3,735	10,048	8,175
Economic costs yr 1	5,187	4,906	959	959
TCO financial per km	0.82	0.77	1.10	0.96
TCO economic per km	0.93	0.87	1.12	0.98

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

TCO Taxis

Parameter	Value	Unit	Source
Average battery size	60	kWh	Nissan Leaf 2020; idem BAIC
Battery lifespan	10	years	idem to vehicle lifespan
Vehicle lifespan	10	years	
Annual mileage	53,000	km	
Daily mileage	171	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 CNG taxis	14,000		1000 more than gasoline taxi
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
CNG consumption	6.3	kg/100km	
Electricity consumption	0.16	kWh/km	Nissan LEAF https://ev-database.org/car/1106/Nissan-Leaf
Charger lifespan	10	years	
Maintenance cost CNG	0.033	USD/km	excludes tyres
Maintenance cost total e-taxi	0.017	USD/km	50% lower than cng
Loan tenure taxi	7	years	Bank conditions
Loan share taxi	80%		

CNG versus e-taxi

Parameter	CNG	e-taxi
CAPEX vehicle	14,000	30,000
CAPEX charger	0	2,000
Total CAPEX	14,000	32,000
Energy cost	954	1,654
Maintenance cost	1,749	875
Finance cost average per loan year	333	761
Economic costs yr 1	492	76
Lifespan in years	10	10
TCO financial per km	0.08	0.12
TCO economic per km	0.09	0.12

LCVs

1. Petrol Van

Parameter	Value	Unit	explanation
CAPEX van	17,500	USD	https://autos.suzuki.com.pe/auto/apv-van
Petrol fuel consumption	8.5	l/100km	https://www.carsguide.com.au/suzuki/apv; Automercados indicates 9l/100km
Maintenance cost	0.04	USD/km	excludes tyres and repairs;
Lifespan	15	years	Based on annual mileage
Daily distance driven	70	km	Automercados; commensurate with annual mileage
Annual distance	20,000	km	95% usage

2. E-Van

Parameter	Value	Unit	explanation
CAPEX e-van	31,000	USD	Maxus E-Deliver (see https://saicmaxus.co.uk/edeliver3/); 4.8 m3 cargo volume; short-wheel base; small battery
Range WLTP	222	km	https://saicmaxus.co.uk/edeliver3
Battery size	35	kWh	
Cost battery	7,000	USD	Based on 200 USD/kWh per battery
electricity consumption	0.15	kWh/km	WLTP
Maintenance cost	0.02	USD/m	50% of fossil (as only engine maintenance is included; no tyres, no repairs)
Lifespan van	15	years	assumed same as fossil
Lifespan battery	8	years	
Capex home charger 7.4kW	2,000	USD	
Lifespan charger	10	years	
Charging at home average	90%		Assumption
Charging fast-chargers	10%		Exceptional if long distances were made

fossil versus e-van

Parameter	petrol	e-van
CAPEX vehicle	17,500	31,000
CAPEX charger	0	2,000
Total CAPEX	17,500	33,000
Energy cost	1,615	495
Maintenance cost	850	425
Finance cost average per year	833	1,570
Economic costs yr 1	187	27
Lifespan in years	15	15
TCO financial per km	0.20	0.21
TCO economic per km	0.21	0.21

Impact

GHG, PM2.5 and NOx impact per vehicle unit

Reductions in tons of EV versus fossil

Parameter	urban bus		taxi		LCV	
	annual	lifespan	annual	lifespan	annual	lifespan
GHG TTW reduction	81	1,303	10	100	4	58
GHG WTW incl. BC reduction	90	1,433	12	121	4	59
Cradle to grave GHG reduction	86	1,382	11	114	3	52
PM2.5 reduction	0.000	0.005	0.000	0.00	0.000	0.00
NOx reduction	0.14	2.28	0.003	0.03	0.001	0.02

Lifespan based on EV lifespan

Default comparison: Euro IV unit; CNG bus

CNG taxi comparison

LCV gasoline

Bus per km

Parameter	CNG Euro IV	BEB
Direct emissions energy TTW	1,428	0
Indirect emissions energy WTT	257	246
Black Carbon emissions	0	0
Vehicle production	41	36
Battery manufacturing	0	62
Total lifecycle	1,727	343

Taxi per km

Parameter	CNG	e-taxi
Direct emissions energy TTW	189	0
Indirect emissions energy WTT	34	36
Vehicle production	16	16
Battery manufacturing	0	12
Total lifecycle	239	64

LCV per km

Parameter	gasoline	electric
Direct emissions energy TTW	215	0
Indirect emissions energy WTT	41	33
Vehicle production	28	28
Battery manufacturing	0	24
Total lifecycle	284	86