Public bus electrification

สำนักงานนโยบายและแผนการขนส่งและจราจร

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Mobilise Your City

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IKI INTERNATIONAL CLIMATE INITIATIVE

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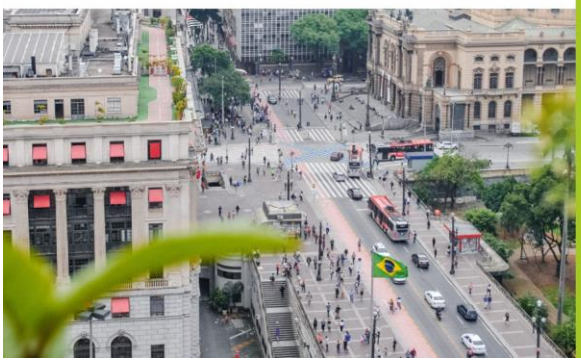
Facilitating climate actions in mobility



Towards a Net Zero Mobility Future!

We enable the rapid development of zero emission transport systems to secure a liveable and just future.

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Project Background

Transport is the highest energy-consuming sector in 40% of all countries worldwide and causes about a quarter of energy-related CO_2 emissions. To limit global warming to two degrees, an extensive transformation and decarbonisation of transport is necessary. The TRANSfer project's objective is to increase the efforts of developing countries and emerging economies for climate-friendly transport. The project acts as a mitigation action preparation facility and thus, specifically supports the implementation of the Nationally Determined Contributions (NDC) of the Paris Agreement. The project supports several countries (including Peru, Colombia, the Philippines, Thailand, Indonesia) in developing greenhouse gas mitigation measures in transport.

The TRANSfer project is implemented by GIZ and funded by the International Climate Initiative (IKI) of the Federal Ministry for Economic Affairs and Climate Action (BMWK) and operates on three levels.

Mobilise

Facilitating the MobiliseYourCity Partnership

The goal of the multistakeholder partnership MobiliseYourCity, which is currently being supported by France, Germany and the European Commission, is that 100 cities and 20 national governments commit to ambitious climate action targets for urban transport and take appropriate measures.

Prepare

Preparation of Mitigation Measures

Standardised support packages (toolkits) are developed and used for the preparation of selected mitigation measures. As a result, measures can be prepared more efficiently, until they are ready for implementation and eligible for (climate) financing. Accumulated over 10 years, the targeted measures aim for a total reduction potential of 60 $MtCO_2$.

Stimulate

Knowledge products, Training, and Dialogue

Based on these experiences, TRANSfer is sharing and disseminating best practices. This is achieved through the development of knowledge products, the organisation of events and trainings, and the contribution to an increasing level of ambition. Personal exchange of experience and dialogue is promoted at events, including the annual Transport and Climate Change Week in Berlin, the United Nations Climate Change Conference (COP) or the International Transport Forum.

Meet us at www.changing-transport.org

Disclaimer

Acknowledgements

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Exchange rates

Local Currency	EUR	USD	Date
1 THB	0.02984 EUR	0.03269 USD	03.10.2019

Glossary

AC	Air condition
ADB	Asian Development Bank
AIT	Asian Institute of Technology
ADB	Asian Development Bank
BAU	Business as Usual
BB	Bureau of Budget
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Mass Transit Authority
BOI	Board of Investment
BTS	Bangkok Mass Transit System
CAPEX	Capital Expenditure
CC	Congestion charging
CMF	Clean Mobility Fund
CNG	Compressed Natural Gas
CO	Carbon monoxide
COP26	26th Conference of the Parties
COP27	27th Conference of the Parties
CO_2	Carbon dioxide
DEPA	Digital Economy Promotion Agency
DLA	Department of Local Administration
DLT	Department of Land Transport
DOPA	Department of Provincial Administration
EEC	Eastern Economic Corridor
EGAT	Electricity Generation Authority of Thailand
EUR	EURO
EV	Electric Vehicle
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IKI	International Climate Initiative
LT-LEDS	Long-term Low Greenhouse Gas Emission Development Strategies
LCV	Light commercial vehicle
MEA	Metropolitan Electricity Authority
MOF	Ministry of Finance, Thailand

MOI	Ministry of Interior, Thailand
MOT	Ministry of Transport, Thailand
MRTA	Mass Rapid Transit Authority of Thailand
MRV	Measurement, Reporting and Verification
MtCO2e	Million Tons of Carbon Dioxide Equivalent
NDC	Nationally Determined Contributions
NESDP	National Economic and Social Development Plan
NGV	Natural Gas Vehicle
NO_2	Nitrogen dioxide
NPV	Net present value
NSTDA	National Science and Technology Development Agency
OECD	The Organisation for Economic Co-operation and Development
OTP	Department of Transport Policy and Planning
O_3	Ozone
PDMO	Public Debt Management Office
PM	Particulate matter
PPP	Public Private Partnerships
SDGs	Sustainable Development Goals
SO2	Sulphur dioxide
SMEs	Small and medium-sized enterprises
SUT	Sustainable Urban Transport
TCG	Thai Credit Guarantee Corporation
TCO	Total cost of ownership
TCMP	Thailand Clean Mobility Programme
TGO	Thailand Greenhouse Gas management Organization
THB	Baht
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
VAT	Value Added Tax
ZEV	Zero emission vehicle

Executive Summary

Main idea and motivation

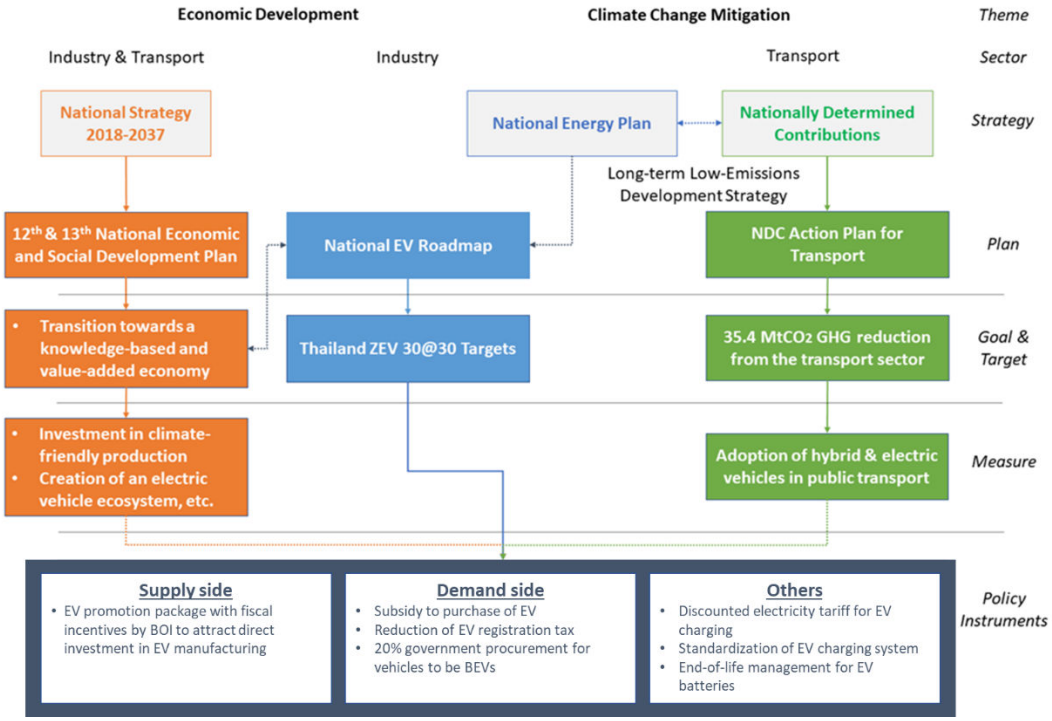
Transport accounts for 27% of energy-related CO_2 emissions globally and continues to remain a rapidly growing sector. According to the latest ITF Transport Outlook CO_2 emissions could increase by 16% by 2050 (ITF, 2021) even if current commitments to decarbonise transport are fully implemented. The reduction in GHG emissions expected from these policies could be more than offset by growing transport demand. According to the Department of Alternative Energy Development and Efficiency (DEDE), the transport sector in Thailand ranks as the most energy-consuming sector in the Kingdom, accounting for 39% of all energy consumed in 2019. The transport CO_2 increased 23% between 2000 and 2015 on a per capita basis.

Thailand submitted the Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015, which aims to reduce its greenhouse gas (GHG) emissions by 20%-25% compared to the projected Business-as-Usual (BAU) level by 2030. After the INDC submission, the NDC Roadmap on mitigation (2021-2030) was developed to provide a policy direction in achieving the GHG emission reduction targets, with the transport sector being one of the four main sectors that have been tasked to fulfil the country´s climate pledge. According to the Roadmap, transport sector is responsible for a GHG emission reduction of 41 $MtCO_2$ in 2030, which comprises of 31 $MtCO_2$ from energy efficiency improvements led by the Ministry of Transport and 10 $MtCO_2$ from biofuel consumption under the responsibility of the Ministry of Energy (MOE).

According to the Thailand NDC Roadmap, the transport sector is responsible for a GHG emission reduction of 41 $MtCO_2$ in 2030, comprising 31 $MtCO_2$ from energy efficiency improvements led by the Ministry of Transport and 10 $MtCO_2$ from the biofuel consumption under the responsibility of the Ministry of Energy. Following the NDC Roadmap, the OTP developed the NDC Action Plan for the Transport Sector, identifying measures for achieving the NDC GHG emission reduction target based on the Avoid-Shift-Improve (A-S-I) approach. The target of overall GHG reduction potential from this action plan is approximately 35.4 $MtCO_2$, exceeding the 31 $MtCO_2$ reduction target. At COP 26, the Prime Minister announced a new target to reach carbon neutrality by 2050 and zero greenhouse gas emissions by 2065. Moreover, Thailand also set out the ambitious NDC target of 40% GHG emissions reduction by 2030 with international support.

Public transport electrification is closely linked to a variety of policies, which can be roughly categorized into two main themes: economic development and climate change mitigation. As the foundation of all policies, the National Strategy 2018-2037 paves the country's pathway towards a secure, prosperous, and sustainable future. From the economic perspective, the 12th and 13th National Economic and Social Development Plan (NESDP) highlight the goal of transitioning towards a knowledge-based and value-added economy, of which EV production is one of the strategic industries to be promoted. Linking to this economic development goal, the National EV Roadmap was formulated as the masterplan to guide the country's pathway towards electromobility. The ZEV 30@30 targets send a clear message that the automotive industry in Thailand will undergo a profound transformation towards EV production. Finally, EV development is one of the areas covered by the National Energy Plan in formulating the country's Low-term Low-Emissions Development Strategy, which further supports Thailand's Nationally Determined Contributions (NDCs) for climate change. EV adoption coupled with public transport modernization is considered a key measure for GHG reduction from the transport sector.

Figure 1: Policy framework for transport sector electrification



Source: Own design

The objective of bus electrification is to lead to an improvement of the public transportation system. and is intended to reduce the use of private vehicles and thus lead to an improvement in the transport system and associated negative impacts. The mitigation action therefore raises the attractiveness of public transportation by the creation of electric on-demand last-mile services and reduction of rail-based tariffs in Thai cities that low-income groups currently cannot afford (Pull Measures). On the other hand, it will promote travel demand management measures to disincentivize car travel, such as CC or parking management measures (Push Measures), to free up road space as a prerequisite to improved bus services and sustainably finance the public transport improvements (Transport-Finances-Transport). The introduction CC internalizes (part of) the external costs of car travel, creates leeway for installing designated bus lanes, and generates revenues for SUT projects in Thai cities.

Approach for transformational change

Main outcomes encompass GHG and air pollutants mitigation through the (1) increase of the number of electric busses and public transport ridership in Bangkok through the (2) availability of accessible funding for vehicle purchase and deployment resulting into an (3) overall public transport system improvement regarding carbon footprint, while the government has enhanced capacity to established a financing tool for a continuous development of sustainable and low-emission transportation services through the setting-up of a Clean Mobility Fund which will be financed from and redistribute the CC revenue collected in a Clean Air Zone in Bangkok, that is planned by the government. The impact will therefore result in initiating public transport electrification and transformation in a Clean Air Zone in Bangkok, contributing to NDC targets, and advancing the country to the Long-Term Low GHG Emissions Development Strategy.

By implementing CC scheme and promotion of 90 electric buses, the direct GHG mitigation in Bangkok area is expected to be 0.31 MtCO2e in the first 5 years and 6 months, accounting for 56,504 tCO2e/a. In addition, the project could lead towards additional GHG emission reduction of 2.70 MtCO2e in next 10 years and 6 months, as shown in the summary table below. Therefore, the total direct mitigation potential is expected to sum up to 3.01 MtCO2e. The total indirect GHG mitigation potential is expected to be 3.24 MtCO2e from replacing 30% and 50% of conventional diesel bus fleets with electric buses by 2030 and 2050, respectively. Therefore, the total mitigation potential is expected to be 6.25 MtCO2e.

Currently, the development of electric buses in Thailand is still in its early stages and not an electric bus is in commercial operation in the country. By supporting the funding of 90 electric buses and public transport vehicles and charging facilities in Bangkok, the feasibility and benefits of using electric buses and vehicles to provide quality public transport services can be demonstrated. While electric buses are not yet a competitive technology for most investors in Thailand, this mitigation action can act as a catalyst by significantly reducing perceived risk by subsidising capital expenditure and improving access to finance through guaranteed support for SMEs. Once the technology is proven viable and the perceived risk is removed, the cost of financing electric buses will be lower, attracting more private investors and reversing the flow of funds from other domestic financial institutions and bus operators to expand the use of electric buses. The technology will eventually catch on once economies of scale are achieved, putting Thailand on a carbon-neutral path. For example, the project will electrify 90 buses and public transport vehicles, among others, but Bangkok's entire bus fleet consists of more than 14,000 buses, offering significant potential to expand and replicate the model.

The Mitigation Action at a glance

Contribution to NDC implementation	- Mitigation of CO_2 / GHG emissions - Reduction of PM2.5 levels and overall air pollution in urban areas		
Type of action	National Programme	**Subsector**	Transport
Geographical scope	Bangkok Metropolian Region (BMR)	**Type of policy instruments**	Regulations: yes Economic instruments: yes Public spending/ investments: yes Communication and information: yes
Organisation	Responsible organization: Office of Transport and Traffic Policy and Planning (OTP) Involved national partners: Bangkok Metropolitan Administration (BMA), Department of Land Transport (DLT), Local governments, Ministry of Finance (MOF)		
Main mitigation measures	Public bus electrification		
Schedule	**Phase 1:** "Detailed Preparation Phase (DPP)" **Phase 2:** "NSP implementation"		
GHG mitigation effect and other benefits	GHG mitigation: 2.69 $MtCO_2e$ (over 10 years); average annual mitigation 0.27 MtCO2e Other benefits: 2.87 $MtCO_2e$ (indirect emission reduction) over 10 years		
Feasibility	Financial feasibility: NPV of the electric bus outweigh that of diesel counterpart; however, the upfront investment cost is the key barrier. Without intervention the bus operators are more likely to procure diesel bus.		
Type of required support	Technical support: e-bus fleet operation, capacity building for the maintenance, and technical design charging infrastructure Financial support: International Climate Finance for the investment of the bus electrification and charging infrastructure		

Source: GIZ

Expected benefits: GHG mitigation and more

The introduction of a congestion charging (CC) zone in combination with the electrification and improvement of public transport services entails an expected reduction in GHG emissions due to the shift of passengers from cars to buses and is expected to account for 5% over the next 16 years. In addition, the promotion of 90 electric buses will reduce GHG emissions resulting from the replacement of current diesel internal combustion engine technology with electric buses. The total mitigation potential of direct GHG emissions is expected to be 3.01 $MtCO_2e$. In addition, the indirect mitigation potential will be a further 3.24 $MtCO_2e$, mainly resulting from other bus operators replacing 30% and 50% of conventional diesel buses with electric buses by 2030 and 2050 respectively. The above figures do not include the indirect mitigation effects made possible by using CC revenues for additional Sustainable Urban Transport (SUT) projects using the Clean Mobility Fund (CMF). These estimations and assumptions

underlying the GHG mitigation calculations are based on the national information and studies from government agency, such as DLT, BMTA, and OTP.

Table 1: Direct GHG mitigation potential

	Unit	Implementation	10 years after project end	Technology lifetime
Annual average mitigation potential	tCO_2e/a	56,504	269,776	202,023
Total mitigation potential over period	tCO_2e	310,771	2,697,760	3,232,375

Source: Own calculation by author

Table 2: Indirect GHG mitigation potential

	Unit	Implementation	10 years after project end	Technology lifetime
Annual average mitigation potential	tCO_2e/a	65,396	287,742	215,807
Total mitigation potential over period	tCO_2e	359,678	2,877,423	3,452,908

Source: Own calculation by author

Regarding Thailand's efforts to develop a Long Term - Low Emission Development Strategies (LT-LEDS) the transport sector will be part of Thailand's long-term targets with the implementation of measures to enhance sector electrification and shift towards more energy and emission efficient modes such as public and mass transport. The government is executing its investment plans to expand mass rapid transit in Bangkok metropolitan area, high-speed train, double-track train, as well as water transport infrastructure, where CC will help to catalyse modal shift and increase the effectiveness of investment in public transport infrastructure.

Financing concept

Regarding the current bus service market structure, the DLT as the regulator used to authorize the sole public bus operator BMTA to manage the operating licenses of all service routes. Given the large size of the entire system, BMTA would sub-contract a fixed share of licenses to private operators making the system highly fragmented, even though some license-holders run their service jointly with other operators. As of 2014, there were approximately 776 license-holders and 32,374 joint operators, of which 94% own only one vehicle. Most of these operating entities are small and family-owned firms. However, a major reform has been undertaken in which the licenses are gradually re-issued directly by DLT. All operators who seek to extend their license or get a new licence are required 70% of their bus fleet to constitute of vehicles on average not older than 2 years. This measure tends to result in coalitions of small operators as many of them are not able to afford the substantial capital investment in new bus fleet.

Currently, the initial capital cost of an electric bus is around 2-2.5 times higher than of a diesel bus. As most of the bus service operators are SMEs, it is challenging and of high risk for them to make such a considerably huge investment. Regarding bus service accessibility and affordability of bus fares in Bangkok, bus fares have been regulated by the Thai Government to ensure their affordability to the public at large. Even after the introduction of electric buses, the fares are expected to remain stable and affordable mainly due to the bus transit system in Bangkok being a formally regulated market, with the fares capped by the government without subsidies to the operators.

From interviews with commercial banks and private operators in Bangkok, only few financing channels for investment in bus fleets are available, significantly impeding the renewal or upgrade of existing bus fleets on the demand side. In most cases, operators procure or lease second-hand buses rather than invest in new ones. On the supply side, banks normally process financing requests for investment in buses through corporate finance, which implies that the loan terms can be quite rigid and hence unaffordable for most private operators which are SMEs.

Financing needs for public transport electrification were assessed including extensive interviews with operators, banks, producers, and governmental actors resulting in the need for a subsidy of the incremental TCO through a leasing programme and a guaranteed scheme to improve the access-to-finance for SMEs operators. Electric (mini-) buses currently have considerably higher CAPEX (EUR 220.000) compared to conventional vehicles (EUR 95.000). A study looking at additional vehicle types is currently underway. It is expected that electric buses reach cost parity in the medium term, with decreasing battery costs and economies of scale. Furthermore, with reference to current energy cost and fuel consumption rate for a conventional diesel Bangkok bus using the cheapest diesel grade, energy costs for a CNG bus, a diesel hybrid bus and an electric bus are 30%, 38% and 69% lower than for the conventional diesel bus technology. Given a typical average daily distance for a bus route in Bangkok of 250 km/day, energy refuelling cost and time must be considered accordingly.

As the bus modernization measure requires investment in new vehicles which presently feature higher lifecycle costs than the current options, the investment in 'green' vehicles is not financially attractive for private operators. However, providing financial support measures for such an investment may still be beneficial at the economic level if the socioeconomic benefits exceed the financial costs of the program. Unlike the financial analysis undertaken from the operator perspective, the economic evaluation considers the real economic costs and benefit, net of taxation, which is simply a monetary transfer within the economy. Taxation counts for a significant proportion of the financial purchase cost of an electric bus, with typical import tax of 40% and a further 7% on the taxed value.

When the real economic cost of the bus vehicle alternatives is considered, the lifetime cost of an EV, whilst still higher in net present value (NPV) terms, aligns more closely with that of a conventional bus. Therefore, the economic cost of fleet renewal is lower than the financial cost faced by the operator.

The bus modernization measure shows benefits from CO2 and PM reductions leading to a positive socioeconomic benefit NPV. The socioeconomic benefit NPV calculation for bus modernization does not include any benefits for the improved attractiveness of bus travel, with the associated benefits of reduced congestion and reduced traffic accidents. The benefits may therefore be considered conservative. Table 21 shows that at the prevailing discount rate, economic net present costs slightly exceed net present benefits, thus leading to a negative net present value. However, falling EV bus prices may lead to a net positive economic outcome if pursued in the coming years.

Table 3: Summary of statistical results of the analysed measures

Measure	Operator Financial Cost NPV (MTHB)	Societal Cost NPV (MTHB)	Socioeconomic Benefit NPV (MTHB)	Societal Net Present Value (MTHB)
Bus Modernization	-4,001 [~ EUR -119 million]	-1,180 [~ EUR -35 million]	849 [~ EUR 25 million]	-331 [~ EUR 10 million]

Source: Clean Mobility Fund Report (2020)

1. Introduction

A rapid increase in population and economic growth has led to high congestion levels in Thai roads, especially during peak hours. Even though there was 42% less traffic in 2021 versus 2019, people in Bangkok still lost more than 70 hours per year caused by congestion (TomTom, 2022). According to the Energy and Policy Planning Office (EPPO), the transport sector accounts for 28% or 69.1 Mt out of 246.9 Mt of Thailand's CO_2 emissions (EPPO, 2022). Transport contributes to 72.5% of PM2.5 emissions in the Bangkok Metropolitan Region (BMR) (AIT 2019), which has increasingly threatened the Thais' health over the past few years. Data from 9 hospitals in Bangkok show that there were 9,980 respiratory-related cases in January 2019 (November - February is the peak period of PM2.5) comparing to 6,445 cases in 2018.

The main reason of traffic congestion and air pollution from transport in urban areas is the fact that most people still heavily rely on the use of private vehicles. Based on the statistic, in BMR there were approximately 10,784 million trips per year, of which 80% commuted by private vehicle and only 20% commuted by public transport mode.

Faced with these and other negative effects of congestion, Thailand aims to reduce its greenhouse gas (GHG) emissions by 20%-25% compared to the projected business-as-usual (BAU) level by 2030. Internationally, Thailand committed in 2015 to the United Nations Framework Convention on Climate Change (UNFCCC) to reduce 115.6 $MtCO_2$ until 2030. Thereof 41 $MtCO_2$ are supposed to be reduced by transport, and the Office of Transport and Traffic Policy and Planning (OTP) has included "Congestion Charging" (CC) as one of the measures to combat climate change into their Nationally Determined Contributions (NDC) Action Plan. However, the Prime Minister announced a new target to reach carbon neutrality by 2050 and zero greenhouse gas emissions by 2065 at COP26.

To achieve these targets, electrification of public transport vehicles is one of the key measures to reduce GHG emissions and air pollution in Thai cities, given that road transport accounts for the highest CO_2 emissions of the whole transport sector. To promote electromobility in Thailand, the National Electric Vehicle (EV) Policy Committee has recently announced a master plan aiming for 100% of the vehicles produced in Thailand to be electric by 2035. This plan also targets 50% of the country's total vehicle production to be EVs by 2030 and provides a clear direction for the EV market in the country.

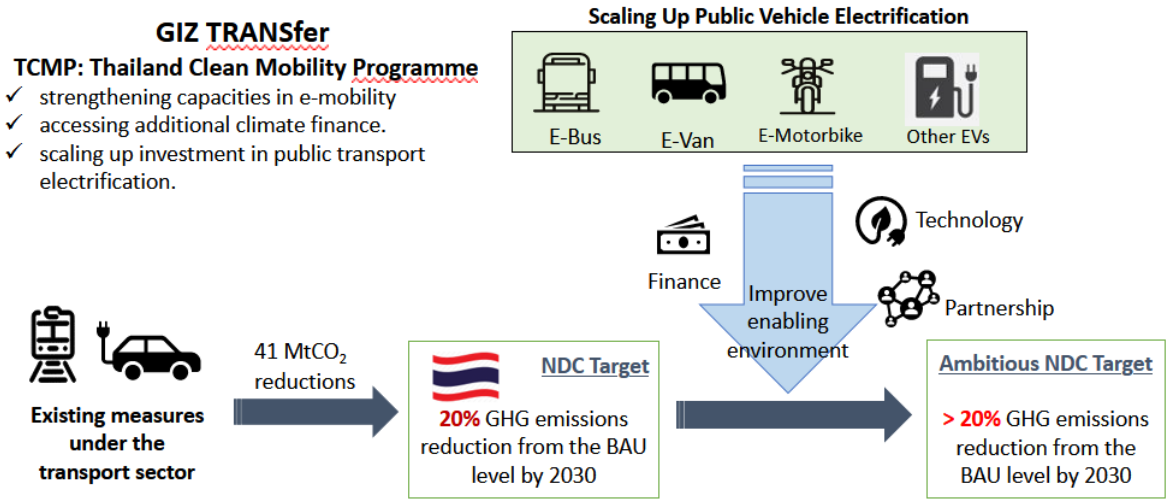
Although the government is currently planning to allocate significant investment budgets for the transportation sector, most budgets are dedicated to large-scale infrastructure investments such as double track rail network and mass transit development for the rail transport to expand capacity and network of the transport system. However, the expansion of network and capacity of transportation system alone cannot guarantee that people will shift mode to commute with public transport. There are still other important barriers preventing people from taking public transport such as high fares, insufficient quality of service (coverage, frequency, reliability, and comfort), lack of first and last mile services and walkability etc.

Realizing the urgent need to shift trips from private vehicles to sustainable transport modes, the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) has been working in Thailand on behalf of the German Government since 2009. Funded by the International Climate Initiative (IKI), GIZ has been implementing the TRANSfer III project to facilitate ambitious mitigation actions for the transport sector, aiming at supporting developing countries and emerging economies to develop climate-friendly transport environments. The programme addresses the two major challenges for a shift towards sustainable transport in Thai cities: a low-quality public transport service based on old vehicles with high specific emissions (25 years on average) and a rapid increase in private motorization (300,000 new vehicles/a).

In Thailand, the GIZ TRANSfer project is supporting the OTP in the "Development on Public Transport Electrification" to identify and develop effective financing and business solutions to upscaling investment in electric public vehicles in Thailand. This is part of the activities under the Thailand Clean Mobility Programme (TCMP), which is expected to support Thailand in its pursuit of the NDC target in a more ambitious manner.

To improve the transport system in the BMR, the TCMP employs a Push and Pull Approach, that makes public transport more attractive by improving connectivity, reducing fares, and improving technology (Pull), and disincentivizes car travel by internalizing road usage costs and environmental externalities by means of a CC (Push), inducing a shift from private to public modes in a sustained manner. The rationale of the TCMP is presented in Figure 2.

Figure 2: Project rationale of the TCMP



Source: Own design

Road transport is the highest emitter of all sub-sectors in transport in Thailand. Experience from other cities (van Amelsfort & Swedish, 2015) that have introduced CC, shows a reduction of car trips by 20% to 70% and increase public transportation ridership by 20% to 40%. Under the TCMP, the number of electric buses and other public transport in Bangkok is expected to increase as funding becomes available for the purchase and deployment of vehicles. The public transport improvement, focusing on bus electrification, will lead to an improvement of the public transport system in terms of carbon footprint, among other benefits outlined in this document. While there are many components within the road transport sector, this study is focused on bus electrification. The reasons of such prioritisation are not only because this is one of the main modes of public transport in Thai cities, but also because various models of electric buses are available in the market.

Moreover, since public transport markets generally differ from one city to another, it would not be practical to study all the markets within the country. The study is therefore specifically focused on the largest metropolitan area, the BMR, as its road transport sector is most developed and presumably most carbon intensive. The results of this study will serve to provide a financing blueprint for large-scale electrification of public transport fleets in the country.

2. Sector overview: Mobility in the Bangkok Metropolitan Region

2.1 Relevance of the transport sector in the Bangkok Metropolitan Region

Thailand´s urbanization rate is still comparatively low. However, urbanization has increased sharply in the last decade, from only 36% in 2008 to 50% in 2018. Of all urban dwellers, 48% live in the BMR (GIZ, 2019). In 2020, the urban population growth rate for Bangkok reached 2.3, compared to other comparable cities with rates ranging between 1.2 and 1.4 (World Popultion Review, 2022).

Table 4: Population and density of urban areas in Thailand

City or Municipality (Urban Area)	Province	Population*	Area (km²)	Density (people/km²)
Bangkok Metropolitan Administration (BMA)	Bangkok	10,350,204	1,568	6,600
BMR in urban areas	BMR	12,586,200	2,871	4,384
Nakhon Ratchasima	Nakhon Ratchasima	174,332	39	4,470
Chiang Mai	Chiang Mai	174,235	47	3,707
Hat Yai	Songkhla	159,233	21	7,583
KhonKaen	KhonKaen	129,581	52	2,492
Phitsanulok	Phitsanulok	89,480	19	4,709
Phuket	Phuket	75,536	12	6,295

Source: Department of Provincial Administration (DOPA), NESDC

Bangkok, the country's capital city, has an estimated population of round 12.1 million inhabitants as of 2030 (World Popultion Review, 2022). Together with 5 adjacent provinces including Nakhon Pathom, Pathum Thani, Nonthaburi, Samut Prakan, and Samut Sakhon, it forms the BMR covering an area of 7,762 km with approximately 15 million inhabitants[1]. Hosting more than a fifth of the country's population, the BMR plays an important role in diving the country's economy, as industrial and residential zones have been developed in these surrounding provinces to accommodate the growth of Bangkok (Robinson, 2011).

Public transport

The city of Bangkok has a variety of different public transport modes, including overground and underground rail, bus, canal-boats, smaller public transport vehicles such as vans and traditional Song-Teaw, as well as last mile services such as motorcycle-taxis or Tuk-Tuk. Even though rail-based mass transit has been rapidly developed over the last decade, the predominant mode of transport is still the individual private vehicle with a share of round 79%.

[1] Bangkok Metropolitan Population report 2018

Especially city dwellers living outside of the BMR core of Bangkok, often rely on private vehicles, as public transport coverage is not sufficient in those areas.

Private motorized modes are followed by the bus, which is chosen primarily by low-income groups and often runs in parallel to rail-based services on the main roads. BMR is served by a total of round 7,300 buses[2] with an average age of 26-30 years[3]. With rising coverage by rail-services and deteriorating service quality (unreliable schedules due to traffic jams and lack of priority lanes, lack of air conditioning on half of the bus fleet leading to breathing in polluted air and rain entering the bus during rainy season, over-crowding due to bad network design), the bus has recently been losing ridership, in particular among people who can afford other modes of transport such as private vehicles or taxis instead of buses (Thongphat & Arporniem, 2017).

Table 5: Number of commutes in BMR by type of transport

Type of Transport	Number of Commuters (Million people-trip/year)	
	2017	2018
Mass transit system[4]	402.26	413.94
BRT bus	5.82	4.56
Bus	2,233.76	2,227.50
Van	211.20	204.60
Boat	71.90	69.28
Total public transport	2,924.74	2,919.88
Total private transport trip	8,568.06	8,989.75
Total trip	10,783.77	10,949.40

Source: Transport Infrastructure Report (2018), (OTP)

The Government has ambitious plans for the rail-based urban mass transit network, which is planned to be extended from 212 km to 565 km within the next decade. Currently there are 8 lines in operation, including Light & Dark Green, Blue, Purple, Airport Rail-Link, and Gold line. Light & Dark Red line started operating in November 2021, Pink and Yellow in 2023, and all planned- 12-metro lines are expected to fully operate in 2029 (DRT, 2022).

Rail and bus services are complemented by round 2,050 so-called "Song-Teaw", a passenger vehicle adapted from a pick-up truck or a larger truck, that is used as a shared taxi or bus mainly in the outskirts of the city were bus coverage is not sufficient. Some Song-Teaw run on fixed routes, while others act as a taxi service. Due to relatively inconvenient and unreliable services of the Song-Teaw, households who can afford motorbikes or cars tend to choose private vehicles instead.

Bangkok´s unique urban structure with few major roads and large blocks with up to 1,500 m radii[5] characterized by narrow roads with round 6,240 km of dead-end streets, equals to 37% of total road distance in Bangkok. (Poonyakanok W. , 2016). Prevalent one-way roads lead to difficulties in access to rail and bus transport. Public transport in Bangkok hence relies on last-mile services such as motorcycle taxis and Tuk-Tuk that bring commuters from the station to their final destinations and vice versa.

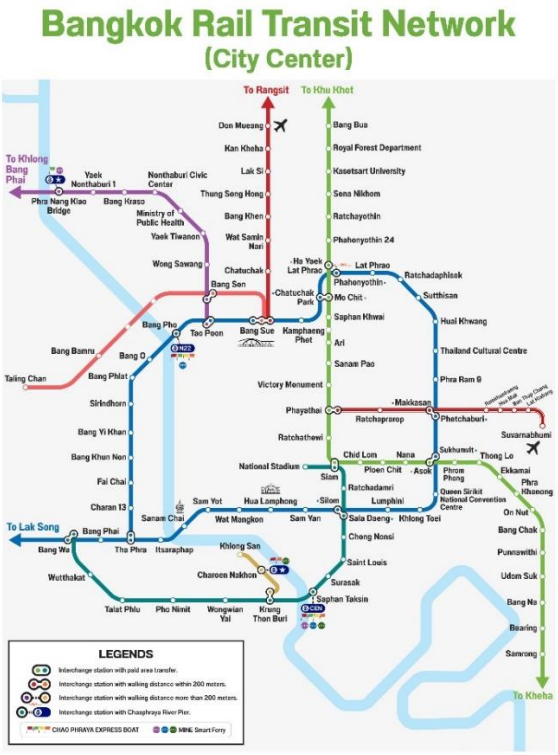
[2] Data from Bangkok Mass Transit Authority (BMTA), 2019

[3] Board of Directors of BMTA 2018

[4] Mass transit system in BMR consists of: BTS Skystrain, MRT Bangkok Metro, Airport Rail Link (ARL), and inner-city train

[5] BMA, 2014

Figure 3: BMR Mass Rail Transit network 2022



Source: LivingPop

Motorisation rates

In 2018 ((DLT), 2018), there were 39 million registered vehicles (all vehicle types) in Thailand (DLT, 2018). 25% or 10 million of these vehicles were registered in Bangkok. Car registration data in the city show that there are 6.1 million registered private cars, or one car for every 2.6 residents. This compares to one car for every 10 residents in Singapore, one for every 7.5 residents in Hong Kong and one for every 3 people in London.

The 10 million cars in Bangkok not only create traffic congestion which cause the waste of time, energy, and money, but they also take up space that could be used for other purposes. For example, footpaths in Bangkok tend to be narrow as the space is dedicated to roads and often needed or occupied by informal sector business. The average width of pedestrian walks in Bangkok is around 1 meter, while the standard walkway should be at least 1.5 meter (GoodwalkThailand, 2016). Lack of walking infrastructure poses a problem in the entire city of Bangkok as well as other compacted cities in Thailand. Moreover, pedestrians must take risks from being exposed to noise and air pollution from massive number of vehicles in the city.

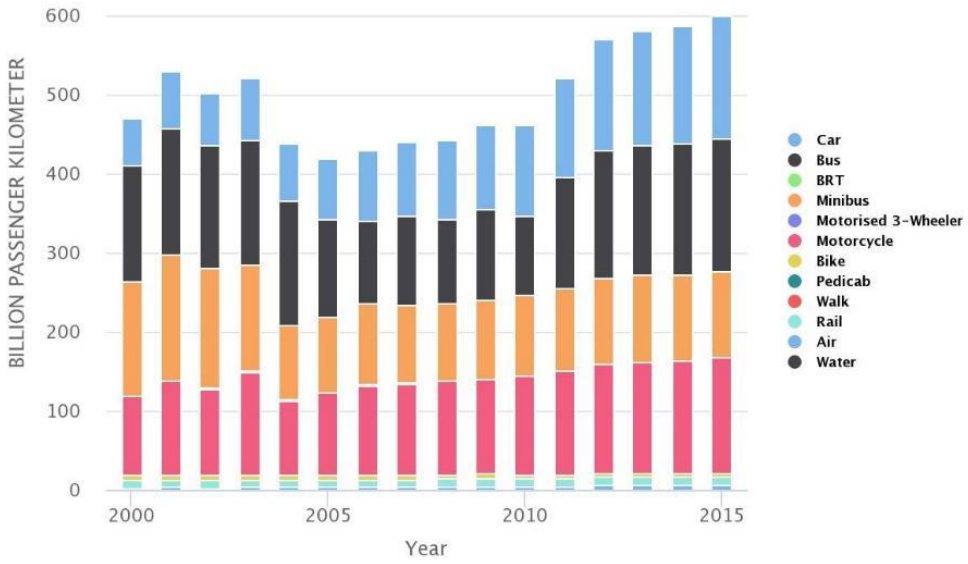
The number and proportion of private cars in Bangkok makes it very difficult to provide adequate road space to meet car use demand. In addition, Bangkok has rather little road space given its proportion of 8% while the standard share of road space within a city ranges between 20-25% (Poonyakanok W. , 2016). Furthermore, the lack of proper city planning, and regulations causes dead-end and long small streets in many cities in Thailand, especially super-block in Bangkok, which undoubtedly leads to congestion (Poonyakanok W. , 2016). Given this starting situation, it becomes clear that demand management measures are required to contain or restrict personal vehicle use alongside supply side improvements to the sustainable transport network. Without policies to discourage greater levels of motorization, the negative impacts of motorization, congestion and its associated economic costs, road safety, air quality and CO_2 emissions could further deteriorate.

Passenger transport demand

Across Thailand, in 2015, cars (26%) and motorcycles (24%) accounted for around half of all passenger-km travelled across all modes, as presented in Figure 4. Buses accounted for the highest share of passenger-km travelled (28%).

This emphasizes buses as being an important transportation mode for a significant proportion of the population that should continue to be at the forefront of tackling congestion, poor air quality and reducing CO_2 emissions.

Figure 4: Passenger km travelled by mode



Source: Asian Development Bank (ADB) Transport Databank, 2018

The growing number of passenger-km travelled implies that the population is becoming more mobile by either making more journeys or making longer distance journeys. At the same time, bus-passenger-km travelled has remained broadly stable. However, it can be seen from the graph that as people become more mobile, they tend to rely more on private vehicles than public transport.

As shown in Table 6, public transportation demand is expected to increase from about 10 Million in 2017 to about 12 Million trips per day in 2042, with mode shares only marginally increasing (from 32% to 34%). The projected growth for Bangkok is so high that the total number of trips is expected to increase from about 32 Million in 2017 to 40 in 2042. Of the 8 Million projected additional trips, 2 Million trips are expected to be effectuated using public transportation. Thus, the investment in public transportation infrastructure supports Bangkok's development of the transport network, however, will not be sufficient to imply a systemic change in public transportation use shares, nor reduce car travel and congestion.

Table 6: Forecasts of travel demand and mode shares for Bangkok (eBUM model)

Mode	Volume of travelling (Million trips/day)					
	2017	2022	2027	2032	2037	2042
Private vehicle	22.44 (68.7%)	23.30 (66%)	24.43 (64.8%)	24.99 (64.5%)	25.00 (63.6%)	24.29 (60.8%)
Car	14.12 (43.2%)	15.60 (44.2%)	17.22 (45.7%)	18.31 (47.3%)	18.98 (48.3%)	19.11 (47.8%)
Motorcycle	8.32 (25.5%)	7.70 (21.8%)	7.21 (19.1%)	6.68 (17.2%)	6.02 (15.3%)	5.18 (13.0%)
Public transportation	**10.21 (31.3%)**	**11.99 (34.0%)**	**13.25 (35.2%)**	**13.77 (35.5%)**	**14.31 (36.4%)**	**15.64 (39.2%)**
Taxi	1.36 (4.2%)	1.59 (4.5%)	1.87 (5.0%)	2.02 (5.2%)	2.19 (5.6%)	2.44 (6.1%)

Mode	Volume of travelling (Million trips/day)					
	2017	2022	2027	2032	2037	2042
Public bus	6.60 (20.2%)	7.83 (22.2%)	8.62 (22.9%)	8.85 (22.8%)	9.09 (23.1%)	9.94 (24.9%)
Shuttle bus	0.62 (1.9%)	0.81 (2.3%)	0.88 (2.3%)	0.96 (2.5%)	1.06 (2.7%)	1.26 (3.2%)
Walking	1.63 (5.0%)	1.76 (5.0%)	1.88 (5.0%)	1.94 (5.0%)	1.97 (5.0%)	2.00 (5.0%)
Total	**32.65**	**35.29**	**37.68**	**38.75**	**39.31**	**39.93**

Source: OTP (2015)

Greenhouse gases, air quality and road safety

In 2014, Thailand contributed 316 $MtCO_2$ to the global GHG emissions with transportation accounting for 25% or 79 $MtCO_2$ (OTP, 2018). Transport CO_2 per capita has increased steadily since 2000. CO_2 emissions from the transport sector equated to 0.95 tonnes per capita in 2000, and 1.17 tonnes per capita in 2015, an increase of 23% in just 5 years.

Cars and motorcycles account for round 40% of the CO_2 emissions while freight vehicles, ranging from light commercial vans to heavy freight trucks, account for 31% of all transport related CO_2 emissions. Busses account for 7%, air transport accounts for 17%. The remaining percentages are shared between rail and water-based transport. Road-based transport therefore accounts for the major share of emissions, and the trend will continue to grow with the growing number of vehicles on the road without any intervention.

Considering air pollution, a study by Greenpeace found that transportation generated 50,240 tonnes of $PM_{2.5}$ and 246,000 tonnes of nitrogen dioxide (NO_2) in 2015 (Greenpeace, 2019) in Thailand. Small Particulate Matter, $PM_{2.5}$ and PM_{10} in particular, are the main pollutants contributing to the poor air quality. Bangkok has severe air quality problems that are to a great extend caused by road transport and results in negative effects on health and quality of life. Resolving air quality problems will require a shift from car use towards an increased use of public transportation, more walking and cycling and the use of cleaner, more emission efficient or entirely zero-emission vehicles, like electrified busses.

In addition to poor air quality, road transport is a major threat to safety. According to the World Health Organization (WHO), Thailand has the highest road traffic death rate among ASEAN countries and the 9th highest in the world ((WHO), 2018). The WHO reports the fatality rate at round 36 death per 100,000 with over 24,000 fatalities per year. This differs slightly from the Ministry of Public Health's record of 24 death per 100,000. It is estimated that the cost of road traffic crashes to the Thai economy ranges between 3% and 5% of the GDP, which suggests that road accidents and particularly fatalities, are a significant issue for Thailand. Motorcycles account for far the biggest share of the fatalities.

2.2 National Covid-19 pandemic context and green recovery strategy

According to the International Energy Agency (IEA, 2021), global EV sales have shown great resilience to the Covid-19 pandemic that broke out in early 2020. While global new car registrations dropped about 16%, EV sales share rose 70% to a record 4.6% in 2020. Europe overtook China as the world's largest EV market for the first time. This phenomenon mainly rests on three pillars, including 1) supportive regulatory frameworks, 2) additional incentives to safeguard EV sales from the economic downturn, and 3) the expanded number of EV models coupled with a continuous drop in battery cost.

In response to the Covid-19 crisis, some countries launched recovery packages with automotive or even EV-specific stimulus measures, which primarily took the form of increased purchase incentives or delaying the phase-out of subsidies, while the others took a more integrated approach by supporting charging infrastructure, public transport, and non-motorised mobility.

Negative impacts from the Covid-19 pandemic on Thailand's economy, the tourism and related sectors were most affected by the pandemic with a projected recovery of more than three years compared to pre-pandemic level entailing negative spill-over effects to many other industries and businesses in the near- and longer-term. The Thai economy contracted by 6.1% compared to pre-pandemic gross domestic product (GDP) levels reaching an unemployment of 1.69 million in 2020 or an increase of around 72% compared to the previous year. Specific sectors strongly impacted by Covid-19 are amusement and recreation, restaurant, hotel, crop, farming and fishery. It is estimated that 30% of 473,324 companies or 143,414 would experience tight liquidity in 2021. Most of the businesses at risk would be small. According to Krungsri Bank (Krungsri Research, 2020) at least THB 2.3 trillion [EUR 68.6 billion] would be required to prevent insolvency of businesses at risk in 2021.

Green Recovery measures in Thailand mainly focus on short term relief-measures, e.g. for income losses of public transport operators. Longer term recovery measures are still being discussed. In transport the discussion mainly circles around speeding up investments in rail infrastructure from planned finalization in 2029 to 2035. Regarding the automobile sector as one of the key economic sectors in Thailand, the government has created incentives for domestic electric vehicle (EV) production that has been recently extended to electric bus producers, with many companies showing interest in the scheme and presenting pilot models. While various EV producers have started production, the demand is not incentivized and thus market uptake has been very slow.

The mitigation of bus modernization may contribute to Green Recovery by channelling investments into a green technology, and thereby sending Thailand onto a cleaner development path. Moreover, an increase in public transport ridership and the creation of a long-term, reliable, annual funding stream for sustainable urban transport (SUT) projects, including fare subsidies for public transport operators, increases the resilience of public transport operators for future challenges, such as presented by the income loss during the Covid-19 pandemic. Currently, bus operators do not receive any operational subsidies, causing high vulnerability to external threats and low potential to invest in clean technology. The creation of viable business models for last-mile electric on-demand services can support raising the NDC ambitions as the private sector contributes to their achievement.

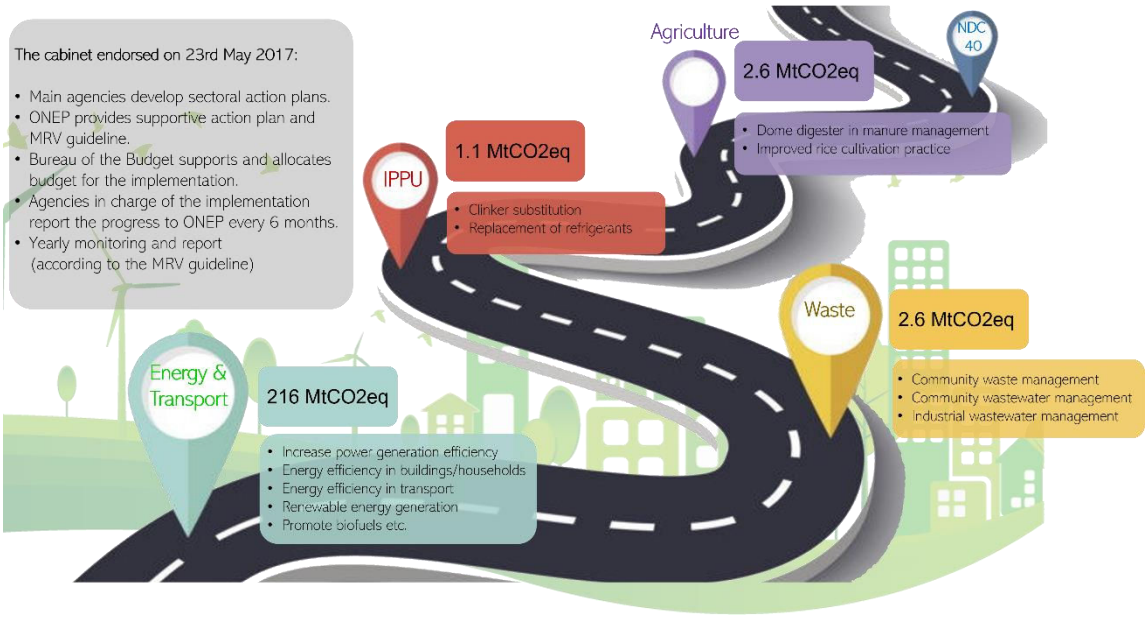
2.3 Transport and climate policy context

According to the Department of Alternative Energy Development and Efficiency (DEDE), the transport sector in Thailand ranks as the most energy-consuming sector in the Kingdom, accounting for 39% of all energy consumed in 2019. The transport CO2 increased 23% between 2000 and 2015 on a per capita basis.

The GHG emission level of 555 Mt CO_2 was used as a reference for Business as Usual (BAU) in 2030 to calculate the NDC target. Thailand committed to UNFCCC in 2015 to reduce 20-25% of its GHG emissions compared to BAU in 2030, translating into 115.6 Mt CO_2 (Laopongpith, 2019). This resulted in the so-called NDC25. With the cabinet endorsement in May 2017, the Office of Natural Resources and Environmental Policy and Planning (ONEP) of the Ministry of Natural Resources and Environment (MNRE) was assigned the task of developing Thailand's NDC Roadmap on Mitigation 2021-2030.

However, the Prime Minister announced a new target to reach carbon neutrality by 2050 and zero GHG emissions by 2065 at COP26. Therefore, Thailand is preparing the updated Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) and NDC. Thailand's updated NDC aims to set GHG emission reduction target at 40% with additional governmental and international support by 2030. The 40% reduction of Thailand's GHG emissions equals to 222 $MtCO_2$ in which 170 $MtCO_2$ can be achieved by the current national measures and the remaining 52 to 53 $MtCO_2$ will require additional governmental and international supports, as shown in Figure 5.

Figure 5: Thailand's updated NDC Roadmap on Mitigation 2021 – 2030



Source: Own design based on the government

At COP26, the Prime Minister announced a new target to reach carbon neutrality by 2050 and zero GHG emissions by 2065. Moreover, Thailand also set out the ambitious NDC target of 40% GHG emissions reduction by 2030 with international support. In tandem with the EV Roadmap, the National Energy Policy Council (NEPC) approved the National Energy Plan (NEP) to support Thailand in pursuing clean energy and becoming carbon neutral. The approved EV Roadmap and NEP show a positive sign that lays out a solid foundation for decarbonizing the transport sector. For the recent updated NDC, the realization of mitigation ambition requires support to enhance electrification of transport, battery charging technologies and capacity building of relevant stakeholders. These include (1) hard investment in infrastructure and vehicles such as development of public transport electrification for buses, vans, motorcycle taxis, etc. and development of charging station infrastructure; and (2) soft investment to improve enabling environment such as strengthening EV market players, creating eco-system for EV auto parts, MRV for transport electrification, financing solutions for EV manufacturers and EV consumers etc. With international support including financial and technical assistance, Thailand could more effectively implement its mitigation measures, track, and report their implementation progress to achieve its pledged target as well as enhance its mitigation ambition beyond its current 20% goal.

Currently, the updated NDC is in the phase of public consultation. The main objective of this phase is to share the result of the revised LT-LEDS and NDC and receive feedback and recommendations from the public for further Thailand's climate policy enhancement and development. The revised LT-LEDS and NDC are planned to be submitted to UNFCCC before COP27 takes place in November 2022.

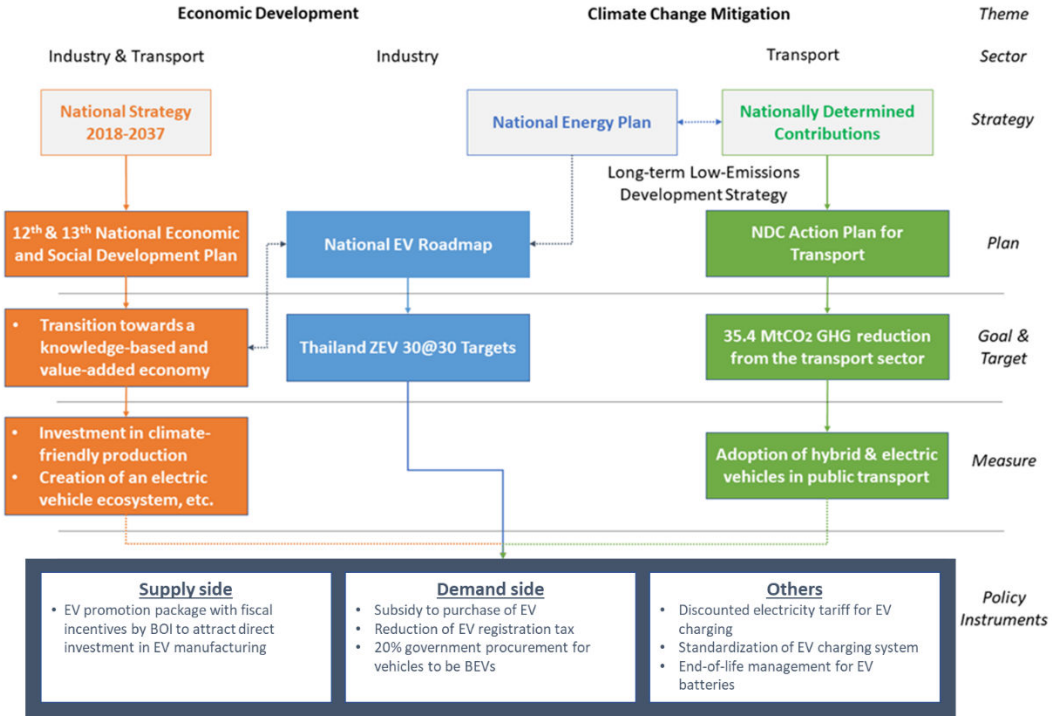
Public transport electrification

Public transport electrification is closely linked to a variety of policies, which can be roughly categorized into two main themes: economic development and climate change mitigation. As the foundation of all policies, the National Strategy 2018-2037 paves the country's pathway towards a secure, prosperous, and sustainable future. From the economic perspective, the 12th and 13th National Economic and Social Development Plan (NESDP) highlight the goal of transitioning towards a knowledge-based and value-added economy, of which EV production is one of the strategic industries to be promoted. Linking to this economic development goal, the National EV Roadmap was formulated as the masterplan to guide the country's pathway towards electromobility. The ZEV 30@30 targets send a clear message that the automotive industry in Thailand will undergo a profound transformation towards EV production. Finally, EV development is one of the areas covered by the National Energy Plan in formulating the

country's Low-term Low-Emissions Development Strategy, which further supports Thailand's Nationally Determined Contributions (NDCs) for climate change. EV adoption coupled with public transport modernization is considered a key measure for GHG reduction from the transport sector.

In short, the policy framework relating to transport sector electrification in Thailand can be structured in a simplified manner as shown in Figure 5.

Figure 6: Policy framework for transport sector electrification

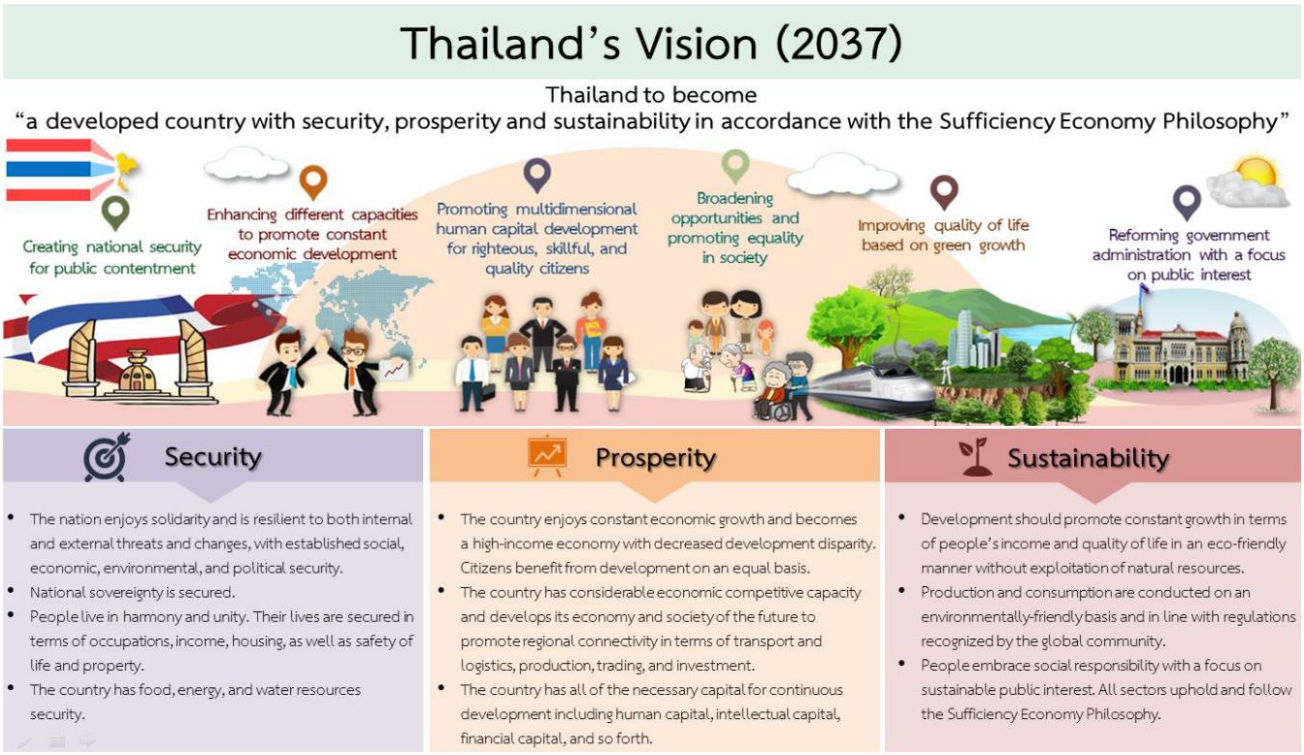


Source: Own design

2.3.1 Economic development: industry & transport

Section 65 of the Constitution of the Kingdom of Thailand stipulates that the State should develop a national strategy to be employed as the country's goal for sustainable national development in accordance with the principle of good governance. To this end, the National Strategy (2018-2037) was drawn up as the country's first national long-term strategy pursuant to the Constitution. It shall be pursued to ensure that the country achieves its vision of becoming "a developed country with security, prosperity and sustainability in accordance with the Sufficiency Economy Philosophy" (Figure 7).

Figure 6: Thailand's Vision (2037)



Source: National Strategy 2018-2037[6]

The National Strategy highlights the goal of enhancing the country's competitiveness. Restructuring manufacturing and services to follow major shifts is in a great need for Thailand. Particularly for the auto manufacturing industry, promotion of the shift from conventional automobiles to electric vehicles, development of energy storage system technology and industry, as well as encouragement of supporting activities in Research and Development (R&D) are specified in the National Strategy. Moreover, to transform Thailand into the hub of the economic corridor for transport, trade, investment, and tourism within the region, the National Strategy also highlights the importance of developing seamless transport networks as well as modern public transport and related facilities to accommodate growing urbanisation and to connect cities within the country and with the neighbouring countries.

In line with the National Strategy's framework, the 12th National Economic and Social Development Plan (2017-2021) started to lay out the agendas and flagship projects required to achieve the nation's economic and social development goals. Supporting small and medium enterprises (SMEs) of high potential through innovation and technology, increasing value-added of the existing production and service bases, as well as investment in knowledge-based production and services, which are both localised and environmentally friendly, are among the strategic measures identified to enhance the competitiveness of the Thai Economy. In the meantime, reducing Thailand's energy use intensity, raising the proportion of passengers using public transportation systems in urban areas, as well as strengthening the supporting components of Thailand's transportation systems, by encouraging development of transport-related industries and strengthening the managerial and regulatory components of the transport sector, are specified as part of the strategy for advancing infrastructure and logistics.

Looking ahead, the Thai Government is formulating the forthcoming 13th National Economic and Social Development Plan (2023-2027), of which the first goal is to transition the country from natural resources-based industries towards a knowledge-based and high value-added economy that is environmentally friendly. An electric vehicle ecosystem, emphasized by the National Economic and Social Development Council, will play a crucial role in enabling supporting industries including smart electrical parts and a smart grid (Theparat, 2021).

[6] http://nscr.nesdb.go.th/wp-content/uploads/2019/10/National-Strategy-Eng-Final-25-OCT-2019.pdf

2.3.2 Climate change mitigation: transport

Thailand submitted the Intended NDC to the UNFCCC in 2015, which aims to reduce its GHG emissions by 20%-25% compared to the projected BAU level by 2030. After the INDC submission, the NDC Roadmap on mitigation (2021-2030) was developed to provide a policy direction in achieving the GHG emission reduction targets, with the transport sector being one of the four main sectors that have been tasked to fulfil the country´s climate pledge. According to the Roadmap, transport sector is responsible for a GHG emission reduction of 41 $MtCO_2$ in 2030, which comprises of 31 $MtCO_2$ from energy efficiency improvements led by the Ministry of Transport and 10 $MtCO_2$ from biofuel consumption under the responsibility of the Ministry of Energy.

Following the NDC Roadmap, the OTP under the Ministry of Transport developed the NDC Action Plan for the Transport Sector in a comprehensive stakeholder consultation and modelling process. The Action Plan identifies detailed measures for achieving the NDC GHG emission reduction target. The Avoid-Shift-Improve (A-S-I) approach is put forward as one of the measures with an overall GHG reduction potential of 35.4 $MtCO_2$, exceeding the 31 $MtCO_2$ reduction target.

To achieve the existing NDC target of 20% GHG reduction, vehicle electrification is one of the core measures listed under the NDC action plan for the transport sector. Existing measures related to EV promotion under the current NDC action plan in the transport sector include:

- The purchase of 35 electric buses including charging stations,
- The purchase of 1,453 hybrid buses,
- The rental of 400 hybrid buses for 7 years,
- The supporting measure to promote public van to electric minibus of 4,626 vehicles,
- The supporting measure to promote public vehicles (e.g., taxi, songthaew) to hybrid vehicles, and
- The change of Internal Combustion Engine (ICE) delivery motorcycle to electric motorcycle in 6 major provinces.

However, these measures only represent a relatively small part of Thailand's ambition in EV development. More specific, concrete, and ambitious targets and measures can be found in the National EV Roadmap.

2.3.3 Cross-cutting area: EV and Energy Transition to support LT-LEDS

Promoting electric vehicles has its cross-cutting mission, which on one hand supports the country's long-term economic development goal, and on the other hand helps the country to achieve its NDC commitments towards climate change mitigation. However, EV development must go with an energy transition to become meaningful in terms of mitigation. That's how the energy sector comes into play. Thailand's energy policies are closely linked to its efforts in advancing NDC implementation. In October 2020 Thailand submitted an updated version of NDC without increasing its mitigation target but laying out the domestic processes to ensure the integration of the NDC target and actions into the National Strategy. The updated NDC indicates Thailand's plan to formulate Long-term Low Emissions and Development Strategy (LT-LEDS) that will guide the country towards a climate-resilient and low GHG emission development. At the same time the LT-LEDS will serve as a basis for enhancing subsequent NDCs to be more ambitious.

The formulation of LT-LEDS encourages participatory processes and close consultations with the energy sector. In August 2021, the National Energy Policy Council (NEPC) approved the framework for the National Energy Plan (NEP) with the key objective to support Thailand in pursuing clean energy and become carbon neutral in the energy sector by 2065/2070. Also included in the NEP is Thailand's EV 30@30 policy with the target of 30% of EVs in the overall domestic vehicle sales by 2030. To reach the EV 30@30 target, the Thai government has assigned a National EV Policy Committee to develop and implement an EV Roadmap, clearly committing to e-mobility as a key measure for NDC and LT-LEDS realization. The approved NEP and EV framework is a positive sign that lays out a solid foundation for Thailand to increase its ambition in LT-LEDS and upcoming NDCs.

The National EV Policy Committee recently agreed on an ambitious master plan aiming for 100% of the vehicles produced in Thailand to be electric, as Zero Emission Vehicle (ZEV) comprising of Battery Electric Vehicle (BEV) and Fuel Cell Electric Vehicle (FCEV), by 2035. The plan also targets 50% of the country's total vehicle production to be ZEVs by 2030, which provides a clearer direction for EV market in the country (Table 7).

Table 7: ZEV targets set by the National EV Policy Committee

Target	Type	ZEV Target (Vehicle / year)		
		By 2025	By 2030	By 2035
Production	Car / Pick up	225,000 10%	725,000 30%	1,350,000 50%
	Motorcycle	360,000 20%	675,000 30%	1,850,000 70%
	Bus / Truck	18,000 35%	34,000 50%	84,000 85%
Deployment (Domestic registrations)	Car / Pick up	225,000 30%	440,000 50%	1,154,000 100%
	Motorcycle	360,000 20%	650,000 40%	1,800,000 100%
	Bus / Truck	18,000 20%	33,000 35%	83,000 100%

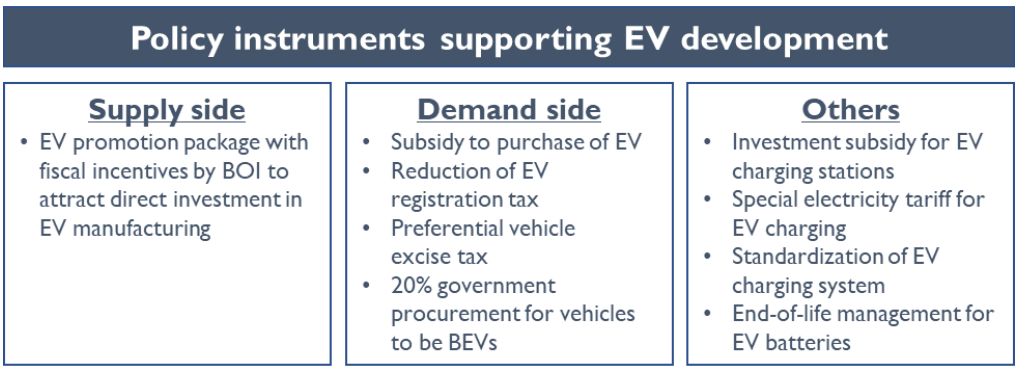
Source: Own design

The upcoming LT-LEDS can incorporate these updated EV targets and measures, which will enhance Thailand's mitigation ambition, and provide concrete guidance towards Thailand's subsequent NDC update.

2.3.4 Policy instruments supporting EV development

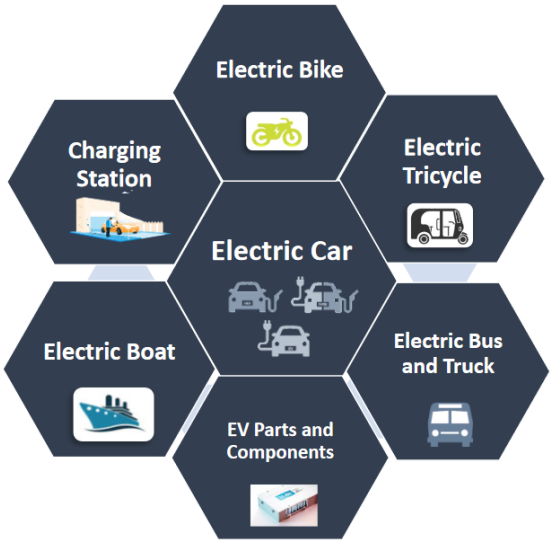
To support the above-mentioned policies and targets, the Thai Government has adopted a series of instruments, mostly using fiscal incentives i.e., tax exemptions and deductions, to stimulate capital investments in EV manufacturing and charging infrastructure on the supply side, while encouraging car users to choose EVs against ICE vehicles on the demand side. In the meantime, support has also been put in place for charging infrastructure development, standardization of EV components and end-of-life management for batteries etc. These instruments are categorized into 3 groups including supply side, demand side, and other supporting measures as shown in Figure 7. Details of each policy instrument are illustrated in Table 8.

Figure 7: Policy instruments supporting EV development



Source: Own design based on the government

Table 8: Policy instruments supporting EV development

Type	Policy	Description
Supply-side policy instruments	EV manufacturing promotion package by BOI	Thailand's Board of Investment (BOI) has been an important promoter of EV investment in the country. It acts under the Investment Promotion Act, which allows it to grant tax incentives and non-tax incentives. For tax incentives, the main types of taxation that BOI may exempt or reduce include corporate income tax and import duties on machinery and essential materials. For non-tax incentives, they can issue a variety of permits to bring in foreign experts, skilled workers etc.as well as to own land and remit money abroad in foreign currency. The first EV promotion package launched in 2017 focused on the production of three types of EVs: hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs). The package covered passenger cars, pickup trucks, and buses, with different rates of privileges based on production technology. During this first promotion period, 26 projects were approved by BOI, of which 7 have already started commercial operations from Nissan, Honda, Toyota, Mercedes-Benz, BMW, and Fomm and Takano. After the expiration of the first EV promotion package in 2018, BOI approved a new list of incentives for EV manufacturing in 2020. In face of a tough competition with Indonesia, the new BOI package aims at covering the supply chain of the entire EV ecosystem (Figure 8), including a variety of vehicle types (i.e., motorbike, tricycle, bus, truck, passenger car and boat) as well as EV parts and components, and charging stations. To enjoy the privileges, companies should submit their business project to BOI for screening and approval. Different types of activities are pre-categorised into 6 groups, which are applicable to different levels of privileges[7]. Figure 8: Eligible Components of The EV Promotion Package by BOI  Source: BOI (2021)[8]

[7] From the most privileged to the least is A1, A2, A3, A4, B1, and B2. Take CIT as an example, activities in Group A1 can enjoy a CIT exemption for a duration of more than 8 years (no cap), 8 years for Group A2, 5 years for Group A3, 3 years for Group A4, none for Group B1 and B2.

[8] https://www.boi.go.th/upload/content/New%20Investment%20Promotion%20Policies%20EN_6034b5448182b.pdf

<table>
<tr><th>Type</th><th>Policy</th><th>Description</th></tr>
<tr><td></td><td></td><td>EV promotion package from BOI include:
3-year tax holidays for PHEV & BEV investments less than THB 5 billion [EUR 149 million] and 8-year corporate income tax exemption (CIT) for BEVs, if the investment exceeds THB 5 billion [EUR 149 million],
Extension of some incentives for BEVs if they meet the requirements set by the government such as minimum production and commencement of commercial operation deadline,
90% reduction on import duties for two years on EV battery raw material both for modules and cells granted to promote local EV battery production,
Specific to electric motorbikes and buses, manufacturers can enjoy 3 years of CIT exemption in general and a possible extension of 1-3 years under different conditions.</td></tr>
<tr><td rowspan="3">Demand-side Policy instruments</td><td>Subsidy on EV purchase[9]</td><td>In August 2022, the cabinet approved THB 2.92 billion [EUR 8.71 million] to subsidise EV purchase. The subsidy rate differs by type of vehicle as shown in Table 9.
Table 9: Subsidy rate for EV purchase<table><tr><th>Type of EV</th><th>Rate of subsidy</th></tr><tr><td>Passenger cars with a price of less than 2 MB & a battery of 10 - 30 kWh</td><td>70,000 THB/unit [2,090 EUR/unit]</td></tr><tr><td>Passenger cars with a battery of more than 30 kWh for completely knocked down (CKD) and completely built-up (CBU) units</td><td>150,000 THB/unit [4,480 EUR/unit]</td></tr><tr><td>CKD pickups with a price of less than 2 million baht & a battery size of more than 30 kWh</td><td>150,000 THB/unit [4,480 EUR/unit]</td></tr><tr><td>Electric motorcycles with a price up to 150,000 baht for both CKD and CBU units</td><td>18,000 THB/unit [5,370 EUR/unit]</td></tr></table></td></tr>
<tr><td>Reduction of vehicle registration tax</td><td>Vehicle registration tax is levied on an annual basis by the Department of Land Transport. In July 2022, the cabinet approved additional tax incentives for EVs by lowering the annual car tax for EVs which are registered between October 2022 and Sept 2025 by 80%.
While the vehicle registration tax may not be considered as a significant cost component relative to the entire cost of purchasing and owning a vehicle, this is still a benefit to vehicle owners especially given that it is a regular expense throughout the entire period of vehicle ownership. It can become quite important to any public transport operators holding a fairly large fleet of vehicles.</td></tr>
<tr><td>Preferential excise tax rate</td><td>The current Thai excise tax structure of vehicles is based on carbon dioxide (CO_2) emissions, and there are four vehicle categories: 1) passenger cars with seats for no more than 10 people; 2) pick-up trucks that are passenger vehicles, double cabs and space cabs; 3) eco-cars and cars that use E85 and B10 biofuel; and 4) EVs. Under the current excise tax structure, battery EVs are tax-exempt from Jan 1, 2020, to Dec 31, 2022, for car makers granted Board of Investment privileges, with the rates levied at 2% after 2022. Manufacturers that did not receive incentives are charged 8% tax (Chantanusornsiri, 2021). Meanwhile, electric motorcycles are subject to an excise tax at 1% while other types of motorcycles are levied at between 3% and 18% depending on their CO_2 emissions. Note that vehicle excise tax is only levied on those considered as luxury items. Therefore, buses and vans of more than 10 seats as public transport vehicles are not subject to excise tax.</td></tr>
</table>

[9] https://www.bangkokpost.com/auto/news/2375490/cabinet-approves-b2-92bn-ev-subsidy-package

Type	Policy	Description
	20% government budget for vehicle fleet to be used for BEV procurement	According to EVAT (Kaewtatip, 2019), the Thai government has set the target that 20% of government budget for vehicle fleet to be used for BEV procurement. For that, public agencies, state enterprises and academic institutions have been planning or introducing EVs, such as the procurement of electric and hybrid buses by Bangkok Mass Transport Authority (BMTA), planning by the Office of Transport and Traffic Policy and Planning (OTP) for a public transport network in the Eastern Economic Corridor (EEC) to be served by electric buses, minibuses and trams (The Nation Thailans, 2021), and the Thammasat Smart City initiative with EVs as a transit mode in Rangsit and Tha Prachan campus (Thammasat University, 2019).
Other supporting policy instruments	Investment subsidy for EV charging stations	The Ministry of Energy launched a 3-yr pilot project between 2017 and 2019 to subsidise investment in charging stations, funded by the Thailand Energy Conservation Fund (ENCON Fund). While the subsidy scheme was open to both public and private actors, including government agencies, academic institutions, state enterprises and private companies, the public sector received more support than the private sector. This was done by allowing the subsidy to cover the costs of chargers and installations if the operator is from the public sector, while private operators could only receive a subsidy for the cost of chargers. While the scheme was not of great success it financed a total of 48 normal chargers and 32 fast chargers in 68 locations nationwide (Thananusak, Punnakitikashem, Tanthasith, & Kongarchapatara, 2021) and therefore kick-started to some degree the deployment of EV charging facilities.
	Special electricity tariff for EV charging	In September 2020, the Thai government approved a special electricity tariff for all EV charging stations at 2.63 THB/kWh [0,079 EUR/kWh] for the off-peak tariff, which is lower than the average tariff of 3.20 THB/kWh [0,096 EUR/kWh]. The on-peak tariff is set at 4.3 THB/kWh [0,128 EUR/kWh] (Sinsadok & Pinthusoonthorn, 2021).
	Standardisation of EV systems	The Thailand Industrial Standard Institute (TISI) has worked to set up the technical requirements for electric vehicles, traction batteries, and charging systems, through 21 Thai Industrial Standards (TIS). 40 additional standards for next-generation vehicles are being considered for approval. This is an important approach to ensuring the quality of products in the market. TISI classified Thai standards for EVs into 9 categories, including 1) Sockets and outlets, 2) Charging systems, 3) Safety for various types of EVs, 4) Performance, 5) Motors, 6) Batteries, 7) Other equipment, 8) Communication system, and 9) Other. While standards under Category 1, 2 and 5 and 7 have been almost completely developed and issued, most of standards under Category 3, 4, 6, and 8 have not been developed. This insufficient coverage of standards for EV components remains to be improved to boost manufacturing of EVs in Thailand (Global Environment Facility, 2020).

Type	Policy	Description
	End-of-life management for EV Batteries	To ensure sustainability in the life cycle of EVs, Thailand has also been working on end-of-life management for EV batteries. The Thailand Energy Storage Technology Alliance (TESTA) is formed by the Ministry of Higher Education, Science, Research and Innovation, EVAT and a number of science and engineering academic institutions. It aims at driving progress in local energy storage technology and enhanced end-of-life management for batteries. As a member of the Basel Convention, regulations related to hazardous waste treatment exist in Thailand. There is a working group chaired by Pollution Control Department and Industrial Works Department set up under the Basel Convention, and a working group on Energy Storage System chaired by the Ministry of Energy that addresses the issue of battery recycling.

2.3.5 Institutional framework

The Government has initiated its policy to promote EV since 2015. Various measures to promote electric vehicle production were launched in 2017. However, the development of EV requires the transition of a whole supply chain from production, infrastructure, and deployment, covering technical, financial, and regulatory dimensions. To drive the EV industry in the most efficiency and effective way, as well as, to integrate the operations, the National Electric Vehicle Policy Committee was established in February 2020. The committee will set the direction and goal of EV development and to approve plans and projects from government agencies to achieve the national EV goal. A number of government agencies must coordinate together to support the goals. As shown in

Figure 9, there are 4 main groups of government agencies, i.e. environment, infrastructure, safety, & standard, transport & licensing, and incentives.

Figure 9: Institutional framework for EV development in Thailand

National Electric Vehicle Policy Committee

Chairman: Prime Minister;

Committee:

1. Industry minister,
2. Transport minister,
3. Energy minister,
4. Permanent Secretary of Ministry of Finance,
5. Permanent Secretary of Ministry of Transport,
6. Permanent Secretary of Ministry of Energy,
7. Secretary, Board of Investment,
8. Secretary, Office of the National Economic and Social Development Council,

Secretaries:

9. Permanent Secretary of Ministry of Industry,
10. Director, Office of Industrial Economics,
11. Director, Energy Policy and Planning Office

1. Chairman of the Federation of Thai Industries,
2. Chairman of the Thai Chamber of Commerce,
3. President of The Thai Automotive Industry Association,
4. Mr. Bundhit Eua-arporn expert,
5. Mr. Werachet Khan-ngern expert,
6. Mr. Siri Jirapongphan expert,
7. Mr. Yossapong Laoonual expert,

Environment	Infrastructure Safety & Standard	Transport & Licensing	Incentives
• **Department of Industrial Work** to prepare EV battery end-of-life plan • **Pollution Control Department** to enact Acts for EV battery end-of-life management	• **Ministry of Energy** to subsidise charging infrastructure • **TISI** to proceed on National Automotive and Tire Testing Facility, to proceed on standards of EV charging system, etc.	• **Ministry of Transport** to support the national policy • **Department of Land Transport** to regulate land transportation	• **Ministry of Finance** to launch EV stimulation package, • **Excise Department** to provide special excise tax rate, • **BOI** to provide privileges on investment of EV • **EPPO** to provide financial support for replacement of EV and charging infrastructure

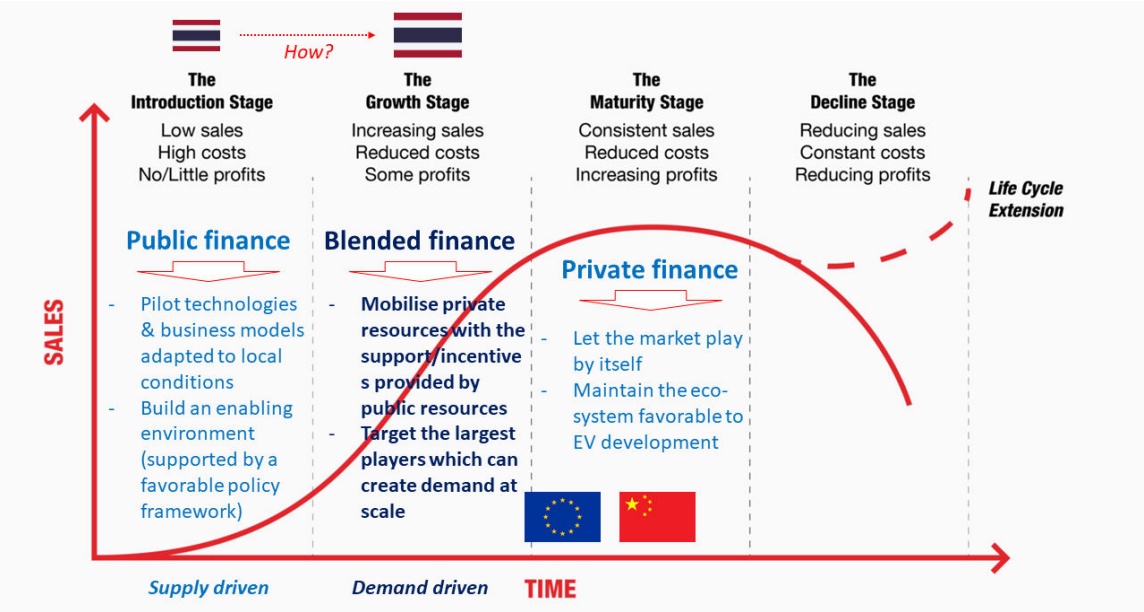
Source: National electric vehicle policy committee[10] & BOI (2022)

[10] https://www.thaiauto.or.th/2020/news/news-detail.asp?l=&news_id=4773

2.4 Governance, market structure and relevant stakeholders

Considering EV fleet transformation in public transport, from a macro perspective, as a market, Thailand is still at the introduction stage where electric public transport vehicles are expensive and few, with no to little profits. This is when public finance plays a major role in identifying the locally suitable technologies and business models, while building an enabling environment through a strong policy framework that is favourable to EV development. This is also when the market is driven by supply-side efforts, which aim at bringing an increasing number of products of better performance. Thailand is facing the challenge of moving towards the growth stage, where blended finance would be crucial to mobilise private resources to provide the significant size of investment required. At this stage, the market would become demand driven. The most efficient strategy would be targeting the largest players in the market which have sufficient capacities to drive a fairly substantial demand for the market to grow. Once the market becomes mature, such as in the case of China and Europe, governments can just let the market play by itself, while maintaining the eco-system that is favourable to EV development (Figure 10).

Figure 10: 4-stage life cycle of the EV market



Source: Own design from www.manrajubhi.com

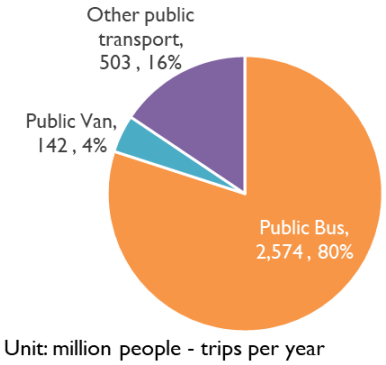
2.4.1 Market structure of public bus

Demand for public bus

In 2019, the total number of commutes in Bangkok Metropolitan Region was 11,124.30 million passenger-trips per year whereas public transport has a share of 19.42%. Among the public transport, public bus contributed 80% to the total commutes by public land transport or 2,574 million people-trips/year (Figure 11).

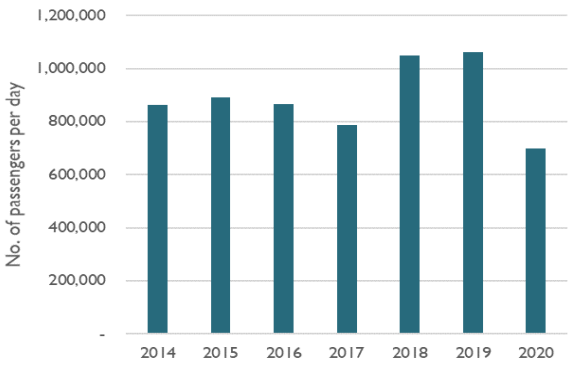
The number of passengers using public buses is fluctuating (Figure 12). The decreasing trend during 2014 – 2017 was caused by undesired conditions of buses and poor level of service quality, i.e., unpunctual service, and risky driving practices. The majority of bus passengers still remain people with low income who have limited capacity to switch to other modes. The provision of new 489 air-conditioned natural gas vehicles (NGV) in 2018 and the rising price of petroleum products during 2018-2019 stimulated the number of passengers of public buses. However, the ridership dropped again in 2020 due to Covid-19.

Figure 11: Share of commutes by public land transport in 2019



Source: Transport Infrastructure Report (OTP) (2019)

Figure 12: Number of passengers per day during 2014 - 2020

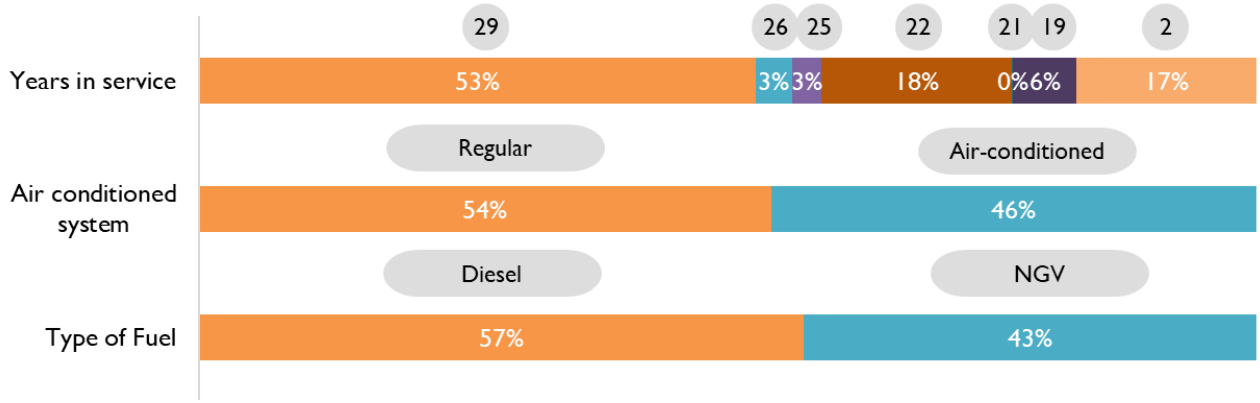


Source: BMTA's Rehabilitation Plan (New Revision) (2020)

Supply of public bus

The conditions of public buses in service are not desirable. There are 3,786 buses covering 180 routes serving passengers in the BMR, as of August 2021. 53% of them had been in services for more than 29 years and 54% of them are not air-conditioned (Figure 13). This causes not only inconvenience for passengers but also high operating cost for the operators. Some of these buses are not well functioning; therefore, insufficient supply of buses lowers the service quality and reduces the income of the operators. Moreover, 57% of these buses rely on diesel whereas the specific fuel consumption is high with a volatile diesel price. Moreover, a diesel bus has 1.5 to 8 times the GHG emissions of an electric bus.

Figure 13: Conditions of public buses in service



Sources: BMTA's Rehabilitation Plan (New Revision) (2020), BMTA's 2020 annual report

Operators of these buses can be divided into 3 groups, i.e., (a) Bangkok Mass Transit Authority (BMTA), a state-owned enterprise, which is a major bus operator with a market share of 83% covering 116 routes, (b) private companies with sublicense of BMTA and (c) private companies with direct licences from DLT. Table 10 shows the number of buses serving in the BMR by operators in 2021.

Table 10: Number of buses serving in the Bangkok Metropolitan Region in 2021

Operators	Number of buses	Share in %
BMTA	2,966	78.3%
Private companies (Sublicence of BMTA)	196	5.2%
Private companies (Direct licences from DLT)	624	16.5%
Total	3,786	100%

Source: BMTA: Bus service statistics (2021)[11]

The new regulation, resolved by the cabinet in 2016, controls the quality of buses in service. About 70% of total buses in the fleet must be new or less-than-2-year vehicles and the remaining 30% must be less-than-25-year vehicles. The regulation allows gradual replacement of old buses in the fleet. The share of new or less-than-2-year vehicles must increase to 30% within the 1st year after getting license, 50% within the 2nd year, and 70% within in the 3rd year. It is expected that in 2022, 70% of buses covering 54 routes that obtained licenses in 2019 must be new or less-than-2-year vehicles.

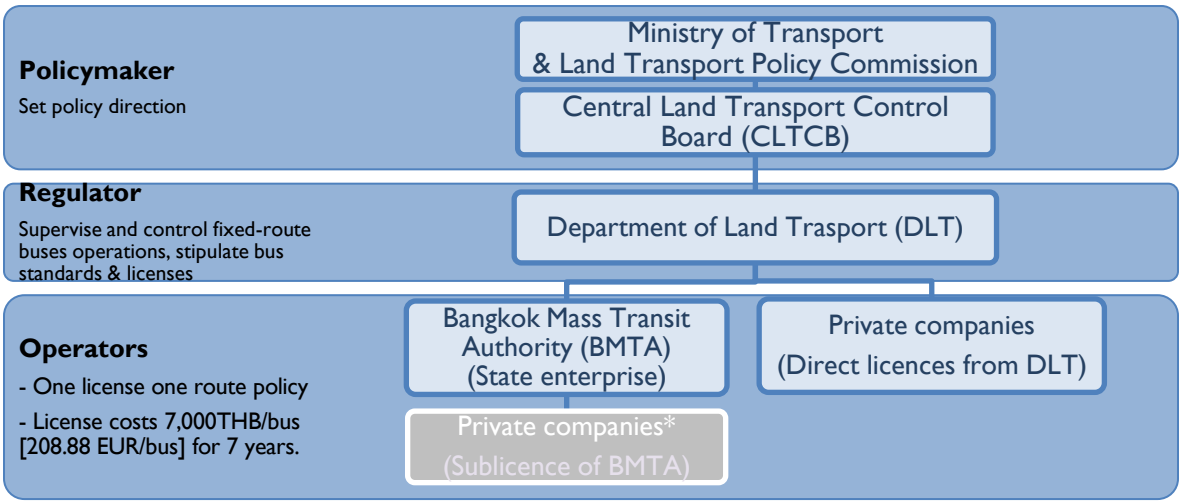
Institutional arrangement of public bus market

As public buses are the basic transport mode in the country, government supervision is necessary to ensure comprehensive coverage and accessibility as well as to maintain fair pricing. Following the Land Transport Act, the Land Transport Policy Commission chaired by Minister of Transport has been established to determine long-term and short-term policies while the Central Land Transport Control Board (CLTCB) chaired by the Permanent Secretary of Ministry of Transport has been put in place to prescribe the routes, number of transport operators, and vehicles for both the fixed routes and the non-fixed routes in Bangkok, between provinces and between countries. Moreover, CLTCB has been responsible for prescribing the rates of transport charges, laying down measures for the prescribing, permitting, revoking of licenses, and controlling the land transport affaires, as well as to carry out other activities prescribes in the Land Transport Act.

Previously, BMTA was both a regulator and an operator with the power to sublicense private operators; therefore, there were 2 groups of operators, i.e., BMTA and its sublicense companies. This licensing system together with the limited capability of BMTA to control the service quality led to the poor level of service. In 2016, the cabinet resolution endorsed the Department of Land Transport (DLT) as a regulator and BMTA as a bus operator, aiming to encourage fair competition for all licensed operators as well as to promote delivery of higher performance and better service quality. The reform is undergoing; therefore, some of private companies sublicensed to BMTA still exist. In the long term, all private companies must get licenses directly from DLT so the operators will be divided into 2 groups, i.e., (a) BMTA as a state-owned enterprise and (b) private companies with direct licenses from DLT.

[11] http://www.bmta.co.th/sites/default/files/files/about-us/o15-october63-december64.pdf

Figure 14: Institutional arrangements of public bus services in Bangkok Metropolitan, 2022



*Remark: *When the BMTA licenses granted to these private joint companies expire, they must apply for licenses from DLT.*

Source: Own design

a) Route and licensing

To prevent overlapping service routes and to ensure coverage and integration with other transportation modes including rail, water, and air, the Department of Land Transport (2019) has reformed service routes of public buses in Bangkok and its vicinity areas. Key issues regarding route and licensing can be summarized as follows:

- The "one route one operator" policy is applied strictly for licensing bus operators.
- The fee of the license is 7,000 THB [EUR 209] and the license is valid for 7 years.
- The new regulation has also mandated the quality of buses in service mentioned earlier and DLT has established 12 indicators to conduct regular evaluation of their service quality, e.g., driving within the specified route, reaching the specified number of trips, punctual schedule.

As per the cabinet resolution on 27 September 2016, the reform plan announced 269 service routes covering the distance of 7,833 kilometres. Table 11 describes allocation of licenses or routes granted from DLT by operators.

- From further reviews of operators, the following was found:
  - Thai Smile bus Co.,Ltd. had 9 licenses in 2021 and received another 71 licenses in 2022;
  - E Transport Holdings Co.,Ltd., which is the subsidiary of Energy Absolute Plc., has acquired 99.99% of the ordinary shares of Smart Bus Co.,Ltd. who received 31 licenses directly from DTL and was also the major shareholders of 6 companies that received 6 another licenses from DTL during 2019-2020;
  - Other private companies granted licenses during 2019-2020 were companies sublicensed from BMTA.

Table 11: Number of licenses or routes granted from DLT by operator (updated in April 2022)

Operators	Number of licences / routes
BMTA	108
Thai Smile Bus Co.,Ltd.	80
E Transport Holdings Co.,Ltd.	37
Other private companies	14
Subtotal	239
Not granted	30
Total	269

Sources: Bangkok Mass Transit Authority's Rehabilitation Plan (New Revision) (2020)[12]

[12] https://classic.set.or.th/dat/news/202204/22041019.pdf, https://thaismilebus.com/about-us/, https://classic.set.or.th/dat/news/202203/22035439.pdf

b) Bus fares

Bus fares are regulated by the government and kept low to ensure that they remain affordable to all commuters especially those with low income. CLTCB has the responsibility to set the ceiling of bus fares, but the actual rates are negotiated between DLT and bus operators. The latest fares were resolved in 2019, with an increase by 1-2 THB [EUR 0.030-0.060] compared to the rates in 2015. Bus fares vary upon operators, types of buses and distance travelled as shown in Table 12.

Table 12: Bus fares applied since 22 April 2019

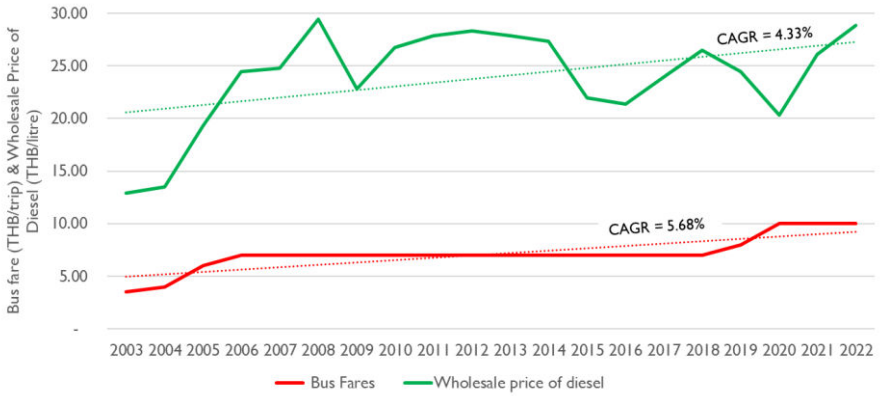
Types of Buses		Bus Fares (Unit: THB)		
		Ceiling Set by CLTCB	**Actual Operated by BMTA**	**Actual Operated by private companies**
	**Non-airconditioned**	10 (0.50 - 10) [EUR 0.298]	8 (0.40 - 8) [EUR 0.239]	10 (0.50 - 10) [EUR 0.298]
	**Air-conditioned (old model)**	13 - 21 (1.05 - 13) [EUR 0.388 – 0.627]	12 - 20 (1.05 - 12) [EUR 0.358 – 0.598]	13 - 21 (1.05 - 13) [EUR 0.388 – 0.627]
	**Air-conditioned (EURO)**	14 – 26 (1.30 - 14) [EUR 0.418 – 0.776]	13 - 25 (1.25 - 13) [EUR 0,388 – 0,746]	14 - 26 (1.30 - 14) [EUR 0.418 – 0.776]
	**Air-conditioned (new model)**	15, 20, 25 (1.25 - 15) [EUR 0.448, 0.597, 0.746]	15, 20, 25 (1.25 - 15) [EUR 0.448, 0.597, 0.746]	15, 20, 25 (1.25 - 15) [EUR 0.448, 0.597, 0.746]

Remark: Numbers in () are the average fares per km of distance assuming that the longest distance is 20 km.

Source: MGR Online (2019)[13]

There were 6 adjustments of minimum bus fares during 2003 – 2022 where the key factor determining the adjustment of bus fares has been the fuel price. Figure 15 illustrates changes of minimum bus fares and diesel price during 2003 – 2022.

Figure 15: Changes of minimum bus fares and diesel price during 2003 - 2022



Sources: MGR Online (2019)[14] & EPPO 2022[15]

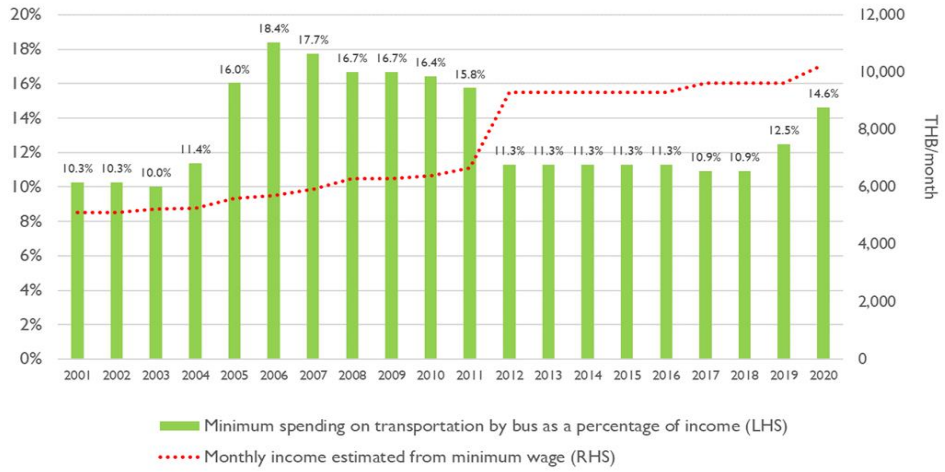
[13] https://mgronline.com/business/detail/9620000039833

[14] https://mgronline.com/business/detail/9620000039833

[15] http://www.eppo.go.th/index.php/th/energy-information

The Sustainable Urban Transport Index on affordability measures monthly expenditure on public transport compared to mean monthly income of the poorest quartile of the population of the city and should range 3.5% - 35% of the income (ESCAP, 2017). In comparison to the index, the fares of public buses in Bangkok are considered as highly affordable since the monthly expenditure on public bus use ranged between 10% - 18% of the minimum monthly income per capita during 2003 – 2019 (Figure 16).

Figure 16: Ratio of monthly expenditure on public transport compared to the monthly income estimated from minimum wages



Remark: The minimum cost of commuting by buses per capita in Bangkok is calculated from minimum bus fares multiplying by 6 trip/day and 25 day/month.

Source: NESDC (2020)[16]

However, the cost of bus operation depends upon not only fuel price but also other economic indicators, e.g., consumer price index, or labour cost index. Since the fare is the major source of revenue for the bus operators, a low bus fare forces the operators to minimize their costs and therefore, lowering the service quality for the passengers. The bus fares should be adjusted to cover all operating costs of buses as well as allow bus operators to invest in improvement of bus and service quality. To ensure affordability for low-income passengers, the government should support the service provision through direct subsidies to low-income passengers, instead of keeping the fare at a low level. Fair pricing together with regular evaluation of operators' performance will lead to higher service quality which is key to encourage the use of public transport for all groups and finally leading towards an improvement in the overall traffic situation of Bangkok.

2.4.2 Financial status and business models of existing bus operators

2.4.2.1 Current financial status of bus operators

Bangkok Mass Transit Authority (BMTA)

BMTA has been incurring deficits since its establishment in 1976 resulting from its high operating costs and low revenues due to fares regulated by the government. Key figures drawn from the review of BMTA's financial status (Figure 17) can be summarized as follows:

- Total cost of BMTA was about 49% - 108% higher than its revenue during 2011 – 2020;
- BMTA's revenues came mainly from the support of the government (55% of total revenue) while only 39% of the revenues came from sales of tickets;

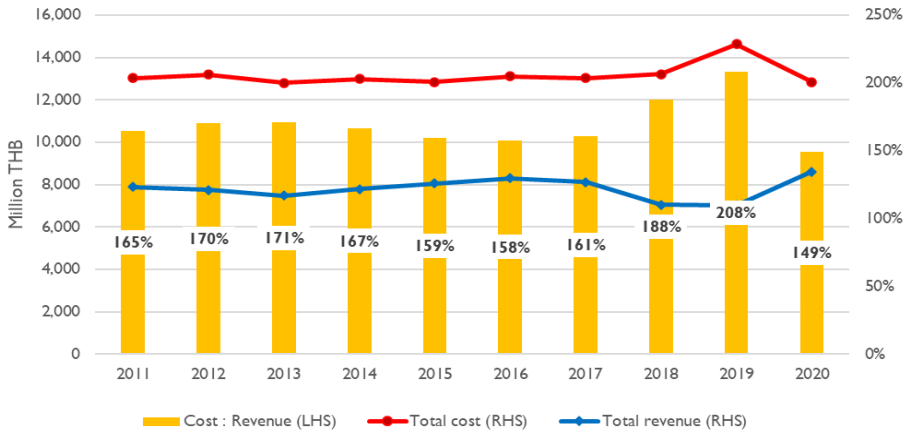
[16] http://social.nesdc.go.th/SocialStat/StatReport_Final.aspx?reportid=3817&template=2R1C&yeartype=M&subcatid=11

- Wages and benefits of all BMTA staff including bus drivers, bus assistants, management team, maintenance team and administration team account for 44% of total cost for BMTA, which is the highest, followed by interest rates, fuel cost and maintenance cost accounting for 21.3%, 13.9%, and 12.7%, respectively. Considering only the operating cost, wages and benefits, fuel cost and maintenance cost amount to share of 56.5%, 17.7%, 16.2%, respectively. As identified in BMTA's rehabilitation plan (2020), the average manpower for operation of a public bus was at 4.65 persons, which is high compared to other cities/countries. For example, there were 4,749 staff operating 2,378 buses, accounting 2 persons/bus in Wales, UK, whereas 79% of the staff are drivers[17].

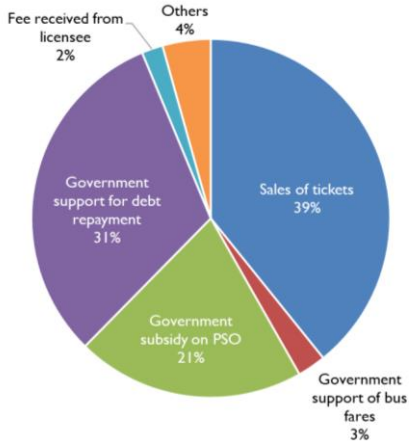
It is recognized that most buses under BMTA are deteriorated leading to high operating costs and low service quality. Additionally, further restraints on capacity result from new regulation determining that 70% of buses in service by operators must be new or less-than-2-year vehicles. BMTA currently has limited capacity to invest in new fleets and as highlighted by BMTA Director, BMTA is seeking for Public-Private Partnership (PPP) to meet the investment needs in new buses.

Figure 17: Financial status of BMTA

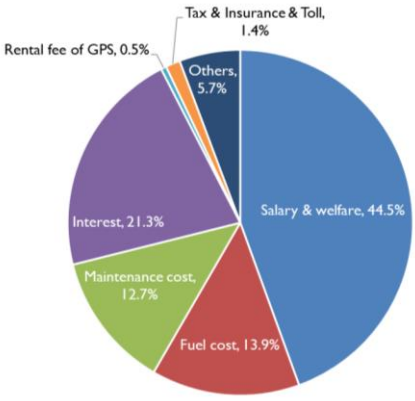
a) Total revenue and cost of BMTA during 2011 - 2020



b) Shares of BMTA's revenues in 2020 (Unit: MB)



c) Shares of BMTA's costs in 2020 (Unit: MB)



Source: Compiled from BMTA annual report (2020) & BMTA (2020)[18]

[17] https://gov.wales/sites/default/files/pdf-versions/2022/4/3/1649859506/public-service-vehicles-buses-and-taxis-april-2019-march-2020.pdf

[18] http://www.bmta.co.th/sites/default/files/files/about-us/o20_0.pdf

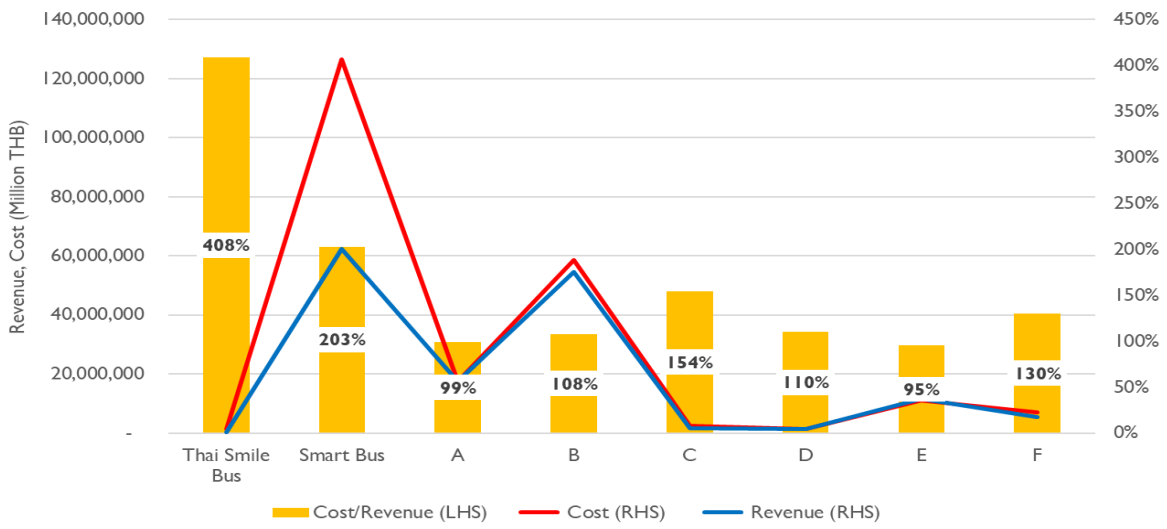
Private companies

Besides BMTA, operators comprise Thai Smile Bus Co.,Ltd, E Transport Holdings Co.,Ltd., and other private companies. The financial status of some private operators is described below:

- Thai Smile Bus Co.,Ltd. (TSB), is a private company registered with a capital of 910 million baht on June 9, 2020, to provide public bus services in Bangkok and its vicinity by deploying EVs. In 2021, the company had 9 licenses from DLT and obtained an additional of 71 licenses in 2022. According to the financial statement of TSB in 2020, the total asset of TSB was THB 214.3 million [EUR 6.39] and a loss of THB 1.07 million [EUR 31,900] was reported. The deficit in 2020 resulted from the high depreciation cost in the early years of operation;
- E Transport Holdings Co.,Ltd., which is the subsidiary of Energy Absolute Plc., has acquired 99.99% of the ordinary shares of Smart Bus Co.,Ltd. on March 18, 2022. Smart Bus Co.,Ltd. is a private company registered with the purpose to provide public bus services in Bangkok and surrounding provinces, obtaining 37 licenses directly from DTL. The financial statement of Smart Bus Co.,Ltd. in 2019 & 2020 shows that the total assets of Smart Bus Co.,Ltd. were THB 2,635 and 2,721 million [EUR 7,860 and 8,120], respectively. The income statement shows that the loss in 2019 and 2020 were THB 64.2 and 372.5 million [EUR 1.92 and 11.1 million].

Figure 18 illustrates the total revenues and costs of private bus operators in 2019. Companies A to F were formerly sublicensed by BMTA. The sizes of companies vary. Companies C and D are the operators with total revenues below THB 3 million [EUR 89.500]. The proportions of cost to revenue of Thai Smile Bus and Smart Bus are high, resulting mainly from their initial investment. The cost of operator A and E were lower than their revenues while the costs of other operators were about 8% - 54% higher than their revenues, causing net loss. This can be seen as evidence that current bus fare levels cannot cover the operating cost resulting in limited capacity to invest in improvement of bus infrastructure and service quality.

Figure 18: Total revenues and costs of private bus operators in 2019



Source: Compiled from financial statement and income statement from DBD DataWarehouse+[19]

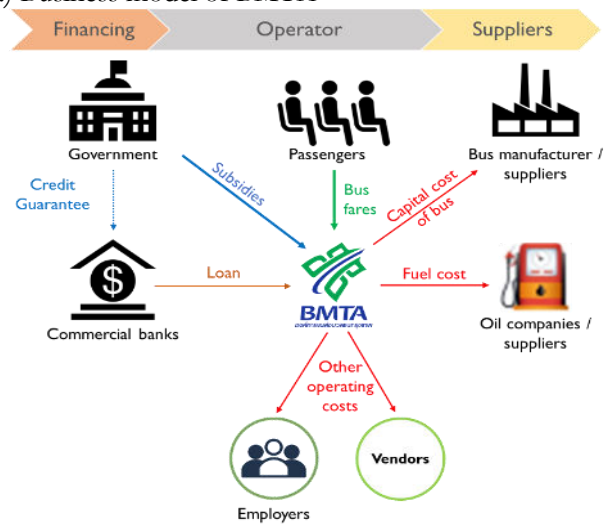
[19] https://datawarehouse.dbd.go.th/

2.4.2.2 Existing business models of bus operators

As described earlier, there are three groups of operators in 2022 including BMTA, private companies sublicensed from BMTA, and private companies getting licenses directly from DLT. The existing business models of bus operators show that all three groups of operators are owning their vehicles, running services, and maintaining their fleet (Figure 19). Only in 2011, BMTA was allowed to rent 117 buses under the performance-based contract where the bus service provider is in charge of buses and maintenance services. The operating cost includes fuel cost, employee wages and benefits, and other costs such as cost of ticket, license fee etc. while the revenues of the operators mainly come from bus fares. Only BMTA has received subsidies from the government. The annual subsidies were about THB 1,917 - 2,338 million [EUR 57.2 - 69.8 million] during 2018 – 2022.

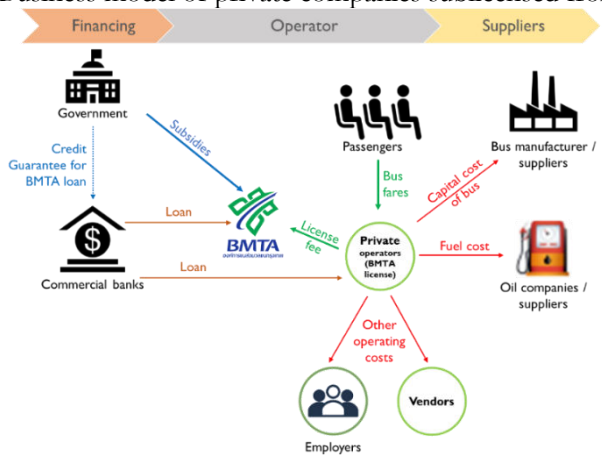
Figure 19: Existing business models of bus operators

a) Business model of BMTA



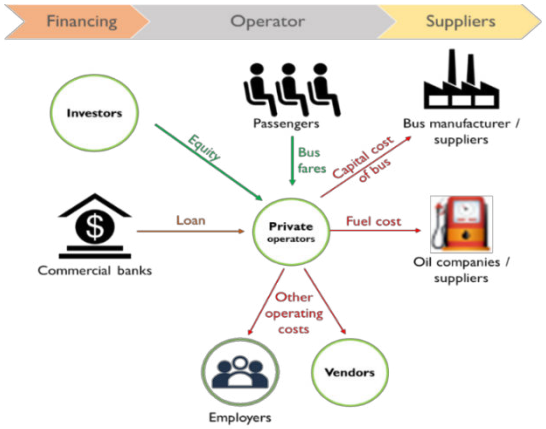
- BMTA is a state enterprise receiving various forms of subsidies from the government to support its operation.
- Due to its continuous deficit, BMTA must acquire loans from the commercial banks through the credit guarantee supported by the Ministry of Finance.
- Revenues of BMTA mainly come from bus fares.
- BMTA must own and operate the fleet and pay both the capital cost and the operating cost. The operating cost covers fuel cost, employee wages and benefits, and other operating costs.

b) Business model of private companies sublicensed from BMTA



- In this model, BMTA sublicensed the companies to own and operate the public buses.
- The operating cost as well as the collection of bus fares are incurred by the private operators.
- Also, the private operators must pay a license fee to BMTA.
- The new regulation does not allow this model since the service quality was very poor.

c) Business model of private companies getting licenses directly from DLT



- In this model, private operators receive licenses directly from DLT.
- The operators own and operate the fleet by themselves.
- The revenues of the operators come from the collection of bus fares without any financial support from the government.

Source: Own design

2.4.3 EV trends

In Southeast Asia, interest in EVs is also growing. On one hand, air pollution from land transport is serious and harmful to human health in many ASEAN cities, which draws much attention towards cleaner fuel technologies[20]. On the other hand, several ASEAN countries in addition to Thailand, such as Indonesia and Malaysia, have been important production bases for the world car manufacturing industry, therefore promoting electric vehicles is often regarded not only as an important measure to pursue cleaner transport, but also as a strategic lever to trigger an industrial transformation towards more sustainability. Although EV adoption has been relatively limited so far, the regional trend is making headway towards a promising EV uptake.

Global sales of EVs have expanded significantly over the last decade and continued increasing sharply in 2022. Based on BloombergNEF's analysis (BloombergNEF, 2022), under its Economic Transition Scenario, where changes are driven by techno-economic trends and market forces, and no new policies are assumed to be enacted, the share of zero-emission vehicle (ZEV) sales around the world for all types of vehicles would increase to a great extent, among which buses would see a strong growth from 39% in 2020 to 91% in 2050. To achieve the net-zero target by 2050, the global fleet of all types of road transport should then be fully electrified. While buses would only require a bit of a push in the net zero scenario, some targeted support would significantly benefit the sales of electric cars and light commercial vehicles (LCVs).

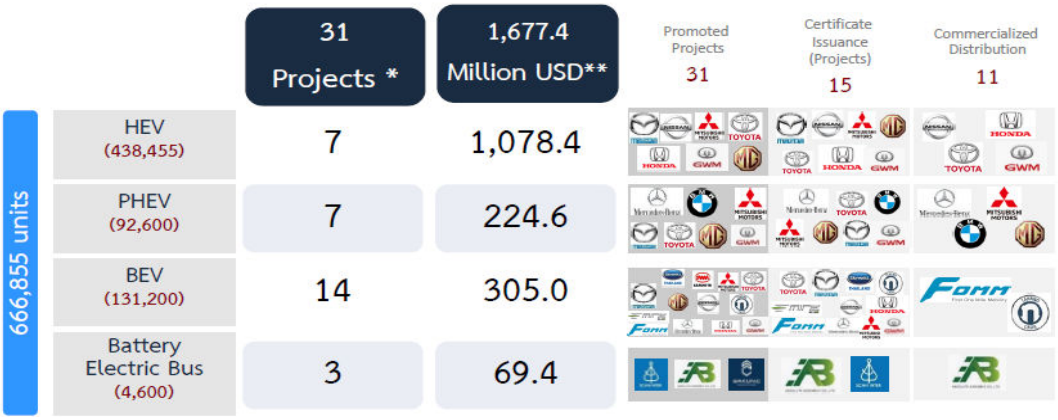
Due to a combination of policy support, improvements in battery technology and cost, more charging infrastructure being built, and new compelling models from automakers, EV sales are surging particularly for buses and 2/3 wheelers. In 2020, the overall size of electric bus fleet was nearly 600 thousand, accounting for 16% of the global fleet. The concerned issue of battery pricing has also shown a significant improvement with lithium-ion battery pack falling 89% from 2010 to 2020. The volume-weighted average hit $137/kWh in 2020. The global EV market is fragmentedly growing, with electrification running far ahead in China, Europe, and some smaller markets like Norway. In the meantime, EV adoption remains relatively low in emerging economies.

EV investment trends in Thailand

As of April 30, 2022, there are 31 projects with a total amount of 1,674 million USD [EUR 1,528 million] investing in HEV, PHEV, BEV, and battery electric bus applying for BOI privileges whereas 11 projects are commercially distributed (BOI, 2022).

[20] https://eias.org/op-ed/electric-vehicles-driving-asean-sustainable-growth/

Figure 20: Promoted EV projects under BOI

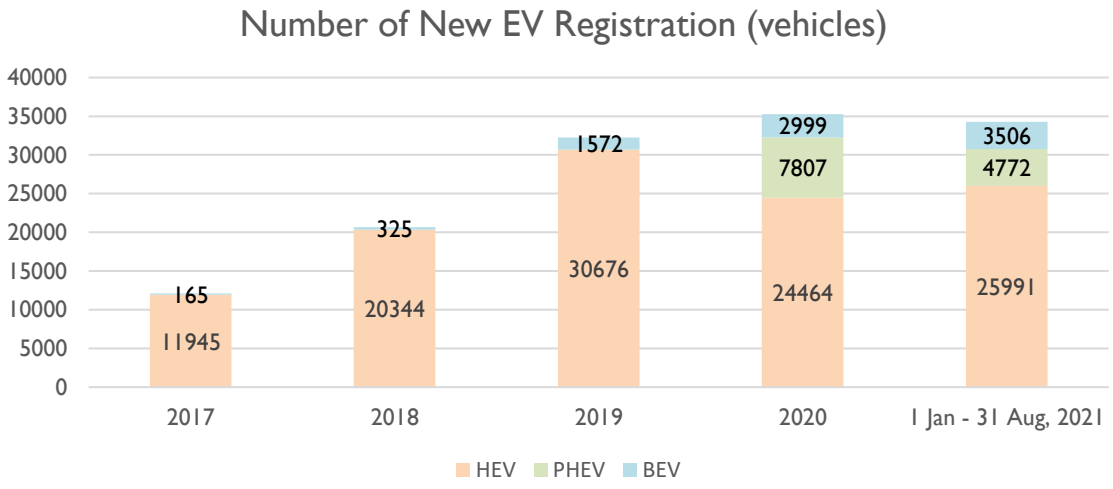


Remarks:
** 17 promoted entities,*
*** Investment values excluding cost of land and working capital, THB 34.5 = USD 1 (May, 2022)*

Source: BOI (2022)

The popularity of electric vehicles in Thailand was fairly limited before 2017, but started growing year after year since then. According to the latest statistics from the Electric Vehicle Association of Thailand (EVAT), the number of new EV registrations has been increasing since 2017. The compound annual growth rate of newly registered hybrid EVs (HEVs) and Plug-in EVs (PHEVs) is 39% between 2017 and 2020, while that of newly registered battery EVs (BEVs) is 163%. The year 2021 has set a historical record in the growth of new EV registrations with nearly the same number of new registrations from the previous year in 8 months (Figure 21).

Figure 21: Evolution of new EV registration during 2017 - 2021



Source: EVAT (2021)

However, most of the newly registered vehicles are electric passenger cars and motorcycles. For buses, only 4 battery electric buses (BEBs) were added to the market in the first eight months of 2021, amounting to 126 BEBs in total, as well as 1 hybrid electric bus (HEB).

Charging infrastructure remains quite limited. The total number of outlets nationwide as of 22 September 2021, amounted to 2,285, spreading over a total of 693 charging stations, according to EVAT[21]. There is a chicken-egg dilemma in charger deployment. As EV adoption is still limited, the concern over profitability might have constrained the expansion of chargers. However, without sufficient charging infrastructure, people would be less willing to adopt EVs. This is obviously an important issue to be taken into account in the overall analysis of large-scale EV deployment.

2.4.4 Key stakeholders

There are two main key stakeholders in the component of bus modernization. Key stakeholders are actors, that are directly involved in the decision-making of the project and can strongly influence the implementation of the project.

Department of Land Transport (DLT)

For bus modernization, the key stakeholders are the DLT and the BMTA/ private bus operators.

Under the Ministry of Transport (MOT), the DLT's role is to design criteria and support bus operators to change to a new bus fleet. They are responsible for the following six key areas of transport delivery:

- Performing duties under land transport law, motor vehicle law, and other relevant laws;
- Improve rail and road safety to bring down the rate of accidents;
- Promote and develop land transport networks;
- Systematize land transport;
- Establish cooperation with other relevant national and international agencies and organizations regarding the land transport and international conventions and agreements;
- Perform other duties as stipulated by law or delegated by the Minister of the Cabinet.

The Land Transport Control Board is the regulatory body identified within the Land Transport Act that is responsible for planning and defining fixed route urban public transport services across Thailand. It defines the contractual basis within which bus services are provided, including the setting of fares, determining route alignments, peak vehicle requirement, bus stopping locations as well as other service requirements.

While the DLT is supposed to be responsible for the planning and implementation of public transport services, the Department typically authorizes service providers (either private or government enterprises) to carry out some of these tasks. For example, BMTA (Bangkok Mass Transport Authority) provides bus services within the BMR while the transport company plans and provides intercity bus services.

Bangkok Mass Transit Authority (BMTA)

BMTA is the main operator of bus services in Bangkok. In this mitigation action its role is to participate in and support the bus modernization scheme. As of October 2017, BMTA operated 2,554 buses, of which 1,543 are standard buses and 1,011 are air-conditioned buses. BMTA sub-contracts the operation of some bus services to private operators, which (as of October 21017) operated 11,433 large and small vehicles. BMTA used to be responsible for managing the private bus operators, however after 2019, this responsibility is being transferred to the DLT, so that BMTA's sole focus is operating bus services.

[21] http://www.evat.or.th/attachments/view/?attach_id=256246

2.5 Financing and funding transport

2.5.1 Overview of costs and revenues of electric bus operation and maintenance

This section explores the capital expenses (CAPEX) as well as operational expenses (OPEX) of a diesel bus, a NGV bus, and an electric bus and provides a comparative analysis of the results from the evaluation of the total costs of ownership (TCO) covering CAPEX and OPEX over the lifetime of a diesel bus, a NGV bus, and an e-bus. The data used for the evaluation of TCO have been collected through both desk research, direct interviews, and stakeholder consultation workshops. This section describes key findings from the analysis.

CAPEX and OPEX of bus operation and maintenance

Capital Expense (CAPEX) is the total cost of bus acquisition. For a diesel bus and an NGV bus, the CAPEX will only be the cost of a bus invested in Year 0 while the CAPEX of an electric bus will cover the cost of the bus invested in Year 0 and the cost of battery replacement after 2000 charging cycles or approximately 7 years of operations. Compared to the CAPEX of a diesel bus, the CAPEX of an NGV bus is 17% lower while that of an electric bus is 102% higher (Table 13).

Table 13: CAPEX of a diesel bus, a NGV bus, and an electric bus

Items	CAPEX (THB)			Description
	Diesel bus	NGV bus	E-bus	
Cost of bus at Year 0	4,900,000 [EUR 146,000]	3,600,000 [EUR 107,000]	6,650,000 [EUR 198,000]	12-m bus with 31 seats
Cost of battery at Year 7	-	-	3,500,000 [EUR 104,000]	Battery size: 350 kWh
NPV of CAPEX	4,900,000 [EUR 146,000]	3,600,000 [EUR 107,000]	9,000,660 [EUR 2.69 million]	
Ratio of the CAPEX of a diesel bus, an NGV bus, and an electric bus compared to the CAPEX of diesel bus	100%	73%	202%	

Remarks:
1. Cost of a diesel bus and an e-bus is collected from the interview and stakeholders' consultation workshop.
2. Cost of a NGV bus is obtained from BMTA' Rehabilitation Plan (Revision: May 2019).

OPEX of a public bus covers fuel cost, maintenance cost, cost of a bus driver and an assistant, bus tax and license fee, GPS, and ticket costs. The total OPEX of a diesel bus is the highest at 2,619,500 THB/year [78,200 EUR/year] while that of a NGV bus and an e-bus account for 75% and 58% of the OPEX of a diesel bus, respectively (Table 14). The largest contribution to the OPEX of a diesel bus and a NGV bus is fuel cost while that of an e-bus is the cost of a bus driver and an assistant (Table 14).

Table 14: OPEX of a diesel bus, an NGV bus, and an electric bus

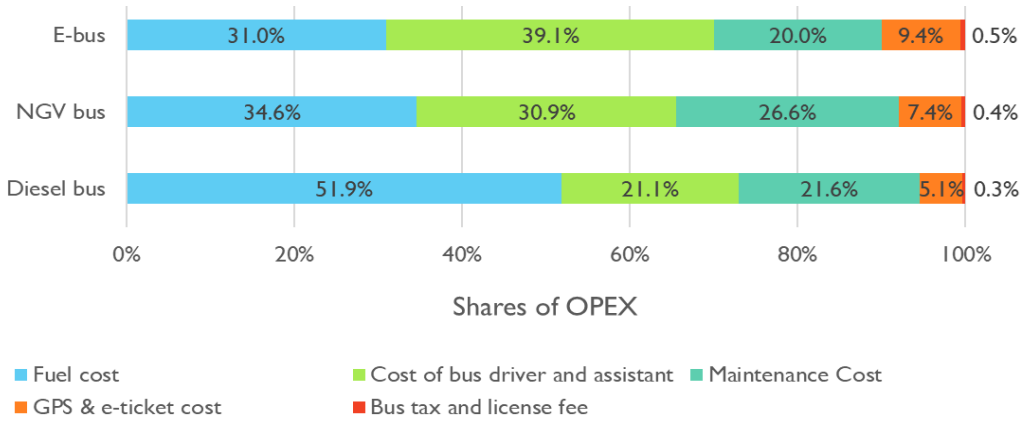
Items	OPEX (THB/year)		
	Diesel bus	NGV bus	E-bus
1. **Fuel cost** [1]	1,252,987	693,701	468,000
- **Fuel consumption**	0.65 litre/km	0.60 kg/km	1.1 kWh/km
	26.8 THB/litre	16.09 THB/kg	6 THB/kWh

Items	OPEX (THB/year)		
	Diesel bus	**NGV bus**	**E-bus**
- **Fuel price**	[0.800 EUR/litre]	[0.480 EUR/kg]	[0.179 EUR/kWh]
2. **Bus driver and assistant cost** [2]	600,000 [EUR 17,900]	600,000 [EUR 17,900]	600,000 [EUR 17,900]
3. **Maintenance cost** [3]	614,073 [EUR 18,300]	516,000 [EUR 15,400]	307,037 [EUR 9,160]
4. **GPS & e-ticket cost** [4]	144,000 [EUR 14,300]	144,000 [EUR 14,300]	144,000 [EUR 14,300]
5. **Bus tax & license** [5]	8,440 [EUR 252]	8,440 [EUR 252]	8,440 [EUR 252]
Total	2,619,500 [EUR 78,200]	1,962,141 [EUR 58,600]	1,527,477 [EUR 45,600]
Ratio of the OPEX of a diesel bus, an NGV bus, and an electric bus compared to the OPEX of diesel bus	100%	75%	58%

Remarks:

1. ***Estimated from the service distance of 72,000 km/year (30 km/trip * 8 trips/day * 300 day/year)***
2. ***Estimated at 50,000 THB/month [1,490 EUR/year]***
3. ***2,046.91 THB/day [61.1 EUR/day] for diesel bus, 1,720 THB/day [51.3 EUR/day] for NGV bus, and 1,023.46 THB/day [30.5 EUR/day] for e-bus (BMTA's Rehabilitation Plan (New Revision), 21 April 2020)***
4. ***Estimated from the 2020 BMTA's annual report***
5. ***License fee at 7,000 THB/year [209 EUR/year] and bus tax at 1,440 THB/year [43.0 EUR/year]***

Figure 22: Share of OPEX



Total cost of ownership of bus operation and maintenance

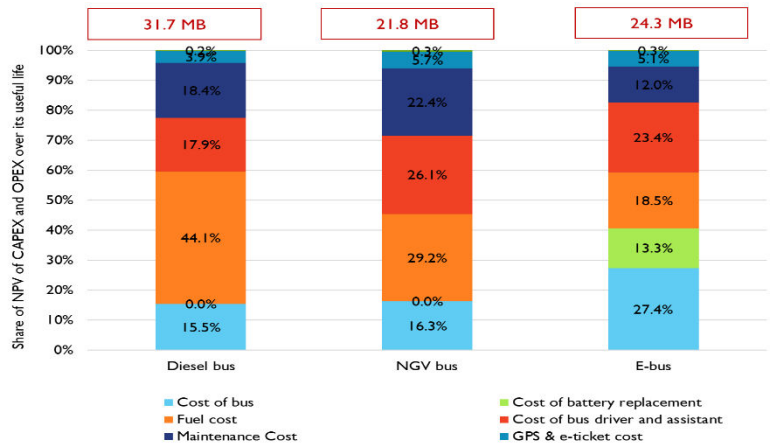
The total cost of ownership (TCO) is estimated by the following formula:

$$TCO = \frac{\text{Net Present Value (NPV) of (CAPEX + OPEX over the lifetime)}}{\text{Total distance in service over the lifetime}}$$

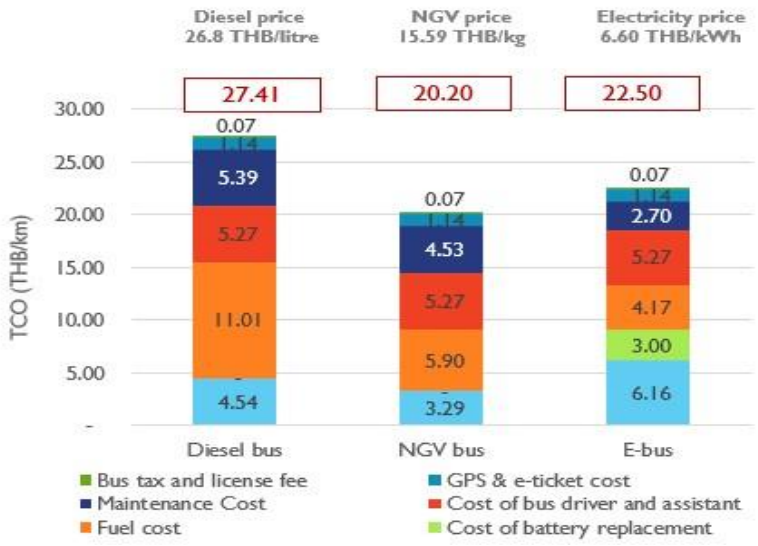
The result of the estimation is shown in Figure 23.

Figure 23: Key results of the analysis on TCO of public bus operation and maintenance

a) NPV of CAPEX and OPEX over the lifetime



b) TCO of public bus operation and maintenance



Remark: Other assumptions applied in the analysis are shown in the table below:

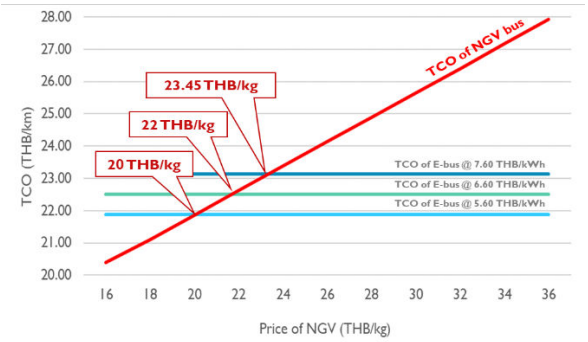
Assumptions	Amount
Inflation rate	1.8%
Discount rate	8.0%
Project lifetime	15 years
Operating days	300 days/year

From the analysis, the TCO of an e-bus is about 22.50 THB/km [0.671 EUR/km] which is lower than that of a diesel bus (27.41 THB/km [EUR 0.818/km]) by 22% but higher than that of a NGV bus (20.20 THB/km [0.603 EUR/km]) by 10%. The total NPV of capital expenses and operating expenses over the lifetime of a diesel bus is the highest at 31.7 MB while that of an e-bus and a NGV bus, account for 77% and 69% of the total NPV of the diesel bus, respectively. The share of the total NPV on the CAPEX of a diesel bus and a NGV bus is approximately 15%-16% while that of an electric bus is 41% since the CAPEX of an electric bus covers both cost of a bus and cost of battery replacement.

It can be concluded that the TCO of an e-bus is competitive, compared to that of a diesel bus but not as attractive when compared to a NGV bus. During the beginning of 2022, when natural gas prices continued to rise and the

price of NGV without subsidies from the government would have reached 20-22 baht/ kilogram, the total cost of ownership of a NGV bus is equivalent to that of an e-bus (Figure 24). However, an e-bus requires higher upfront cost than both a diesel bus and a NGV bus.

Figure 24: TCO of an NGV bus at different NGV prices



Sensitivity analysis on TCO of buses

The sensitivity analysis helps assess the importance of parameters on the TCO of the bus. When adjusting the value of each parameter by 10%, the changes of the TCO are as shown in Figure 25.

The increase of annual distance and discount rate reduces the TCO for all 3 types of buses while the cost of the buses, the cost of battery replacement (for an e-bus only), fuel costs, maintenance costs, and the inflation rate increase the TCO. The TCO of all types of buses changes the largest with the annual mileage travelled. The impact of change in the annual mileage travelled on the TCO of an e-bus (7.4%-9.1%) is the highest among the three types of buses (5.1%-6.2% for a diesel bus and 6.4%-7.9% for a NGV bus).

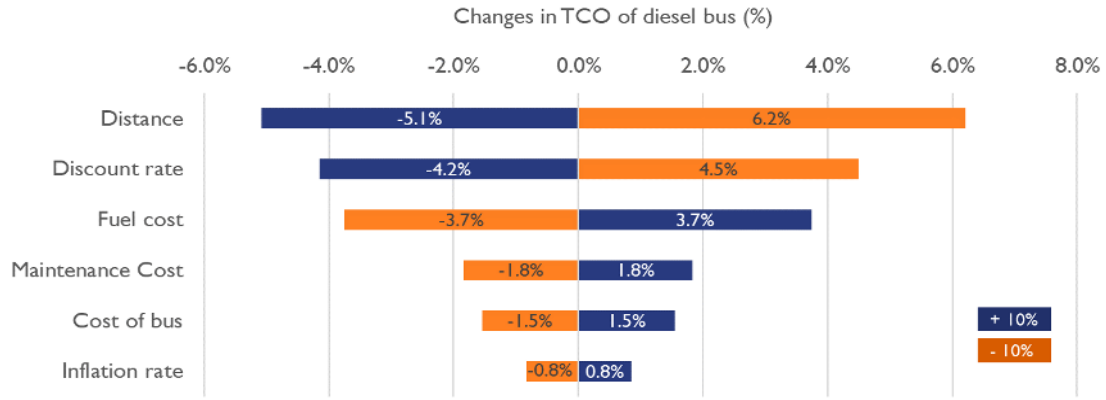
Since OPEX during year 1 – year 15 of a diesel bus and a NGV bus are so large that the total NPV of OPEX is almost 80% of the NPV of the total cost. The parameter causing the second largest impact on the change of the TCO of a diesel bus and a NGV bus is the discount rate, followed by cost of bus, fuel cost, maintenance cost, and inflation rate. The increase of the discount rate by 10% reduces the TCO of a diesel bus and a NGV bus by 4.5% and 4.4%, respectively.

For an e-bus, the parameter having the second largest impact on the change of its TCO is the cost of bus followed by the discount rate, cost of battery replacement, fuel cost, maintenance cost, and inflation rate. The change of cost of the bus by 10% leads to the changes of TCO by 1.5%, 1.7%, and 2.7% (4.3% when including the cost of battery replacement) for a diesel bus, a NGV bus, and an e-bus, respectively.

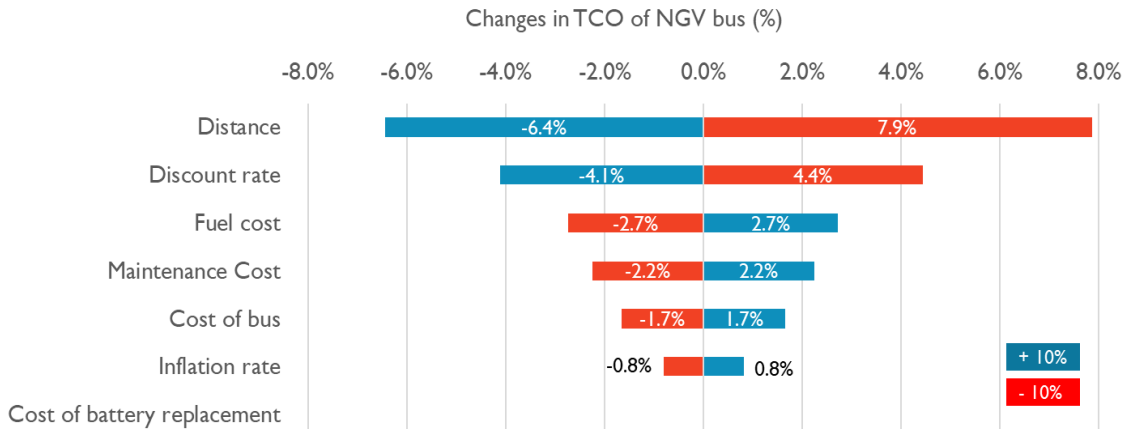
As the price of fossil fuel is on an upward trend and the change in fuel cost has the second highest impact on the TCO of a NGV bus and a diesel bus, the TCO of both types of buses moves upwards accordingly. Meanwhile, the costs of an e-bus and batteries are decreasing; therefore, the TCO of an e-bus tends to move downward. The gap between the TCO of ICE buses and an e-bus will increase over time, increasing the attractiveness of e-bus investment. Moreover, since the change of fuel cost incurred during the operation has more impact on the TCO of ICE buses than that of an e-bus, the volatile fossil fuel price leads to a higher risk in the operation of a diesel bus and a NGV bus.

Figure 25: Sensitivity analysis on TCO of buses

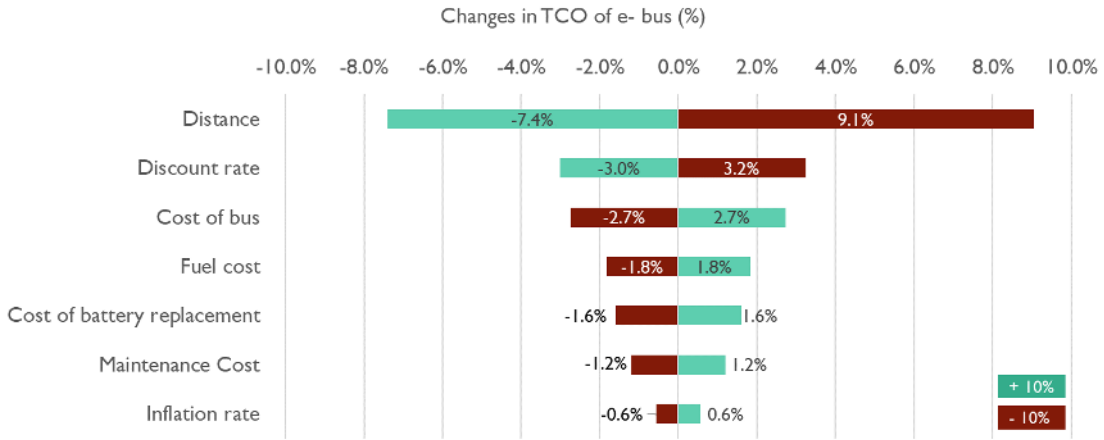
a) Sensitivity analysis on TCO of a diesel bus



b) Sensitivity analysis on TCO of a NGV bus



c) Sensitivity analysis on TCO of an e-bus



Funding for transport is specific for investments for infrastructure (such as railway infrastructure, bus stops and lanes etc.) and operations (rolling stock, maintenance costs etc.).

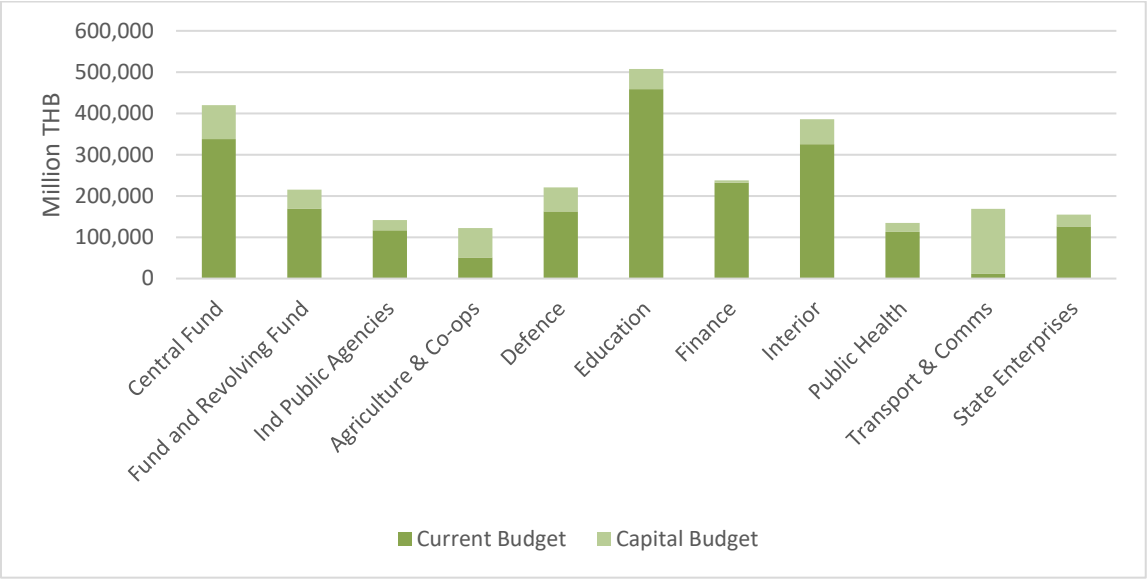
2.5.2 Central government

Public finance is the most straightforward source of funds that governments can leverage. Central government departments play a key role in the funding and delivery of transport networks and services. However, rather than simple allocation of funds to those in need, the way a funding/financing mechanism is designed and operated is crucial to its overall performance.

The central government obtains most of its revenues through taxation and the issuing of bonds and allocates revenue to all departments, of which the MOT is one of the beneficiaries. The central government budget for 2018 was THB 3.04 trillion[22] [EUR 90.7 billion] of which THB 168.77 billion [EUR 5.04 billion] is allocated to the MOT. This accounts for 5.5% of the overall national budget[23].

Figure 26**Error! Reference source not found.** highlights the funding allocated to government departments receiving more than THB 100 billion [EUR 2.98 billion] per year. Transport receives the seventh largest annual funding after the central fund, revolving fund, defence, education, finance and MOI. Notably for the Ministry of Transport, 7.25% of its budget is 'current budget' whereas over 90% of the budget is 'capital budget' to fund the investment in infrastructure. This highlights the focus on investing in transport infrastructure across the Kingdom, but at the same time illustrates its weakness as far as only a minor share is allocated towards operating transport services.

Figure 26: Central government spending by ministry



Source: Ministry of Finance (MOF)

For the MOI, funding is the opposite of that for the MOT. The majority of MOI's funding stems from the current budget with less than 20% of its budget allocated for capital spending. As existing public transport services are delivered by local governments using funding from the general budget allocation and/ or local taxes, this partly overcomes the issue of the MOT having a high proportion of its budget for capital projects.

The Central Fund is a discretionary fund allocated to the Prime Minister to meet new priorities during the year. The Fund and Revolving Fund is not clearly described by the Ministry of Finance (MOF), but it is understood it refers to several priorities including energy efficiency revolving fund and a community development fund.

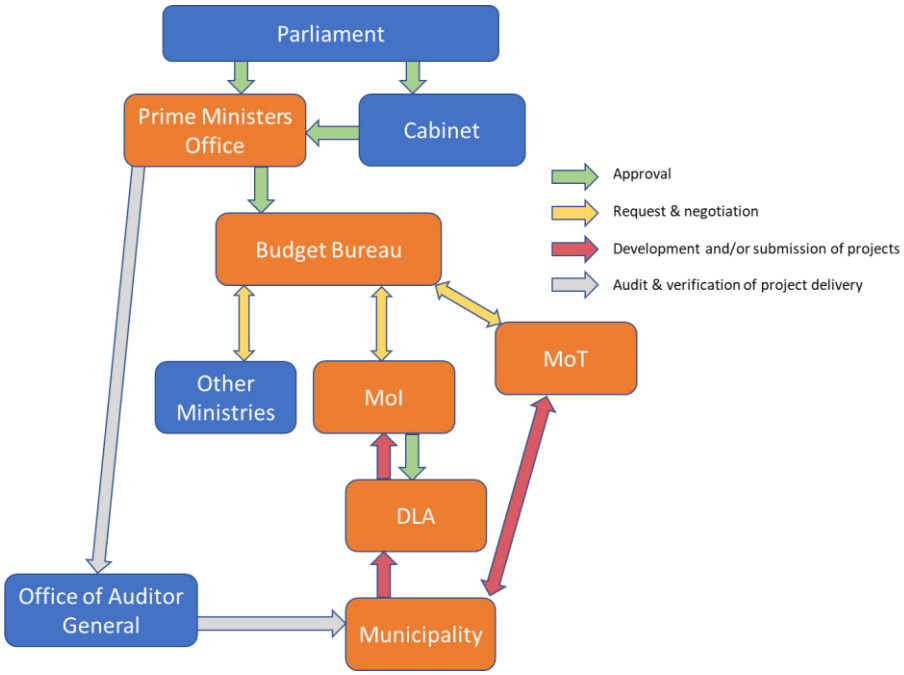
[22] http://dataservices.mof.go.th/Dataservices/GovernmentExpenditureEconomyMinistry?language=EN

[23] By comparison to neighbouring countries, it is notable that in Singapore 12.25% of central government budget is spent on transport whereas in Malaysia 2.8% of the government budget is directed towards transport

Generally, funding for transport project is derived from tax (both the general tax and dedicated tax) and loans. Three organizations in the Ministry of Finance (MOF) are responsible for the general tax collection: the Revenue department, the Excise department, and the Customs department. There are other departments in the MOF that also obtain funds for transport including the Public Debt Management Office (PDMO). Specifically, the PDMO can submit a transport loan proposal to receive approval from the cabinet to find loans from national or international banks or other funding agencies.

Every year, the Bureau of Budget (BB) under the Ministry of Prime Minister's Office sets about preparing the transport budget with each transport department of the MOT and MOI. The share of funding dedicated to urban transport is unclear. After thorough discussion between each department and the BB, the BB will discuss the total budget with the Office of the Permanent Secretary of the ministry again and if the total budget exceeds the proposed transport budget initially planned for (and received approval from the cabinet) by the BB, a round of budget cutting is necessary. At this stage some projects would be taken out or pending for cabinet approval again. The criteria for removing projects from the budgeting process is not publicly available, although decisions are likely to be political. This process is described in Figure 27.

Figure 27: Illustration of decision-making process for transport funding



Source: Own design based on OTP & GIZ (2019)[24]

For the MOI, the Department of Local Administration (DLA) is responsible for gathering transport projects proposed by the municipality and submitting them to the BB. The transport projects proposed by the municipality (including those projects planned by OTP and DPT as part of the urban transport planning process) will be gathered by the office of the Governor and submitted to the DLA. Generally, if the budget is less than THB 50 million [EUR 1.49 million], the mayor would assume responsibility and approve the project. If the project is between THB 50-100 million [EUR 1.49 – 2.98 million], the Governor is responsible. If it is higher, the Governor and the director of the DLA are responsible. For large (budget >THB 100 million [EUR 2.98 million]) or extraordinary projects, the proposing organisation would need to discuss detail of the project with the BB. At the time of writing, it was not clear if there was any mechanism for joint funding of projects between the MOT, MOI or other departments or agencies.

[24] https://changing-transport.org/wp-content/uploads/2019_Thailand_Development-of-a-NUMP-1.pdf (page 78)

Once Parliament has agreed the relevant budgets, then for the MOI budget will be transferred to the provincial office of the Controller General. Each provincial department and municipality would need to contact this office to receive funding for transport projects. Project implementation is generally carried out via bidding process.

For the MOT, the budget approved by Parliament is transferred to the department office of the Controller General. This office will contact the departments that receive funding and work together to go through the bidding process. The budget spending process must follow rules and regulations issued by the Office of Prime Minister. At the end of the year, the Office of the Auditor General would review the proposed projects and check whether the projects had been carried out as stated in the budget proposal.

Aside from funding transport, central and local government benefits from taxation and charges on transport services. The vehicle licence registration fee is collected by DLT each year, and the amount paid depends on the engine size (cc), vehicle type, age, weight, and fuel type. According to PDMO, the revenue generated by all existing transport related taxes are allocated to a dedicated area of spending. For example, expressway road tolls are dedicated for the operation and maintenance of existing toll roads and the construction of future toll roads.

Revenue is also generated through fuel taxes. These are levied upon consumers when they purchase fuel for vehicles. The retail price structure of oil briefly consists of: Refinery oil price – the summation of the crude oil price, refinery costs and transportation costs

Taxes – these include:

- Excise tax collected by the Excise Department (MOF) which contributes to the general budget. This ranges between 0.975 THB/litre [0.029 EUR/litre] for gasohol 95 E85 and 6.6 THB/litre [0197 EUR/litre] for unleaded gasoline;
- Municipality tax collected by each municipality in which petrol stations are located for local developments and range from 0.0975 THB/litre [0.0029 EUR/litre] to 0.65 THB/litre [0.019 EUR/litre] ;
- 7% of Value Added Tax (VAT) collected by Revenue Department (MOF).

Funds – there are two funds that fuel taxes contribute to:

1. The Fuel Fund is used for to help stabilize prices during periods of price fluctuations. For example, when the oil prices are high, this fund is used to subsidise the domestic retail price, whereas when oil prices are lower, the tax is used to build the fuel fund reserves The fuel fund is also used to subsidise the price of some fuel types such as Gasohol 95 E85, as shown in \
2. Table 15. Each oil type has different rates to collect into this fund ranging from -6.38 THB/litre [-0.011 EUR/litre] for Gasogol 95 E85 to 8.08 THB/litre [0.241 EUR/litre] for unleaded gasoline;
3. Energy Conservation Fund is used for renewable energy promotion in the country. All oil types are taxed in the same rate of 0.10 THB/litre [0.003 EUR/litre] .

Marketing margin – this denotes the retailers profit margin which typically varies between 2.07 THB/litre [EUR 0.062/litre] and 3.46 THB/litre [EUR 0.103/litre] .

According to the Ministry of Energy, fuel taxes are used for generating tax for general spending with no evident ring fencing of transport revenue for funding transport projects. \

Table 15: Example of Retail price structure of oil in Thailand

UNIT:BAHT/LITRE	Refinery oil Price	Excise Tax	Municipality Tax	Fuel Fund	Energy Conservation Fund	WHOLESALE PRICE(WS)	VAT 7%	WHOLESALE + VAT	MARKETING MARGIN	VAT 7%	RETAIL (Wholesale+ Marketing+Vat)
ULG	13.1384	6.5000	0.6500	8.0800	0.1000	28.4684	1.9928	30.4612	3.4568	0.2420	34.16
GASOHOL95 E10	13.9656	5.8500	0.5850	2.1200	0.1000	22.6206	1.5834	24.2041	2.3794	0.1666	26.75
GASOHOL91	13.5702	5.8500	0.5850	2.1200	0.1000	22.2252	1.5558	23.7809	2.5225	0.1766	26.48
GASOHOL95 E20	14.8848	5.2000	0.5200	-0.7800	0.1000	19.9248	1.3947	21.3195	2.2621	0.1583	23.74
GASOHOL95 E85	20.0321	0.9750	0.0975	-6.3800	0.1000	14.8246	1.0377	15.8623	3.4371	0.2406	19.54
H-DIESEL	15.4336	5.9800	0.5980	0.2000	0.1000	22.3116	1.5618	23.8734	2.0716	0.1450	26.09
H-DIESEL B20	16.1963	5.1520	0.5152	-4.5000	0.1000	17.4635	1.2224	18.6859	2.2468	0.1573	21.09
LPG (UNIT:BAHT/KILO)	14.8635	2.1700	0.2170	-0.0710	0.0000	17.1795	1.2026	18.3821	3.2566	0.2280	21.87

Source: EPPO[25]

[25] http://www.eppo.go.th/index.php/th/petroleum/price/structure-oil-price?orders[publishUp]=publishUp&issearch=1

Government also receives revenue through Public Private Partnerships (PPP) concessions as well as toll charges. When charges are made on toll roads, some of this revenue is ring fenced to cover construction and maintenance costs, other revenue is used to cover the concessionaire fee.

Given the intensifying fiscal constraints in the Covid-19 era, it is not advisable to rely solely on public subsidies as an incentive for the electrification of public transport. It is therefore important to advance structural reforms at the local level, which are crucial for sustainable development.

2.5.3 Local government

Local government receives funding from a variety of sources. 'Shared tax income' is derived from:

- VAT collected in its province (11.1% of all VAT collected within the province);
- Specific business tax collected in its province (10% of tax collected);
- Excise and alcohol tax (10%);
- Real estate registration (100%);
- Mineral and petroleum taxes (unknown %).

In addition to shared tax revenue, local governments collect:

- Property and building taxes;
- A local development tax based on the median appraisal value of occupied land;
- Signage tax.

Local governments also collect revenues from other sources, such as animal slaughter fees, waste collection fees, driving licence deliverance and building permit deliverance. Local governments can collect car parking charges as Bangkok Metropolitan Authority does on some streets in Bangkok. In other urban areas, local governments appear not to implement charges to any great extent.

In addition to tax revenue, local governments receive general operation grants and block sectoral grants dedicated to the improvement of a specific public service obligation. According to the Organisation for Economic Co-operation and Development (OECD)[26] 94.1% of grants are current grants to cover revenue spending, whereas 5.9% of grants received by local government are capital grants. It is from these sources of revenue that local governments can fund day to day transport services. However, it is unclear which government departments provide which grants and what share of a municipality's transport budget is made up of grants from the MOT, MOI, or other departments.

2.5.4 National development banks

The banking sector is increasingly active to engage in sustainable finance activities. In Thailand, the Working Group on Sustainable Finance, consisting of the Fiscal Policy Office, the Bank of Thailand, the Securities and Exchange Commission, the Office of Insurance Commission, and the Stock Exchange of Thailand, have joined forces to steer and align the direction of Thailand's sustainable finance policies. The Sustainable Finance Initiatives for Thailand have been developed in recognition of the significant role that the banking sector plays in tackling Thailand's sustainability challenges and realising Thailand's sustainability commitments. This represents an extraordinary opportunity to tap into abundant resources from the credit institutions in Thailand for public transport electrification.

The Small and Medium Enterprise Development Bank of Thailand acts as a national development bank to support Small and medium-sized enterprises (SMEs) to grow and support the Thai economy. The bank aims to support private sector organisations and entrepreneurs, rather than provide funding for large scale projects, such as the role of international development banks and donor agencies.

[26]https://www.oecd.org/regional/regional-policy/profile-Thailand.pdf

Commercial Thai banks do play a role in financing and investing in projects, often playing a role in scrutinising and the financing of PPP projects. The PPP process requires a thorough financial investigation with statements of approval from banks and other investors. Most national banks can participate in joint ventures for the bidding of projects, for example, Bangkok Bank is partnering with Bangkok Mass Transit System (BTS) to invest in the BTS train and will fund most of the land development projects carried out by BTS around stations.

2.5.5 Private sector

Public finance is facing increasing challenges as governments have a lot to deal with on their agenda. On the other hand, private finance has much potential to contribute to public transport electrification as financial institutions and companies are increasingly seeking sustainable investments and business models.

The private sector plays an important role in the funding and delivery of transport projects. Private bus operators are involved in the delivery of public transport services under contract to DLT or BMTA. They don't, however, play any role in funding transport services, merely operating them and receiving revenue as contractually obliged.

At present, there are no laws or regulations that require private sector employers or developers to contribute towards transport infrastructure or services. There have been examples where businesses have looked to contribute towards infrastructure costs. For example, Nava Nakorn Industrial Park was facing access issues due to traffic congestion and OTP carried out a study to identify solutions to overcome the congestion. It was agreed that an overpass will be built and that the industrial park should fund the work, although in the end the Department of Highways took responsibility for the construction.

For large infrastructure projects PPP are encouraged by the Thai government. PPP are governed by the Private Investments in State Undertakings Act 2013, superseding the Public Participation in State Undertakings Act 1992. The Act sets out a framework for the comprehensive planning and quality of PPP projects which includes the development of a PPP policy committee, a PPP fund, a PPP strategic plan and rules on the use of experts and consultants.

The PPP Strategic Plan is prepared every five years for the purpose of determining a policy framework around which projects can be delivered. The plan provides the governments priorities for PPP projects, identifies where investment is required and sets targets and timeframes for the planning and delivery of PPP projects. The purpose of this plan is to encourage participation and investment from the private sector. The plan suggests that allowing the private sector to participate and jointly invest in major infrastructure projects not only helps reduce financial restrictions based on the government budget and decrease the need for government loans, but involving the private sector helps to improve the efficiency of delivering such projects.

The 2015-2019 Strategic Plan identified six priority infrastructural project types where private sector investment is required:

- Development of Urban Rail Transit System for the Population;
- Development of Toll Roads in Major Metropolitan Urban Areas;
- Development of Port Logistics;
- Development of High-Speed Rail;
- Development of Telecommunication Network and Assets;
- Development of High-Speed Internet.

Alongside these six sectors, a further 14 project types are identified where government encourages private sector investment, of which the following represent those that affect transport projects:

- Development of Toll Roads between Major Metropolitan Urban Areas;
- Development of Packaging Stations;
- Development of a Common Ticketing System;
- Development and Management of Airport Ground.

Finally, the PPP Strategic Plan requires the responsible ministries and/ or agencies to co-operate through the planning of PPP projects so that where synergies between projects exist, these are identified and planned for so the benefits of projects can be maximised.

In 2017, a second PPP Strategic plan was introduced that covered the period from 2017 to 2021. This aligned the PPP strategy with the newly developed National Economic and Social Development Plan (NESDP). The priorities changed slightly from 2015, with just the following four subsectors which require private investment, and with 19 subsectors where private investment is encouraged:

- Development of Urban Rail Transit Lines;
- Development of Toll Roads in Metropolitan Areas;
- Development of Public Logistics Ports;
- Development of High-speed Rail Lines.

In 2019, another Act is due to be passed that helps to speed up the process of delivering PPP projects. The PISU Promotion Act 2019 is currently planned to reduce the average project approval time. There are three key stages to the development of a PPP project. The first stage is the development of a feasibility study while this is followed by a project appraisal process. The third and final step is the tender evaluation and contract award. The impact of the PISU Promotion Act 2019 aims to reduce the time of these three steps from an average of 25 months to just 9 months.

2.5.6 Blended financing

Apart from solely public or private finance, blended finance coupled with an innovative business model can be more powerful and sustainable to finance and operate electric public fleets. In the developing world, China has been most successful in bus electrification supported by a strong policy framework coupled with ambitious action taking at municipal level. Apart from China, Latin America has been an area of focus where the major cities are actively seeking to transform their public transport services towards cleaner and low carbon solutions. More importantly, they are realizing public fleet electrification through innovative business models that have the potential for replication around the world. The IFC and C40 report (2020) (Graham & Courreges, 2020) analysed and compared the traditional model to the innovative models for city bus systems in Latin America, from which it concluded that unbundling asset (i.e., vehicles, batteries, charging infrastructure, etc.), ownership, and operation is the crucial innovation that enables the business models some Latin American cities are experimenting. The unbundled model for funding, financing, procuring and operating city buses can accelerate public fleet electrification mainly because of its risk sharing mechanisms.

2.6 Related initiatives

The Thailand component of the global IKI financed project TRANSfer III ("Preparation facility of ready-to-implement low carbon transport measures"), has been supporting the preparation of the TCMP since 2017 and will continue until June 2022.

ADB is currently engaging in a pre-feasibility study on electrifying boats in Thailand, which is planned to be submitted to the Green Climate Fund (GCF) and is complementary to the described project (further accelerating economics of scale).

The bilateral International Climate Initiative (IKI) call for Thailand, among other topics has asked for support on electrification of commercial and public transport fleets, looking at corresponding aspects from an energy transition perspective with a focus on regulatory and policy framework, scenario building, grid integration, charging and battery recycling. The approach can contribute to the replication and scaling up of the approach. The electrification efforts of beforementioned projects are only sustainable with the complementary transport demand management approach including CC and Clean Mobility Zone being in the focus of the project.

Moreover, UNIDO is supporting Eastern Economic Corridor (EEC) office on the collaboration with Thailand Greenhouse Gas Management Organization (TGO) and the National Science and Technology Development Agency (NSTDA) on the implementation of a GEF-7 project on "Accelerating the adoption and life-

cycle solutions to electric mobility in Thailand". The objective of the GEF-7 project is to introduce electric mobility in Special Economic Zone in Chachoengsao, Chonburi and Rayong provinces.

3. Barriers for public bus electrification

Technical and financial barriers

In Thailand's urban agglomerations and cities like Bangkok, road-based public transportation is the backbone of metropolitan mobility and transport systems. Despite the ongoing development of rail-based transportation, public transportation and paratransit supplied by busses and minibuses sustain the mobility supply to a large proportion of the population. In daily practice however, the bus system lacks coverage, connectivity, interoperability, or even designated bus lanes resulting in inconvenience due to low service quality and reliability. Buses are on average more than 20-year-old diesel engine vehicles, leading to severe air pollution exposure of the users. Consequently, private car travel is the preferred and prevalent option. Future-proofed, environment and climate-oriented bus technologies such as electric busses still have not yet made their way through into the market mainly due to the absence of affordable or profitable financing options as well as innovative business models for vehicle purchase and operation. Also, electric buses have considerably higher Capital Expenditure (CAPEX) and higher Total Cost of Ownership (TCO) compared to conventional 25-year-old diesel buses when taking charging infrastructure cost into account. Especially, but not only SMEs lack access to financing. Partly due to the nature of small business, partly due to the unprofitability of bus service operation in Bangkok, private bus operators have difficulties in mobilising affordable financial support from commercial finance providers. Thai Government has worked with the Krungthai Bank to provide concessional loans for private van operators to invest in new mini-bus fleet replacement of outdated vans for road safety purposes. However, there is no similar concessional loan scheme for normal-size bus operators or other mode of public transport. Moreover, a voluntary loan scheme alone is not attractive enough to trigger any capital investment if other barriers are not dealt with. Also, overall experience and technical know-how with EV deployment and maintenance under public transportation provision requirements is lacking among the operators. Absence of practical use cases and experience with EVs under local conditions regarding congestion, high air conditioning needs and expertise on suitable charging concepts pose an additional barrier to electrification. And finally charging infrastructure to ensure smooth vehicle operation is widely missing.

The financial and technical challenges can be divided by three groups of key stakeholders: e-bus manufacturers, public bus operators, and charging service providers, covering the technical and financial dimensions as shown in Table 16.

Table 16: Financial and technical challenges of public bus electrification

	Technical	Financial
Bus manufacturer	• Uncertain demand of e-buses • Regulations on technical specification of public buses do not support local EV manufacturers • Limited production capacity of local manufacturers	• Difficult access to financing • Lack of confidence from financial institutions on the EV system integrating business • No benchmark for the residual value of e-buses causing difficulties for commercial banks to provide loans
Bus operator	• Overlapping of routes in service • Lack of skilled capacity to maintain and repair e-buses • Lack of confidence on sufficient charging structure	• High upfront cost of e-buses • Difficult access to financing • Regulated bus fare leading to the low bus fare and limited financial capacity of operators to improve their fleets • Lack of confidence from financial institutions and insurance sector

	Technical	Financial
Charging service provider	• Uncertain demand due to small number of e-buses • Availability of land or space for charging infrastructure • Timely and complicated permission process	• High upfront cost especially when upgrading transformer needed • Uncertain electricity prices

Source: Creagy (2020)

Market structure and efficiency barriers

Bus transit in Bangkok is mainly served by numerous small-scale private operators who are the subcontractors of the sole public operator, BMTA. This fragmented structure has led to a high market competition where several operators sometimes are running the same or similar routes. Rerouting is challenging given the complicated road networks in Bangkok. Different sizes of bus fleets are needed to serve the main roads and provide feeder services. Meanwhile, the new requirement of fleet renewal tends to lead to a consolidation of small-scale private operators as they are not individually capable of making such investments.

Regulated bus fare and pricing barriers

Bus fares are fixed at low levels to guarantee access to mobility to low-income groups and ownership structures are mostly small scale. With bus fares in Bangkok being highly regulated by the government to ensure the affordability of most commuters, they are kept at a subsistent level which further hampers the commercial viability of most operators who are small-scale to increase their service standards through planned investment, also impeding the investment in zero-emission technologies.

Behavioural and regulatory barriers

Due to rapid urbanisation and economic development Bangkok is experiencing a high rise in travel and transportation demand mainly met by individual motorised transport resulting in negative environmental externalities, i. a. air pollution, GHG emissions and congestion that not only reduce societal wellbeing, but have severe economic, environmental and climate impacts in the short, mid, and long run. Hence, the main behavioural and regulatory barriers are strong car dependency among Bangkok's citizens, the fact that the cost of private car travel does not reflect the societal cost in terms of environmental externalities as well as general lack of an effective regulatory framework to discourage private car use and encourage or incentivise the use of energy and emission efficient modes such as mainly rail based public transportation.

Lack of risk mitigation or risk sharing mechanisms barrier

An affordable and well-served public transit system is desirable to improve the welfare of a society. Considering that public transport riders help to reduce the externalities caused by private car users, a redistribution mechanism should be put in place through subsidies or other types of public support to mitigate the financial risks of public transit services at least partially. However, no adequate risk mitigation or risk sharing mechanisms are being implemented in Bangkok.

Further need to support public bus electrification

Table 17: Further need to support public bus electrification

	Technical	Financial
Bus manufacturer	• Uncertain demand of e-buses • Regulations on technical specification of public buses do not support local EV manufacturers • Limited production capacity of local manufacturers	• Difficult access to financing • Lack of confidence from financial institutions on the EV system integrating business • No benchmark for the residual value of e-buses causing difficulties for commercial banks to provide loans
Bus operator	• Overlapping of routes in service • Lack of skilled capacity to maintain and repair e-buses • Lack of confidence on sufficient charging structure	• High upfront cost of e-buses • Difficult access to financing • Regulated bus fare leading to the low bus fare and limited financial capacity of operators to improve their fleets • Lack of confidence from financial institutions and insurance sector
Charging service	• Uncertain demand due to small number of e-buses • Availability of land or space for charging infrastructure • Timely and complicated permission process	• High upfront cost especially when upgrading transformer needed • Uncertain electricity prices

Source: Creagy (2020)

4. The Mitigation Action

4.1 Objective and outcome

The objective of bus electrification is to lead to an improvement of the public transportation system. and is intended to reduce the use of private vehicles and thus lead to an improvement in the transport system and associated negative impacts.

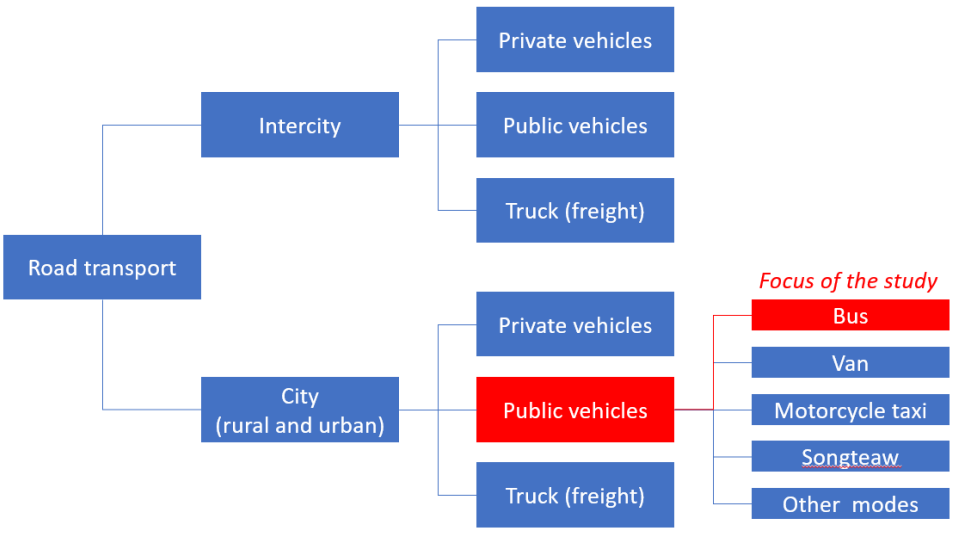
The mitigation action therefore raises the attractiveness of public transportation by the creation of electric on-demand last-mile services and reduction of rail-based tariffs in Thai cities that low-income groups currently cannot afford (Pull Measures). On the other hand, it will promote travel demand management measures to disincentivize car travel, such as CC or parking management measures (Push Measures), to free up road space as a prerequisite to improved bus services and sustainably finance the public transport improvements (Transport-Finances-Transport). The introduction CC internalizes (part of) the external costs of car travel, creates leeway for installing designated bus lanes, and generates revenues for SUT projects in Thai cities.

Main outcomes encompass GHG and air pollutants mitigation through the (1) increase of the number of electric busses and public transport ridership in Bangkok through the (2) availability of accessible funding for vehicle purchase and deployment resulting into an (3) overall public transport system improvement regarding carbon footprint, while the government has enhanced capacity to established a financing tool for a continuous development of sustainable and low-emission transportation services through the setting-up of a Clean Mobility Fund which will be financed from and redistribute the CC revenue collected in a Clean Air Zone in Bangkok, that is planned by the government. The impact will therefore result in initiating public transport electrification and transformation in a Clean Air Zone in Bangkok, contributing to NDC targets, and advancing the country to the Long-Term Low GHG Emissions Development Strategy.

4.2 Scope

Road transport is the highest emitter of all sub-sectors in transport in Thailand. While there are many components within the road transport sector, this study is focused on the public vehicles of three selected modes of transport, including bus, van, and motorcycle taxi. The reasons of such prioritisation are not only because they are the main modes of public transport in Thai cities, but also because various models of electric buses, electric vans, and electric motorcycle are available in the market. The scope of the study is a part of road transport sector in Thailand as shown in Figure 28.

Figure 28: Scope of the mitigation action



Source: Own design

Moreover, since public transport markets generally differ from one city to another, it would not be practical to study all the markets within the country. The approach is therefore specifically focused on the largest metropolitan area, namely the BMR, as its road transport sector is most developed and presumably most carbon intensive.

The establishment of a Clean Mobility Fund (CMF), fed by the CC, can also be considered as an additional source of funding to further subsidise bus and public transport electrification. The feasibility of the CC was assessed in a pre-feasibility study with an expected return on investment within three years of project implementation and initial investment costs of around EUR 350 million depending on the technology chosen.

4.3 Target group

Main target group of the mitigation action are public transport/ bus operators, including the BMTA as well as SMEs private bus operators providing mobility services based on primarily minibuses, Songthaews, Tuk-tuks or Motorcycle Taxis. It is expected to finance at least 90 electric buses and public transport vehicles. The number of operators or direct beneficiaries will be determined by the support demand of each finance seeker.

Referring to the regional spread of the beneficiaries, the mitigation action will focus on bus and public transport vehicle operators serving the inner area of the blue MRT circle line in Bangkok, as this area is most affected by air pollution from the outdated bus fleets. The EV buses will also strengthen the last-mile service to connect passenger with the blue MRT circle line. The funding support will allow the operators to overcome the barrier of limited access to finance.

Another target group are the MOT and the Bangkok Metropolitan Administration who are the main partners for the implementation. Furthermore, in November 2018 the Thai Government has created an inter-ministerial Steering Committee to jointly design the mitigation action together with thematic working group according to the core topics. Each working group feeding into the Steering Committee contains officials from all relevant government bodies and representing further target group, incl. Ministry of Finance, Department of Land Transport, Ministry of Energy, Ministry of Natural Resources and Environment, BMA, Bangkok Metropolitan Transport Authority (BMTA), Pollution Control Department, Royal Thai Police.

Various local Universities, i.e., KMITL, KMUTT are knowledgeable and active in the field and will be involved in the project for local capacity building purposes.

Implementing partners will be fixed resulting from the Detailed Preparation Phase (DPP) however, to successfully approach and involve the target groups during the project development and implementation effectively communication is key. During the phase of project development, extensive stakeholder consultations will be carried out to understand the willingness and concerns of different parties, incl. public regulator/ operator, private operators, finance providers, technology providers, energy suppliers etc. A clear focal point will be set up to provide comprehensive information and consultation of interested parties. All target groups and partners have been consulted and engaged through multiple rounds of discussion during conceptualization.

4.4 GHG mitigation actions

The introduction of a CC in combination with the electrification and improvement of public transport services entails an expected reduction in GHG emissions due to the shift of passengers from cars to buses and is expected to account for 5% over the next 16 years. In addition, the promotion of 90 electric buses will reduce GHG emissions resulting from the replacement of current diesel internal combustion engine technology with electric buses. The total mitigation potential of direct GHG emissions is expected to be 3.01 $MtCO_2e$. In addition, the indirect mitigation potential will be a further 3.24 $MtCO_2e$, mainly resulting from other bus operators replacing 30% and 50% of conventional diesel buses with electric buses by 2030 and 2050 respectively. The above figures do not include the indirect mitigation effects made possible by using CC revenues for additional SUT projects using the CMF. These estimations and assumptions underlying the GHG mitigation calculations are based on the national information and studies from government agency, such as DLT, BMTA, and OTP.

Table 18: Direct GHG mitigation potential

	Unit	Implementation	10 years after project end	Technology lifetime
Annual average mitigation potential	tCO_2e/a	56,504	269,776	202,023
Total mitigation potential over period	tCO_2e	310,771	2,697,760	3,232,375

Source: Own calculation by author

Table 19: Indirect GHG mitigation potential

	Unit	Implementation	10 years after project end	Technology lifetime
Annual average mitigation potential	tCO_2e/a	65,396	287,742	215,807
Total mitigation potential over period	tCO_2e	359,678	2,877,423	3,452,908

Source: Own calculation by author

Regarding Thailand's efforts to develop a LT-LEDS the transport sector will be part of Thailand's long-term targets with the implementation of measures to enhance sector electrification and shift towards more energy and emission efficient modes such as public and mass transport. The government is executing its investment plans to expand mass rapid transit in Bangkok metropolitan area, high-speed train, double-track train, as well as water transport infrastructure, where CC will help to catalyse modal shift and increase the effectiveness of investment in public transport infrastructure.

By the promotion of 90 electric buses and implementing CC scheme, the direct GHG mitigation in Bangkok area is expected to be 0.31 $MtCO_2e$ in the first 5 years and 6 months, accounting for 56,504 tCO_2e/a. In addition, the mitigation action could lead towards additional GHG emission reduction of 2.70 $MtCO_2e$ in next 10 years. Therefore, the total direct mitigation potential is expected to sum up to 3.01 MtCO2e. The total indirect GHG mitigation potential is expected to be 3.24 $MtCO_2e$ from replacing 30% and 50% of conventional diesel bus fleets with electric buses by 2030 and 2050, respectively. Therefore, the total mitigation potential is expected to be 6.25 $MtCO_2e$.

4.5 Project concept

4.5.1 Proposed technologies/ practices

Currently, the bus system in Bangkok mainly uses diesel and CNG vehicles. According to the Department of Land Transport, out of 151,547 public passenger vehicles, including buses and Songthaews registered in 2020, only 120 (or 0.08%) are electric, of which 113 electric buses are registered as non-fixed route bus or private bus at demonstration fleets. Hence, on-field demonstration of electric fixed-route bus operation is still lacking but could expedite government's plan to buses electrification.

The strong reliance on almost solely fossil fuel consumption results in a high level of GHG and local air pollutants' emissions, such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and particulate matter (PM) (< 10 microns PM10 and < 2.5 microns PM2.5). Moreover, the bus route network has grown over time without implementation of a comprehensive master plan, resulting in long and overlapping routes and inefficiencies in the systems.

Thai Government has initiated various plans to reform and improve the efficiency and sustainability of the bus system in Bangkok targeting service amelioration as well as improvement of environmental performance of the vehicles to reduce local as well as GHG emissions. Measures considered include bus re-routing, organisational changes, regulatory system modification, privatisation of bus operation, bus priority measures, bus rapid transit and integrated ticketing. However, complex institutional structure in which coordination, cooperation and decision-

making are challenging, political difficulties, lack of practical planning and design standards, car-oriented planning, lack of bus interchange stations and driver behaviour make reform planning and implementation challenging.

To improve air quality and mitigate GHG emission, the government initiated a policy to promote alternative clean technology vehicles by replacing conventional diesel buses, with CNG and electric buses. Electric buses have become commercially available recently and seem to be a promising vehicle technology to improve air quality and mitigate GHG emissions in urban areas. At the same time, bus electrification has been identified by the Thai Government as a priority for the improvement and transformation of the public transport sector and is part of the Thai Electrification Strategy and Roadmap the Government is currently elaboration by setting up National EV Policy Committees within relevant Ministries under the lead of The Prime Minister or assigned Deputy Prime Minister as the assigned committee chairman.

4.5.2 Business model related to the proposed technologies/practices

Regarding the current bus service market structure, the DLT as the regulator used to authorize the sole public bus operator BMTA to manage the operating licenses of all service routes. Given the large size of the entire system, BMTA would sub-contract a fixed share of licenses to private operators making the system highly fragmented, even though some license-holders run their service jointly with other operators. As of 2014, there were approximately 776 license-holders and 32,374 joint operators, of which 94% own only one vehicle. Most of these operating entities are small and family-owned firms. However, a major reform has been undertaken in which the licenses are gradually re-issued directly by DLT. All operators who seek to extend their license or get a new licence are required 70% of their bus fleet to constitute of vehicles on average not older than 2 years. This measure tends to result in coalitions of small operators as many of them are not able to afford the substantial capital investment in new bus fleet.

Currently, the initial capital cost of an electric bus is around 2-2.5 times higher than of a diesel bus. As most of the bus service operators are SMEs, it is challenging and of high risk for them to make such a considerably huge investment. Regarding bus service accessibility and affordability of bus fares in Bangkok, bus fares have been regulated by the Thai Government to ensure their affordability to the public at large. Even after the introduction of electric buses, the fares are expected to remain stable and affordable mainly due to the bus transit system in Bangkok being a formally regulated market, with the fares capped by the government without subsidies to the operators.

From interviews with commercial banks and private operators in Bangkok, only few financing channels for investment in bus fleets are available, significantly impeding the renewal or upgrade of existing bus fleets on the demand side. In most cases, operators procure or lease second-hand buses rather than invest in new ones. On the supply side, banks normally process financing requests for investment in buses through corporate finance, which implies that the loan terms can be quite rigid and hence unaffordable for most private operators which are SMEs.

Financing needs for public transport electrification were assessed including extensive interviews with operators, banks, producers, and governmental actors resulting in the need for a subsidy of the incremental TCO through a leasing programme and a guaranteed scheme to improve the access-to-finance for SMEs operators. Electric (mini-) buses currently have considerably higher CAPEX (EUR 220.000) compared to conventional vehicles (EUR 95.000). A study looking at additional vehicle types is currently underway. It is expected that electric buses reach cost parity in the medium term, with decreasing battery costs and economies of scale. Furthermore, with reference to current energy cost and fuel consumption rate for a conventional diesel Bangkok bus using the cheapest diesel grade, energy costs for a CNG bus, a diesel hybrid bus and an electric bus are 30%, 38% and 69% lower than for the conventional diesel bus technology. Given a typical average daily distance for a bus route in Bangkok of 250 km/day, energy refuelling cost and time must be considered accordingly.

4.5.3 Key milestones and activities during the implementation

The implementation of the mitigation action encompasses the following key milestones and activities:

- Accessible and affordable financing for vehicle and fleet electrification is provided to public transport as well as SMEs private bus operators providing mobility services based on primarily minibuses, Songthaews, Tuk-tuks or Motorcycle Taxis.

- Investment in electrification of public transport and the creation of last-mile on-demand electric public transport schemes is conducted offering attractive public transport alternatives to raise the attractiveness of public.
- Technical feasibility studies, business model creation and stakeholder coordination are carried out to support the electrification and improvement of public transport together with the development and application of a CC and a CMF scheme within a Clean Mobility Zone in Bangkok.

4.6 Transformational change

By implementing CC scheme and promotion of 90 electric buses, the direct GHG mitigation in Bangkok area is expected to be 0.31 MtCO2e in the first 5 years and 6 months, accounting for 56,504 tCO2e/a. In addition, the project could lead towards additional GHG emission reduction of 2.70 MtCO2e in next 10 years and 6 months, as shown in the summary table below. Therefore, the total direct mitigation potential is expected to sum up to 3.01 MtCO2e. The total indirect GHG mitigation potential is expected to be 3.24 MtCO2e from replacing 30% and 50% of conventional diesel bus fleets with electric buses by 2030 and 2050, respectively. Therefore, the total mitigation potential is expected to be 6.25 MtCO2e.

Currently, the development of electric buses in Thailand is still in its early stages and not an electric bus is in commercial operation in the country. By supporting the funding of 90 electric buses and public transport vehicles and charging facilities in Bangkok, the feasibility and benefits of using electric buses and vehicles to provide quality public transport services can be demonstrated. While electric buses are not yet a competitive technology for most investors in Thailand, this mitigation action can act as a catalyst by significantly reducing perceived risk by subsidising capital expenditure and improving access to finance through guaranteed support for SMEs. Once the technology is proven viable and the perceived risk is removed, the cost of financing electric buses will be lower, attracting more private investors and reversing the flow of funds from other domestic financial institutions and bus operators to expand the use of electric buses. The technology will eventually catch on once economies of scale are achieved, putting Thailand on a carbon-neutral path. For example, the project will electrify 90 buses and public transport vehicles, among others, but Bangkok's entire bus fleet consists of more than 14,000 buses, offering significant potential to expand and replicate the model.

Table 20: Direct and indirect mitigation potential

`	Direct mitigation potential		Indirect mitigation potential	
	During implementation	10 years after implementation	During implementation	10 years after implementation
	tCO_2e/a	tCO_2e/a	tCO_2e/a	tCO_2e/a
Year 1	8,632		0	
Year 2	28,277		28,774	
Year 3	49,072		57,548	
Year 4	71,065		86,323	
Year 5	94,305		115,097	
Year 6	59,421	59,421	71,936	71,936
Year 7		144,726		172,645
Year 8		172,012		201,420
Year 9		200,754		230,194
Year 10		231,010		258,968
Year 11		262,836		287,742
Year 12		296,293		316,517
Year 13		331,443		345,291
Year 14		368,348		374,065
Year 15		407,074		402,839
Year 16		223,844		215,807
Average	**56,504**	**269,776**	**65,396**	**287,742**
Total	**310,771**	**2,697,760**	**359,678**	**2,877,423**
Grand total	**3.008.531**		**3.237.101**	
Over technology lifetime:				
Average	**202,023**	tCO_2e/a	**215,807**	tCO_2e/a
Total	**3,232,375**	tCO_2e	**3,452,908**	tCO_2e

Source: Own calculation by author

4.6.1 Catalytic effect

Electrification of (mini-) buses currently has higher TCO than conventional technologies making grants indispensable for first movers. However, decreasing battery prices, economies of scale and local manufacturing will provide a valid business case in the medium term, which has been proven e.g. in Shenzen in China, were bus fleet electrification led to substantial reductions in price and a gradual phase out of support. The Theory of Change has been proven in various cities around the world, including London, Stockholm, and Singapore, where a congestion zone paired with improvements to public transport have created a paradigm shift in urban transport.

Furthermore, regarding digitalisation and technological innovation different technologies can be used for CC as well as smart and integrated last-mile mobility solutions resulting in efficiency gains and costs reduction. However, more analyses need to be carried out in terms of impact assessment and catalytic effects on the acceleration of digitalization and technological innovation in the economic and social sectors targeted by the project. Technical feasibility studies will hence examine in more detail potential spill-over effects of the project regarding e. g. digitalisation as well as expedited public transport electrification and service improvement.

Moreover, traffic safety and effective enforcement of traffic regulations has long been a problem in Bangkok, resulting in one of the highest fatalities worldwide. Cameras installed for the CC can significantly improve traffic rule enforcement, including the implementation of dedicated bus lanes and buses equipped with GPS serving a digital, real-time traffic information system which currently does not exist. In 2018 the Thai Government has established the Digital Economy Promotion Agency (DEPA), one of the tasks being to advise and train government bodies on big and open data approaches and data security. DEPA will be involved in detailed project design to further examine and untap additional catalytic effects regarding e. g. digitalisation and traffic safety.

By embedding bus electrification in a transport demand management programme (CC) and a financing environment, a systemic paradigm shift in transport demand will be initiated by introducing CC (push measure) to discourage the use of fossil-fuelled private vehicles and by improving clean technologies and service quality of public transport operators through an electrification programme (pull measure) to attract more passengers. Throughout the measure, public transport operators and financial institutions will work together to develop pilot projects for electric operation of public transport and the financing mechanisms tailored to the needs of these operators.

Through technical support during the mitigation measure, operators build their capacities on green mobility technologies and on project development that will help to create technically sounded projects necessary for accessing to finance. With supports on knowledge management, financial institutes can familiarize with these public-transport operators and nature of their business operations which can contribute to standardization of business cases and better designs of financial products for further upscaling. The experiences gained from these pilots can bridge the gap between operators and financial institutes and generate a pipeline for sustainable business cases on public transport electrification and continuous funding opportunities for upscaling.

While electric buses are still not a cost-competitive technology to most investors in Thailand, the project can act as a catalyst by significantly lowering the perceived risk through subsidies on CAPEX, as well as by increasing the access to finance through guaranteed support for SMEs private bus operators. Once the technology is proved to be practical and the perceived risk is removed, the financing cost for electric buses will be lower, attracting more private investors and reversing the fund flow from other domestic financial institutions and bus operators to expand the deployment of electric buses. The technology will eventually take off once the economies of scale are reached leading Thailand towards a carbon-neutral pathway along with an increasing share of renewable electricity.

Funded from CC, the CMF will serve as a source of financial support for further upscaling of the electrification of public transportation fleets, and possibly for other sustainable transport technologies and non-motorized transport in the future. The operation of the CMF aims to create a pipeline of sustainable transport projects through a financial mechanism that engage commercial banks and financial institutes to provide finances to the public transport operators. The CMF could also inspire innovation and linkage to service improvements, for example, the use of digitalization for upgrading service quality, operation and maintenance, and road safety which could be in a form of a real-time traffic information and management system.

The upscaling of electric public transport can trigger economies of scale, cost reduction of battery and other infrastructure, and localization of manufacturing which enable sustainable business cases without additional financial supports. The mitigation project supports the development of MRV system for relevant government agencies to measure, track, and monitor the mitigation through the operation of CMF as well as to evaluate the mitigation potential which can contribute to Thailand NDC Roadmap and more ambitious target setting.

Moreover, enhanced electrification of the transport sector in line with the Thai EV Strategy Roadmap will further boost the overall transition of the transport and energy sector towards a decarbonisation path by sector and grid integration of renewable energy and electricity production through mobile use and storage in EVs.

4.6.2 Sustainability

At present, the development of electric buses in Thailand is still in its early phase and no electric bus is operating at a commercial scale in the country. By supporting the financing of 90 electric buses and the corresponding charging facilities in Bangkok the mitigation action can demonstrate the feasibility and advantages of using electric buses to provide public transport services of good quality.

While electric buses are still not a cost-competitive technology to most investors in Thailand, the project can act as a catalyst by significantly lowering the perceived risk through subsidies on CAPEX, as well as by increasing the access to finance through guarantee support for SMEs bus operators. Once the technology is proved to be practical and the perceived risk is removed, the financing cost for electric buses will be lower, attracting more private investors and reversing the fund flow from other domestic financial institutions and bus operators to expand the deployment of electric buses. The technology will eventually take off once the economies of scale are reached leading Thailand towards a carbon-neutral pathway along with an increasing share of renewable electricity.

Mitigation measures in transport sector link to 11 of the Sustainable Development Goals (SDGs), which mostly relate to good health and well-being (SDG 3), decent work and economic growth (SDG 8) and sustainable cities and communities (SDG 11). The TCMP and the implementation of CC together with the CMF and the Clean Air Zone in Bangkok will therefore decrease private car use as well as related GHG and local air pollutant emissions by shifting travel demand towards improved and successively electrified public transport and therefore improve air quality and mitigate health risks attributed to air pollution in urban areas.

4.6.3 Replicability and scalability

Currently, there are no financial products available for financing EV buses in Thailand because of a limited demand and the resulting lack of market. With the mitigation measure the financing cost for electric buses in the market will be lower and attract domestic financial institutions to develop more financial products to serve the emerging demand for electric buses.

The credit guarantee scheme for electric bus operators will also be scalable to cover all eligible electric buses in Thailand, which is expected to reduce the guarantee fee rate based on a growing portfolio of electric buses to such an extent where it can be afforded by operators or covered by public budget under an existing credit guarantee scheme. It is furthermore expected that the TCO of an electric bus will be equal to the diesel bus within the next 5 years, leading to a broader adoption of electric buses in the major cities in Thailand.

4.7 Supportive actions

4.7.1 Political, legal and regulatory framework

The Thai Government has pledged a 20% reduction in GHG emissions until 2030 - 25% with international support. One third of the savings are to be contributed by the transport sector. Not only is road transport one of the key contributors to air pollutants and GHG emissions, predominant car dependency has been also the major cause for negative externalities imposed on society, environment, and climate. Significant air quality issues together with congestion are severe problems especially in the larger cities, with Bangkok leading the way as one of the top-ten worst congested cities in the world.

Passenger bus services in Thailand are regulated by the DLT under the Land Transport Act B.E. 2522, with three types of operations requiring different licencing and regulations. Unfortunately, poor enforcement of regulations has led to inefficient operation of the business and low-quality and unsafe services for passengers. The MOT statistics shows a drop in bus ridership each year consecutively, while bus accidents have been continuously on the

rise. More than 80% of public buses in Thailand are diesel-fuelled vehicles older than 20 years, resulting in severe air pollution PM2.5 and GHG emissions. Bangkok´s bus fleet is on average 25 years old causing significant GHG emissions and air pollution.

The Thai Government is addressing the problem by building an urban rail network. Within the next 5 years 170 km of additional rail lines will be added to the network. Yet, scenarios based on the Bangkok Transport Model show that the rail network expansion will not suffice to shift commuters from private cars to public transport, due to a lack of last-mile options and low service quality of the bus network, in particular low reliability, and comfort due to congested roads and old vehicles resulting from the lack of funding and fixed tariffs. The dependency of local governments on national funding and a lack of dedicated national funding lines for sustainable transport projects are main reasons for the nonexistence of financing schemes for sustainable transport projects.

CC is being recognised as one of the most sophisticated and effective instruments of travel demand and traffic management and it is anchored in the Thai NDC Action Plan for the Transport Sector as medium-term measure with a planned implementation between 2022 and 2025 together with the electrification of minivans as planned for 2026-2030. The introduction of CC would internalize the external costs or road transport and generate revenue to support public transport improvement. A sound and designated communication strategy implemented prior to the introduction of a CC scheme would increase public acceptance of the programme.

4.7.2 Capacity development and technical assistance

The technical assistance of the mitigation action will focus on addressing existing implementation barriers and on building corresponding capacities required for the implementation. Measures developed will comprise technical assistance for accessing financing support products, piloting a CC Scheme, CMF, and public transport electrification in a Clean Air Zone in Bangkok, including technical and financial needs, organisational and operational planning as well as legal, regulatory, and administrative requirements. Target groups of the measures will encompass public transport and mobility service providers, bus operators, EV manufacturers and distributors, utilities and charging infrastructure providers as well as partner banks and financial stakeholders. On the policy side, technical support measures will target main political partners and related institutions in the context of TCMP development, including CC and the CMF.

To address and overcome perceived technology risks and technical capacity barriers impeding the use of EV technologies, training programmes will be delivered to relevant stakeholders, e.g., EV distributers, charging infrastructure providers, bus operators, maintenance service providers, drivers etc. To promote the EV bus financing scheme, knowledge and experience sharing as well as awareness raising based on best practice examples of first mover beneficiaries will be promoted through the establishment of communities of practice to further stimulate a wider market transformation.

Technical knowledge products, including guidelines, manuals, and recommendation on specific aspects of electric bus implementation and transport system integration as well as regarding quality and performance standards, technical norms, and protocols regarding relevant aspects of charging infrastructure provision and deployment will further mainstream EV technologies and practices into the market.

Capacity development will be also provided for business and financial management financial component to allow for restructuring existing and adopt new business models.

Technical assistance will be provided on the further development of the CC scheme for a Clean Air Zone in Bangkok, including the establishment of CMF by addressing all relevant requirements for the implementation of these measures, including legal, regulative, technical, processual as well as communication requirements.

Assistance and capacity building support will be delivered to set up and operationalize a MRV system for the mitigation action that will feed into the update of the NDC Action Plan for the transport sector as well as contribute to the NDC implementation, update, and ambition enhancement in the context of the current development of the LT-LEDS.

5. Financing concept

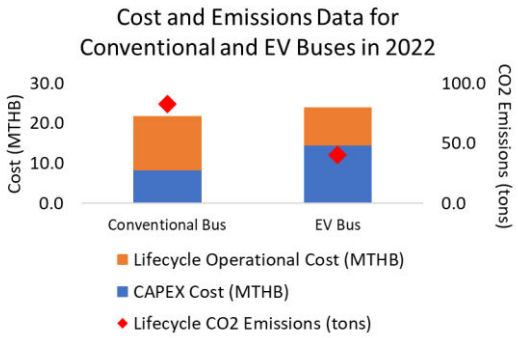
5.1 Overview of costs and revenues

Currently, electric buses have a higher total lifecycle cost than conventional or hybrid vehicles. Over time, EV buses are forecast to become cheaper than conventional and hybrid buses in terms of lifecycle cost. This measure seeks to fill in the financing gap between EV buses and conventional buses prior to this breakeven point being reached.

Based on the data from BMTA's rehabilitation plan, the capital costs of a conventional bus (natural gas vehicle (NGV) bus), a hybrid bus and an electric bus were assumed to 3.84, 8.00 and 12.00 million Baht, respectively. While the operation costs of a conventional bus (NGV bus) and an electric bus were assumed at 1.3 and 0.9 million Baht /bus/year, respectively[27]. These key assumptions were used to estimate the cost and revenues for bus modernization in the model.

From the model result, it shows that there is roughly a THB 4 billion [EUR 119 million] funding gap[28] to convert Bangkok's 2,834 private bus fleet to EV. See a comparison of life cycle costs between conventional and EV buses in Figure 29.

Figure 29: Comparing lifecycle costs of conventional and EV Buses



Source: Clean Mobility Fund Report (2020)

The model assumes that EV and conventional buses have an initial capital cost of THB 16.3 million [EUR 486,000] and THB 8.0 million [EUR 239,000], respectively, based on a Bangkok Post article (Hongtong, 2019). Battery prices are assumed to continue to drop reducing by 18% per year[29] and currently account for 45% of the overall EV price[30]. Capital costs are modelled to decrease over time with decreasing battery price. See a comparison of forecasted costs of EV and conventional buses in Figure 30.

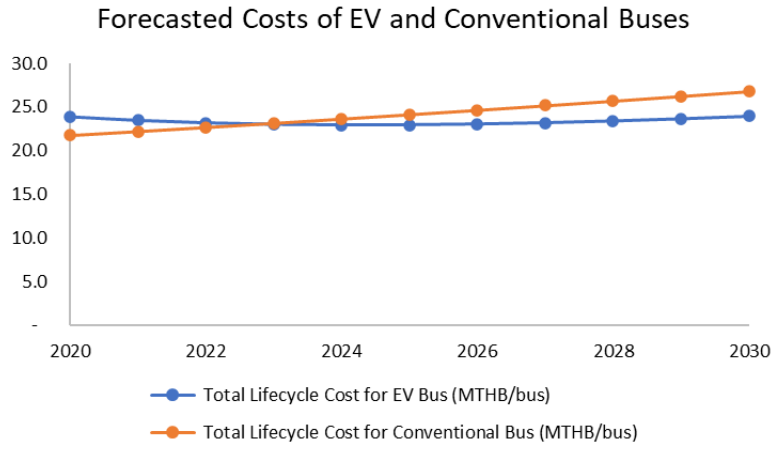
[27] Key assumptions of the model: the "Assumptions" tab of the Excel file contains all underlying assumptions to the financial model (see Annex III).

[28] Based on the NPV difference

[29] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices

[30] Innovative Financing for BRT and Market Opportunities for Indonesian Bus Builders

Figure 30: Comparing forecasted lifecycle costs of conventional and EV Buses



Source: Clean Mobility Fund Report (2020)

Operational costs for conventional buses are based on a 2018 benchmark (Potkány, Hlatká, Debnár, & Hanzl, 2018). Operational costs for EV buses assumed to be 70% of the conventional benchmark according to "Innovative Financing for BRT and Market Opportunities for Indonesian Bus Builders".

The model assumes some socioeconomic benefits for reduced CO2 and PM emissions, aligned with similar analysis for the CC schemes. The socioeconomic benefit is roughly THB 1.4 billion [EUR 41.8 billion] over the planning period.

5.2 Financial and economic viability for bus modernization

As the bus modernization measure requires investment in new vehicles which presently feature higher lifecycle costs than the current options, the investment in 'green' vehicles is not financially attractive for private operators. However, providing financial support measures for such an investment may still be beneficial at the economic level if the socioeconomic benefits exceed the financial costs of the program. Unlike the financial analysis undertaken from the operator perspective, the economic evaluation considers the real economic costs and benefit, net of taxation, which is simply a monetary transfer within the economy. Taxation counts for a significant proportion of the financial purchase cost of an electric bus, with typical import tax of 40% and a further 7% on the taxed value.

When the real economic cost of the bus vehicle alternatives is considered, the lifetime cost of an EV, whilst still higher in net present value (NPV) terms, aligns more closely with that of a conventional bus. Therefore, the economic cost of fleet renewal is lower than the financial cost faced by the operator.

The bus modernization measure shows benefits from CO2 and PM reductions leading to a positive socioeconomic benefit NPV. The socioeconomic benefit NPV calculation for bus modernization does not include any benefits for the improved attractiveness of bus travel, with the associated benefits of reduced congestion and reduced traffic accidents. The benefits may therefore be considered conservative. Table 21 shows that at the prevailing discount rate, economic net present costs slightly exceed net present benefits, thus leading to a negative net present value. However, falling EV bus prices may lead to a net positive economic outcome if pursued in the coming years.

Table 21: Summary of statistical results of the analysed measures

Measure	Operator Financial Cost NPV (MTHB)	Societal Cost NPV (MTHB)	Socioeconomic Benefit NPV (MTHB)	Societal Net Present Value (MTHB)
Bus Modernization	-4,001 [EUR -119 million]	-1,180 [EUR -35.2 million]	849 [EUR 25.3 million]	-331 [EUR 9.88 million]

Source: Clean Mobility Fund Report (2020)

5.3 Financing mechanism and structure

5.3.1 Review and assessment of financial options for public bus electrification

Existing financial options for public bus electrification can be divided into five groups as shown in Table 22. The potentials to overcome the upfront cost and other financial challenges are described and the potentials to overcome the existing barriers to public bus electrification in Thailand are also evaluated in Table 23. Table 24 describes the case study of two financial models that have considerable potential for the promotion of public bus electrification in Thailand.

Table 22: Existing financial options for public bus electrification

Types	Options
Specific for electric fleet	• Demand aggregation • Integrated end-to-end financing • Revolving fund
Lease	• Sale-and-leaseback • Operating lease • Component lease • Financial lease
Bond	• Green bond
Loan	• Concessional loan • Mezzanine Loan
Guarantee	• Partial risk guarantee (PRG) • Residual value guarantee

Source: Compiled from https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf

Table 23: Potential of financing options to overcome the upfront cost and other financial challenges

Financial option	Upfront costs	Maintenance costs	Access to funding / financing	Financing costs / Income
Demand Aggregation	Lower upfront cost	Incurred by either the operator or asset owner	Dependent upon the financing deal agreed	Dependent upon the financing deal agreed
Integrated end-to-end financing	None –operator simply pays for use of service	None –responsibility of service provider	Operators pays for service dependent on its own levels of ridership/bus usage	Operators pay more for integration and a more streamlined interface with infrastructure and energy providers.
Revolving fund	Lower upfront cost	Benefits from the managed services provided by the SPV	Operators only need to be able to afford the rent or lease	Bus operators benefit from better deals from energy companies.
Sale-and-leaseback	Frees up capital for the operator	Dependent upon the leasing arrangement with the asset purchaser	Asset purchaser may not be as willing to refinance mid-life assets	Operators may have to sell the asset at lower than market value as sale-and-leaseback is typically used to recover cash in the short term.
Operating lease	Spread high upfront costs over the leasing period	Maintenance is typically covered by lessor	Lessee needs to show robust/ strong balance sheet position	Relatively manageable lease costs over a short period, and the potential to exclude from balance sheet.
Component lease	Lower the cost of acquiring batteries / infrastructure	The operator is responsible for vehicle maintenance only.	Relatively affordable in the short term	Potentially high lease costs over the period in order to also cover asset maintenance, monitoring, training etc.
Finance lease	Diminish upfront costs significantly	The lessee bears the maintenance costs	A relatively strong balance sheet is required to enter into finance lease	Relatively manageable lease costs over the period; however, a longer lease period (i.e., over the UEL of the asset) may mean higher costs overall than owning / short-term leasing due to the uncertainties around RV of batteries as more time lapses.
Green bonds	Potentially cheaper access to capital	Responsibility of operator	Competition from other types of bonds makes operators exposed to the volatility of the capital market, which may commensurately affect interest rates in the long-term.	Financing costs should be lower if a concessional (ESG) loan is accessible. Interest rates may be more volatile as it is subject to the fluctuations of the green bond market.

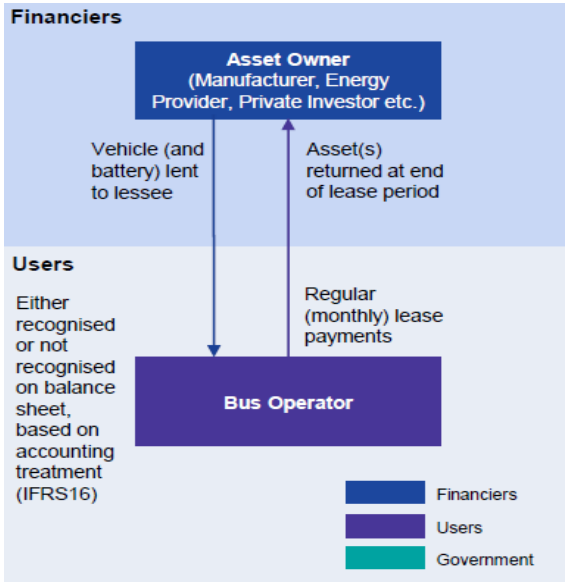
Financial option	Upfront costs	Maintenance costs	Access to funding / financing	Financing costs / Income
Concessional loans	Lessen the impact of upfront costs through use of loan	The operator bears the maintenance costs	Concessional loans can provide access to low-cost capital	Financing costs should be lower if a concessional (ESG) loan is accessible. However, this depends on the operator's ability to demonstrate a strong balance sheet and certain level of revenue certainty.
Mezzanine Loan	Lower upfront cost	Incurred by either the operator or operating lease provider	There is a need to demonstrate a strong credit rating.	Financing cost could be higher due to the higher risk of nonrepayment to financier.
Partial Risk Guarantee (PRG)	Lower upfront cost	Incurred by either the operator or operating lease provider	There is a need to demonstrate a strong credit rating	Financing cost could be lower because the government absorbed some of the risks.
Residual value guarantee	Spread high upfront costs over the leasing period	Incurred by either the operator or asset owner	Guarantee scheme providers may provide on a first come first serve market	Minimum level of guarantee may reduce interest rates/ lease payments

Source: Compiled from Transport Scotland (2021)[31]

[31] https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf

Table 24: Case study of operating lease model and integrated end-to-end financing model

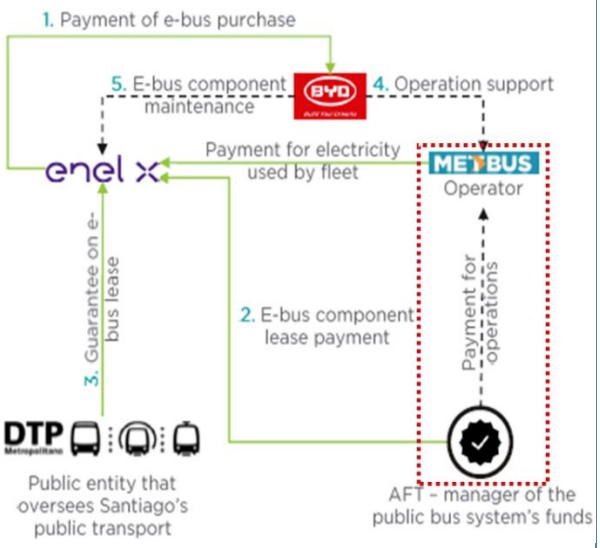
a) Operating lease model: Case study of India (2021)



Sources: Transport Scotland (2021)[32] & The Times of India (2021)[33]

- The local government of Karnataka, India, provided support for 390 electric buses (90 small feeder buses, 300 full-size buses).
- The central and local governments jointly provided investment subsidies of approximately 3.8 million THB/vehicle [1.13 million EUR/vehicle] to the operating lessor, provided that the lease fee charged to operators can be increased by not more than 1 % per year (from the base level of about 10% per year).
- Transport Department provides a 15-year operating lease to the Bangalore Metropolitan Transport Corporation.
- The local government subsidizes around 5 % - 8 % of the operating cost per kilometre in the early years.
- The local government is the fare collector, and it is expected to break even in the 4th year.
- The government supports the domestic battery manufacturing industry, which aims to lower battery prices and reduce the cost of electric buses.

b) Integrated end-to-end financing model: Case study of Chile (2016 - 2019)



Source: C40 Knowledge Hub (2020)[34]

- Activity: Deployment of 100 electric buses in Santiago, Chile
- Investor: ENEL X
  - ✓ ENEL X is one of the ENEL Group's businesses, being an investor of electric buses and charging stations. ENEL Group is the large energy company with a global investment.
  - ✓ It provides an integrated service to operators under a 10-year concession contract.
- AFT (manager of the public bus system's funds) pays a monthly lease.
- A bus operator pays for electricity used by fleet.
- Operator: METBUS
- Electric bus manufacturer: BYD
  - ✓ BYD sells electric buses to ENEL X together with a service package on maintenance and operation support.
  - ✓ BYD provides warranties on all components
- The government provided guarantee for the lease payment provided by AFT.

[32] https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf

[33] https://timesofindia.indiatimes.com/city/bengaluru/karnataka-govt-eyes-green-rewards-from-pricey-electric-push/articleshow/80182608.cms

[34] https://www.c40knowledgehub.org/s/article/Accelerating-a-market-transition-in-Latin-America-New-business-models-for-electric-bus-deployment?language=en_US

5.3.2 Conceptual framework for the proposed business model

From the assessment above, the financing options applicable to the context of Thailand that has a high potential to remove the key challenges for bus operators on the high upfront cost of e-buses and the lack of skilled capacity to maintain and repair electric buses are (i) operating lease and (ii) integrated end-to-end financing. Description of each model is illustrated in Table 25 and Table 26.

Table 25: Operating lease model

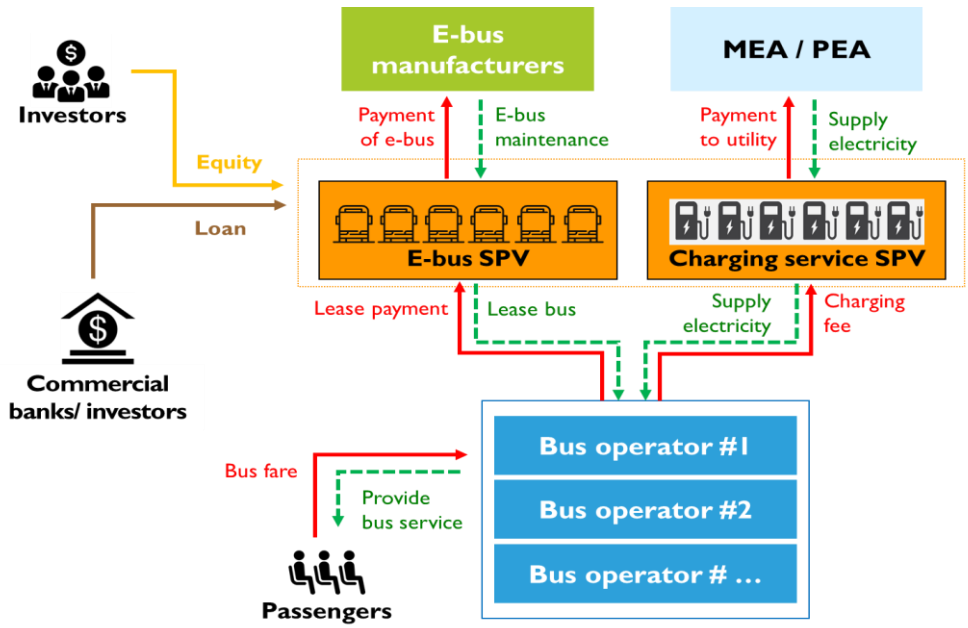
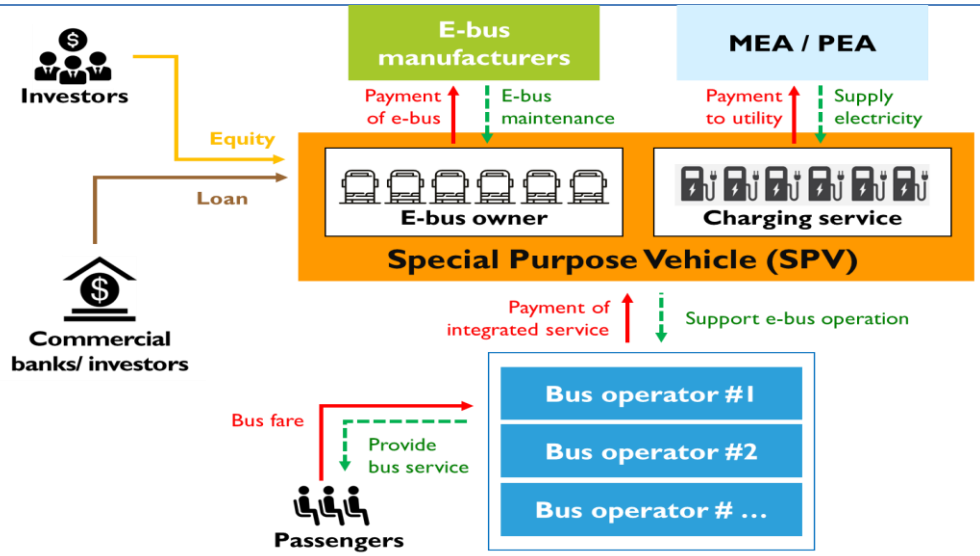
Operating lease model
 Source: Own design
Description: An operating lease is a contract model which allows the lessee use of a vehicle in return for regular lease payments.[35] Key players in this model include: • *a Special Purpose Vehicle (SPV) or E-bus SPV* setting up for owning e-bus through long-term contract between e-bus SPV and e-bus manufacturers and providing lease and maintenance service of e-buses to the operator through leasing agreement between e-bus SPV and bus operators, covering maintenance services, • *an operator* running public buses under the above-mentioned leasing agreement with e-bus SPV and receiving charging services from charging SPV through long-term contracts between bus operators and charging service SPV, and • *another Special Purpose Vehicle (SPV) or charging SPV* setting up for owning charging infrastructure and providing charging service to the fleet under long-term contracts between bus operators and charging service SPV. *E-bus SPV* and *charging service SPV* may be the same or different entities upon the readiness of technical and financial capacity. SPV can be established by the support from the government or potential investors, e.g., bus manufacturers, battery manufacturers, or energy companies.

Table 26: Integrated end-to-end financing model

Integrated end-to-end financing model

[35] https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf



Source: Own design

Description:

This model aims to bundle all services/products required for public bus electrification including vehicles, batteries and charging infrastructure to provide an integrated solution. Key players in this model include:

- *a Special Purpose Vehicle (SPV)* owning all assets required for public bus electrification through long-term contracts with e-bus manufacturers as well as charging infrastructure suppliers and providing an integrated end-to-end service to the bus operators under long-term contracts with bus operators,
- *a bus operator* running buses for public service under the long-term contract on provision of an integrated service between the integrated service SPV and bus operators.

The key advantage of this model is that the operator does not need to pay any upfront cost. Additionally, the operator will engage with only one entity, which is potentially cost saving as it requires less time and effort. The SPV can be bundled up by potential investors from bus manufacturers, component providers, financing institutions, or power companies. This model relies heavily on the capacity of the SPV which must be highly mature and able to assure the availability and the quality of the services provided to the bus operator.

5.4 Scale of investment and support needs for different ambition levels

The assessment of the two proposed business models leads to the estimation of the financial support needs to ensure that the investment is attractive for the key stakeholders.

Table 27 summarises the amount of funding required to support the two proposed business models in various scenarios.

The amount of funding required for the operating lease model for all scenarios are slightly higher than that required for the integrated end-to-end service. This is because there are only two key stakeholders in the integrated end-to-end service, therefore, the total administration cost incurred is lower than the administration cost required for three parties in the operating lease model. However, the integrated service SPV in the integrated end-to-end service model must have a large investment potential since the investment cost covers both e-buses and charging infrastructure. Both models can be applied to the existing context of Thailand. The selection of the model depends upon the investment and technical capacity of the SPV and the direction of policy.

Table 27: Amount of funds required to support the two proposed business models (Unit: MB)

Scenario	Financial options	Operating lease		Integrated end-to-end service	
		w/o risk guarantee	with risk guarantee	w/o risk guarantee	with risk guarantee
1	Exemption of CIT*	274	379	245	350
II	Subsidy for bus operation	1,878	1,983	1,639	1,744
III	Subsidy for e-bus**	1,558	1,641	1,303	1,389
IV	Subsidy for charging infrastructure	1,666	1,764	-	-
V	Exemption of CIT & subsidy of e-bus*	1,543	1,629	1,389	1,379

Remarks:
** The exemption of CIT only cannot make the project feasible.*

*** Subsidy is provided for the investment cost of both e-buses and charging infrastructure in the integrated end-to-end service model.*

When comparing between the support needs estimated for promoting public bus electrification using the proposed business models (as shown in

Table 27) and the existing subsidy scheme for electric passenger cars per passenger-trip over the 15-year lifetime, the current scheme providing 70,000 THB/car [2,090 EUR/car] (or 3.11 THB/passenger-trip [0.093 EUR/passenger-trip]) and 150,000 THB/car [4480 EUR/car] (or 3.33 THB/passenger-trip [0.099 EUR/passenger-trip]) spends approximately 34% and 44% higher than the highest funding required for supporting the public bus electrification through the operating lease model (2.32 THB/passenger-trip [0.069 EUR/passenger-trip]) as shown in

Table 27.Further assessment shows that the GHG emission reduction from the electrification of 500 buses is about 43,091 tCO_2/year. The support needed for 500-public-bus electrification in all scenarios per the amount of GHG abatement are less than 16 USD/tCO_2 [14.605 EUR/tCO_2] (Table 28). The government can use this estimated support per ton of GHG abatement as a reference to compare with the cost required to support other NDC measures for incentivizing low carbon investment to prioritize public finance support.

Table 28: Support needed for promoting 500-public-bus electrification per the amount of GHG abatement (Unit: USD/tCO_2)

Scenario	Financial options	Operating lease		Integrated end-to-end service	
		w/o risk guarantee	with risk guarantee	w/o risk guarantee	with risk guarantee
1	Exemption of CIT	2.20 [EUR 2.01]	3.05 [EUR 2.78]	1.97 [EUR 1.80]	2.81 [EUR 2.57]
II	Subsidy for bus operation	15.09 [EUR 13.77]	15.94 [EUR 14.55]	13.17 [EUR 12.02]	14.02 [EUR 12.80]
III	Subsidy for e-bus*	12.52 [EUR 11.43]	13.19 [EUR 12.04]	10.47 [EUR 12.02]	11.17 [EUR 10.20]
IV	Subsidy for charging infrastructure	13.39 [EUR 12.22]	14.18 [EUR 12.94]	-	-
V	Exemption of CIT & subsidy of e-bus*	12.40 [EUR 11,32]	13.10 [EUR 11.96]	11.17 [EUR 10.20]	11.09 [EUR 10.12]

Remarks:
1. *The exemption of CIT only (Scenario I) cannot make the project feasible.*
2. *Subsidy is provided for the investment cost of both e-buses and charging infrastructure in the integrated end-to-end service model.*
3. *The discounted amount of tCO_2 over 15-year lifetime is 368,836 tCO_2.*
4. *Exchange rate: USD 1 = THB 33.73 (Data from BOT during Jan – Jun 2022); USD 1 = EUR 0.913 (03.10.2019)*

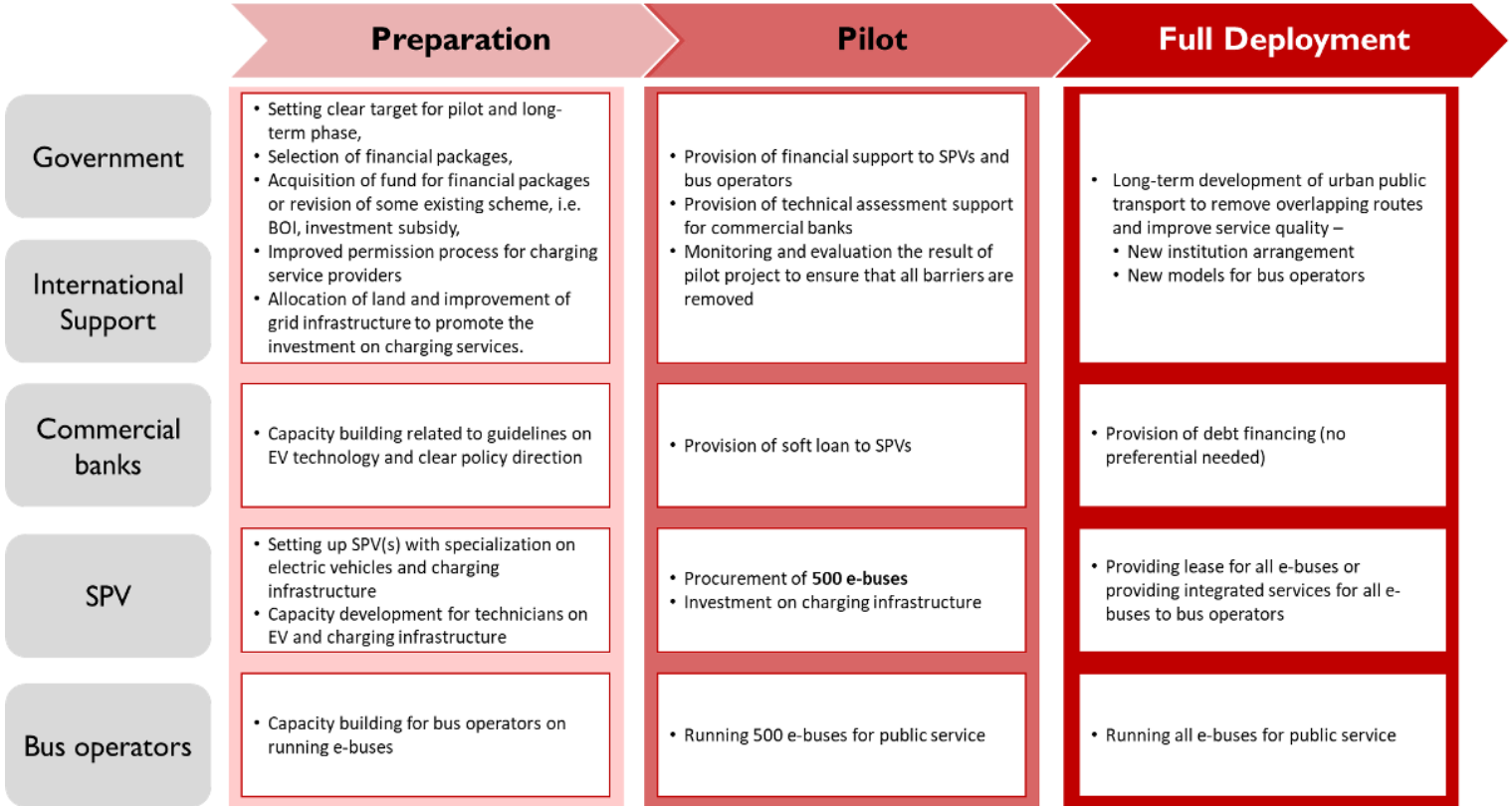
The proposed business model as well as the various financial options illustrated in the sections before can remove the key financial barriers especially those for bus operators including high upfront costs, limited financial capacity, and lack of skilled capacity to maintain and repair e-buses. However, some barriers still exist, and further actions related to government policies and its roles are addressed in Table 29.

Table 29: Further needs to support public bus electrification

Barriers	Further needs
Overall planning of public land transport	
• Unclear planning of public land transport	• Electric buses have a limited driving range and long recharging times. The electrification of bus fleets requires careful planning in terms of strategic, tactical, and operational planning to tackle problems such as placement of charging infrastructure, the electric vehicle scheduling problem, the charging scheduling problem, etc. Also, the integration with other modes of transport must be clear to ensure the convenience of passengers as well as the feasibility of the investment in public bus electrification.
For e-bus manufacturers:	
• Uncertain demand of e-buses	• Clear target setting of public bus electrification
For bus operators:	
• Regulated bus fares at low level, since collection of bus fares is the main source of revenues for the bus operators, the bus operators focus mainly on high passenger volume and minimizing their costs, as a result providing low service quality for passengers	• The Government may consider a new model which allows the main source of revenue of bus operators be linked to the service quality provided. For example, in Singapore, the bus contracting model is applied, i.e., the Government invests in all infrastructure including buses and hires private companies to run public buses through a tendering process. All bus fares are collected by the government.
For charging service providers:	
• Timely and complicated permission process • Availability of land or space for charging infrastructure	• Improved permission process for charging service providers • Allocation of land and improvement of grid infrastructure to promote the investment on charging services

For operationalising financial mechanisms for public bus electrification in Thailand, the roadmap below is developed. The roadmap is divided into three phases, i.e., preparation phase, piloting phase, and full implementation. During the preparation phase, the clear target setting as well as the detailed design of financial supports together with the capacity building programs for relevant stakeholders, mainly commercial banks and technicians will be conducted. During the pilot phase, the first 500 electric bus should be demonstrated. Finally, at the full deployment phase, the entire fleet transitions towards e-buses without additional financial support, but the reform of public bus financing is needed to ensure that the financial status of bus operators will not incur deficit and lack investment capacities to keep improving fleets in the long run. The actions needed by the primary stakeholder groups in each phase are highlighted in Figure 31.

Figure 31: Roadmap for operationalising financial mechanisms for public bus electrification in Thailand



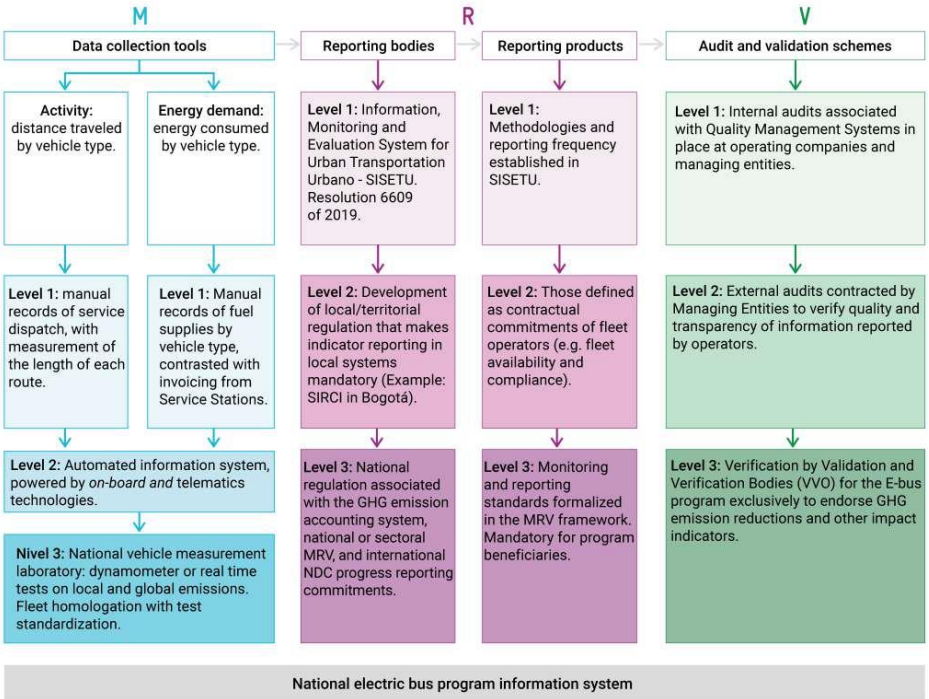
6. Monitoring and reporting plan

The prevalence of private automobiles has led to a continuous accumulation of GHG and air pollutants that result in poor air and life quality especially in urban areas. Hence, with rising concerns on health and environmental consequences, initiatives for "greener" transports have been in continuum. Apart from automation and shared mobility, the most established green transport initiative is electrification. Therefore, the initiative to shift to electricity to power engines is prospected to bring a significant reduction on GHG emissions.

In accordance with the Nationally Distributed Contribution (NDC), Thailand plans to leverage renewable energy while curtailing fossil fuel in transportation. The EV 30@30 policy plans to enforce more use of zero carbon-emitting vehicles to shift away from internal combustion engines (ICE). Especially targeted towards public bus electrification to run on battery (BEV) and fuel cell (FCEV), the policy aims to increase BEVs and FCEVs fleet share on road and in production by 40% and 50% by 2030 respectively.

The MRV framework provides an assessment on how much impact electrification has on the environmental outlook. Designed to help mitigate climate change through navigating GHG emissions, as shown in Figure 32, the MRV consists of three procedures which are: (1) Monitor; (2) Report; (3) Verification. Monitoring (M) collects direct empirical measurements on GHG emissions under pilot protocols and regulations while Reporting (R) keeps track and documents data obtained during Monitoring. In the final step, Verification (V) validates data reliability and accuracy.

Figure 32: Three procedures of MRV



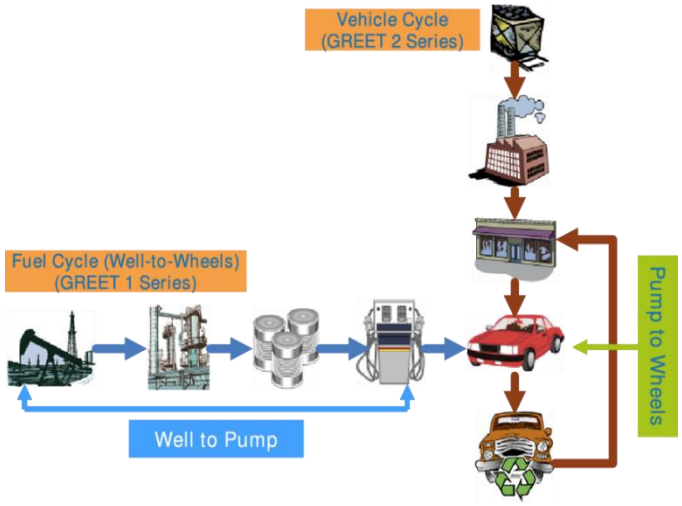
Source: EV document

Here, applying (M) to public bus electrification requires a deliberate examination on the life cycle of GHG, which consists of vehicle cycle and the fuel cycle.

Comparing GHG emissions between two powertrains, Internal Combustion Engine (ICE) and Electric Vehicles (EV), both follow Well-to-Wheels (WTW) cycle. Divided into (1) Well-to-Tank (WTT) and (2) Tank-to-Wheels (TTW), these separated sub-cycles can identify GHG emission source and levels. In the

first step, WTT measures GHG emissions from all procedures relating to fuel production, be it extraction, refining, processing, and distribution, while TTW measures GHG emissions when fuel enters the automobile powertrain, is processed, and discharged out. If compared the level of GHG between the sub-cycles in ICE, the TTW will emit more GHG due to the need to ignite and combust the engine to move the automobile. Although EVs do not rely on fossil fuel to power the automobile, GHGs are unavoidably produced in the WTT cycle through electricity generation from burning fossil fuel. Otherwise, EVs are zero-carbon emitting since they do not undergo chain combustions in the powertrain alike to ICE.

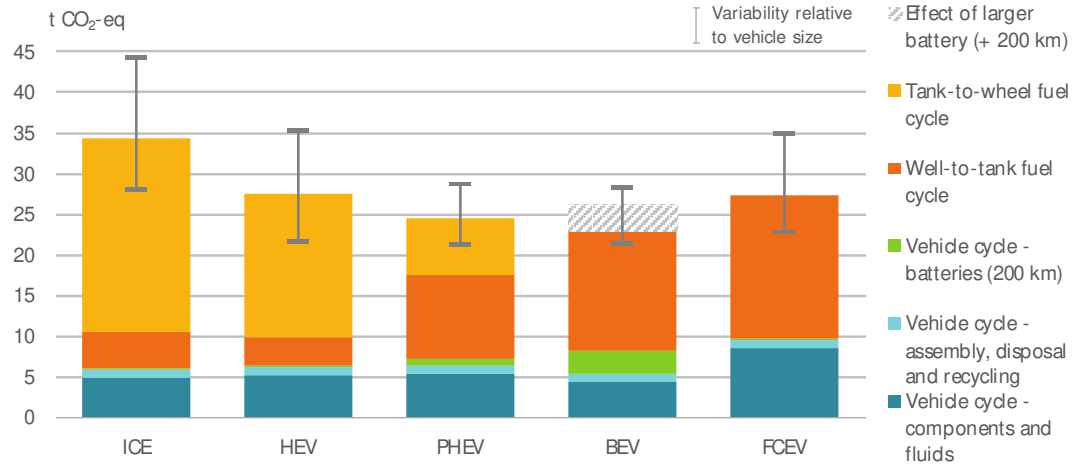
Figure 33: Vehicle cycle and fuel cycle



Source: EV document

Concurrently, there are five types of EVs: (1) HEV; (2) PHEV; (3) BEV; (4) EREV; (5) FCEV. Hybrid Electric Vehicles (HEV) are powered by a combination of fossil fuel and electricity. This dual-energy usage results in lower tailpipe emissions than combustion engines in ICE, but predominantly relies on fossil fuel. Plug-in Hybrid Electric Vehicles (PHEV), similar to HEV, have larger batteries which allow higher charging capacity for longer driving distances. Battery Electric Vehicles (BEV) run singularly on electricity which emit no tailpipe pollutants. However, BEV batteries need to be recharged in every certain running distance, making them unsuitable in long distance drives. With an addition of a small combustion generator in Extended Range Electric Vehicles, EREVs can run in longer periods as the generator can recharge the battery when depleted but will unavoidably emit CO_2. Attempts to improve EVs charging efficacy are presented in Fuel Cell Electric Vehicles (FCEV). Fuel replacements by hydrogen over electricity will speed up charge time as well as avoiding indirect GHG emissions from electricity generation but will still emit more GHG than BEVs.

Figure 34: Comparison of CO2 in fuel cycle during WTW cycle



Notes: This figure portrays mid-size vehicles having similar performance with the exception of driving range. The BEV refers to a vehicle with 200 km range, the addition of the shaded area refers to a vehicle with 400 km range. The ranges suggested by the sensitivity bars represent the case of small cars (lower bound) and of large cars (upper bound) – for BEVs, the lower bound of the sensitivity bar represents a small car with a 200 km range, and the upper bound represents a large car with a 400 km range.The carbon intensity of the electricity mix is assumed equal to the global average (518 g CO_2/kWh). FCEVs are assumed to rely entirely on hydrogen produced from steam methane reforming. Other assumptions used to develop this figure are outlined in the Chapter 4 of the *Global EV Outlook 2019*, focused on life-cycle GHG emissions.

Source: EV document

The graph above compares the fuel cycle of CO_2 during the Well-to-Wheels (WTW) cycle of a mid-size ICE and four EV automobiles run at the same distance. The yellow bar represents CO_2 produced during Tank-to-Wheels (TTW) sub-cycle, and the orange bar represents the emissions from Well-to-Tank (WTT) sub-cycle. FCEVs do not contribute to any CO_2 emission during TTW but emit the most level of CO_2 during WTT. Therefore, BEVs are the most environmentally friendly automobile amongst all types based on the level of CO_2 emissions.

Gaining correlation between automobile types and GHG emission levels can contribute to the MRV framework instalment, however, requires a comprehensive fleet system analysis to draw up a scope of activities and limitations that fall within the MRV guideline and still be in consistent with the NDC. The limit sets include timeframes, emission sources, types of mitigations, GHG inventory categories under the IPCC standards, impact estimations, and GHG pollutant levels. To quantify the level of GHG in an operating ICE and EV automobile, Equation 1 is used for approximation.

Equation 1: level of GHG in an operating ICE and EV automobile

Equation 1.

$$ECO_2eq_{P,i} = ECO_2eq_{C,i} + ECO_2eq_{A,i} + ECO_2eq_{E,i} + ECO_2eq_{T,i}$$

Table 3. *Equation 1 definitions.*

Term	Meaning	IS units
$ECO_2eq_{P,i}$	CO_2eq emissions associated with the program fleet in year i.	$\frac{tCO_2eq}{year}$
$ECO_2eq_{C,i}$	CO_2eq emissions from **fuel combustion during fleet operation**[5] in year i.	$\frac{tCO_2eq}{year}$
$ECO_2eq_{A,i}$	CO_2eq evaporative emissions from **using refrigerants in Mobile Air Conditioning systems** in the fleet in year i.	$\frac{tCO_2eq}{year}$
$ECO_2eq_{E,i}$	Total CO_2eq emissions associated with **WTT emissions of the electricity consumed.**	$\frac{tCO_2eq}{year}$
$ECO_2eq_{T,i}$	Total CO_2eq emissions associated with **Fuel WTT emissions (extraction, refining, transport, and distribution)** in year i.	$\frac{tCO_2eq}{year}$

Source: *Authors' compilation.*

Four primary components in Equation 1 are corresponded to average GHG emission level of a program fleet during WTW by year ***i*** which consisted of: (1) CO_2 from fuel combustion during fleet operation; (2) CO_2 from refrigerants; (3) CO_2 from electricity generation in WTT; (4) CO_2 associated with fuel production.

Following the GHG emission inventory guidelines to determine the level of equivalent CO_2 emitted from fuel combustion during fleet operation, ECO_2eq_i, CO_2, CH_4, and N_2O emissions are measured. CO_2 level is calculated in Equation 2 and only applied to ICE powertrains while EVs remain zero in emission. Both ICEs and EVs are applied in Equation 3 which measures CH_4 and N_2O emission levels during fleet operation.

Equation 2: Calculation of CO2 level

Equation 2.

$$ECO_{2_{C,i}} = \sum_t a_{t,i} \sum_c k_i \cdot \frac{1}{r_{t,c,i}} \cdot NCV \cdot FC \cdot fe_c$$

Table 4. *Equation 2 definitions.*

Term	Meaning	IS units
$ECO_{2_{C,i}}$	CO_2 emissions in year i.	$\frac{tCO_2}{year}$
$a_{t,i}$	Average annual activity by type of bus t, in year i.	$\frac{VKT\,s}{year}$
k_i	Proportion of fleet by type and fuel in year i.	Dimensionless (ratio)
$r_{t,c,i}$	Fuel efficiency[6] by type of bus t and fuel c, in year i.	$\frac{km}{\text{gal diesel}}$; $\frac{km}{\text{m}^3\,NGV}$
NCV	Net calorific value of fuel c.	$\frac{TJ}{\text{gal diesel}}$; $\frac{TJ}{\text{m}^3\,NGV}$
FC	Unit conversion factor.	From kg to t
fe_c	CO_2 emission factor by type of fuel c.	$\frac{kg\,CO_2}{TJ}$

Source: *Authors' compilation.*

Several factors presented in the Equation 2 require direct data collection of the program fleets. This includes: annual running activity of each type of fleets ($a_{t,i}$) , proportion of fleet and fuel types (k_i), and fuel efficiency by fleet type and fuel type ($r_{t,c,i}$).

Equation 3: Measurement of CH4 and N2O emission levels during fleet operation

Equation 3.

$$ECO_2eq_{C,i} = ECO_{2\,C,i} + [I_{GWP-CH4}] \cdot ECH_{4,i} + [I_{GWP-N_2O}] \cdot EN_2O_i$$

Table 5. Equation 3 definitions.

Term	Meaning	IS units
ECO_2eq_i	CO_2eq emissions associated with the program fleet in year i.	$\frac{tCO_2eq}{year}$
$ECO_{2C,i}$	CO_2 emissions from fleet operation phase in year i.	$\frac{tCO_2}{year}$
$ECH_{4,i}$	CH_4 emissions from fleet operation phase in year i.	$\frac{tCH_4}{year}$
EN_2O_i	N_2O emissions from fleet operation phase in year i.	$\frac{tN_2O}{year}$
$I_{GWP\text{ - }CH4}$	Global Warming Potential (GWP) for methane.	*dimensionless*
$I_{GWP\text{ - }N20}$	Global warming Potential (GWP) for nitrous oxide.	*dimensionless*

Source: *Authors' compilation.*

The second component that attributes to the GHG emissions of a program fleet is corresponded with refrigerants. Hydrofluorocarbons (HFC) are pollutants that are indirectly generated from Air conditioning (AC) systems and partake in fuel consumption in a vehicle. HFC emissions during fleet operations and during system maintenance are measured by Equation 4 presented as $ECO2eq_{A,i}$

Equation 4: HFC emissions during fleet operations and during system maintenance

Equation 4.

$$ECO_2eq_{A,i} = \sum_a (FE_{a,t,i} \cdot I_{GWP-HFC} \cdot F_i)$$

Table 7. Equation 4 definitions.

Term	Meaning	IS units
$ECO_2eq_{A,i}$	CO_2eq emissions from air conditioning use in year i.	$\frac{tCO_2eq}{year}$
$FE_{a,t,i}$	HFC emissions factor for leakage, according to type of air conditioning system a, and bus type t.	$\frac{kg\ HFC}{year}$
$I_{GWP\text{ - }HFC}$	Global Warming Potential (GWP) for HFCs, in this case corresponding to R-134a.	*dimensionless*
F_i	Number of buses in operation in year i with air conditioning system a.	$\frac{buses}{year}$

Source: *Authors' compilation.*

In Equation 4, the level of HFC emission ($FE_{a,t,i}$) in year ***i*** is dependent on refrigerant system type, *a* and bus type, *t*. The average HFC emission value is 0.92 ± 0.4 kg HFC/year is derived from HFC-134a, which is the predominant refrigerant type. Besides GHG emission activities during fleet operation, GHG emissions produced from electricity generation and from fuel production are also measured in Equation 5 and Equation 6 respectively.

Equation 5: Amount of electricity generation in year i

Equation 5.

$$ECO_2eq_{E,i} = FE_{E,i} \cdot DE_{E,i}$$

Table 8. Equation 5 definitions.

Term	Meaning	IS units
$ECO_2eq_{E,i}$	Total CO_2eq emissions from electricity generation in year i.	$\frac{tCO_2eq}{year}$
$FE_{E,i}$	Emissions factor for electricity generation by the national energy system, in year i.	$\frac{kgCO_2eq}{kWh}$
$DE_{E,i}$	Electricity demand due to the electric fleet in year i.	$\frac{kWh}{year}$

Source: *Authors' compilation.*

Equation 5 demonstrates the amount of electricity generation in year ***i*** that varies depending on electricity demand to operate EVs in a program fleet ($DE_{E,i}$) whereas emission factors for electricity generation is readily approximated ($FE_{E,i}$). Equation 6 measures the total CO_2eq emissions ($ECO_2eq_{T,i}$) relating to fuel production and transportation by summing all the CO_2eq emissions from each fuel type, c.

Equation 6: Total CO2eq emissions (ECO2eqT,i) relating to fuel production and transportation

Equation 6.

$$ECO_2eq_{T,i} = \sum_c ECO_2eq_{WTT,c,i} \qquad ECO_2eq_{WTT,c,i} = (\alpha) \cdot ECO_2eq_{T,c,i}$$

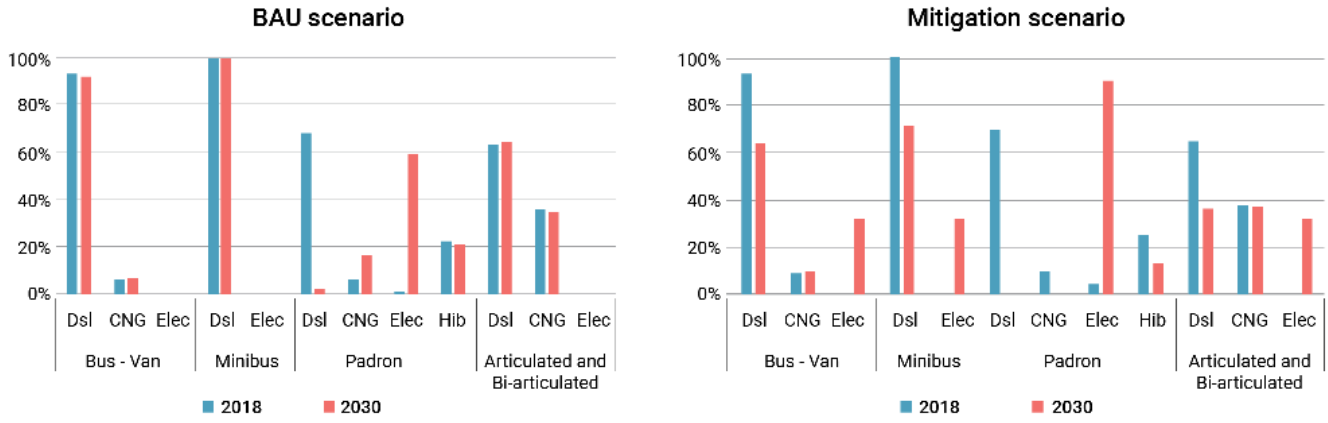
Table 9. Equation 6 definitions.

Term	Meaning	IS units
$ECO_2eq_{T,c,i}$	Total CO_2eq emissions from producing and transporting fossil fuels in year i.	$\frac{tCO_2eq}{year}$
$ECO_2eq_{WTT,c,i}$	CO_2eq emissions from producing and transporting fossil fuel c in year i.	$\frac{tCO_2eq}{year}$
α_c	Proportion of CO_2eq emissions generated in the energy production and transportation phase, by fuel type.	*dimensionless*

Source: *Authors' compilation.*

GHG level measured via the set of calculations above can be used to standardize emission levels in the business-as-usual/baseline scenario (BAU) of which there are no targets and mitigation actions involved. Nevertheless, the calculations can also estimate the level of GHG pollutants if mitigation actions are to be applied through imposing limitations on fleet emission levels, fleet and fuel types that follow the MRV guidelines. For instance, a case study of electric bus program in Colombia compares GHG emission levels between BAU and the mitigation scenario. The BAU scenario is approximated from the most common GHG pollutant types and levels from the country's 15 public transport systems, and other situational assumptions are also estimated to simulate the scenario, which comprise of fleet size, bus type, fuel type and efficiency, and passenger capacity and demand. The GHG target for the mitigation scenario is based on the BAU to create feasibility if measures are to be implemented. The graph below compares fleet types and fuel types by % in 2018 and 2030 (Figure 35).

Figure 35: BAU and Mitigation scenario



The proposed mitigation scenario in Colombia's transportation plan aims to increase the share of EVs by 30% in 2030 for each fleet type or to replace every one diesel bus with one electrical bus. The fleet share of compressed natural gas (CNG) remains unchanged in 2030 due to emitting less GHG level than diesel (Dsl). Lastly, mitigation indicators should be set to evaluate how effective the measures have on the environmental outcome as to finalize or adjust the MRV framework that will entail to future GHG protocols to achieve the NDC. These indicators may include annual CO_2eq emission reduction levels, annual $PM_{2.5}$ emission reductions, or the annual concentration of particulate matters ($PM_{2.5}$, PM_{10}).

7. Recommendations

Upgrading the public bus service to become everyone's choice should be the national agenda to reduce traffic congestion and air pollution, to improve the quality of life of citizens in Thailand. To upgrade the public bus service, the following actions are needed.

a) Replacement of new buses: Approximately 50% of public buses in BMR have been operated for more than 29 years. The replacement of new buses will reduce maintenance cost born by the operators, reduce air pollution from the deteriorated diesel buses, and allow the provision of better service with reliable schedule. The better quality of service will escalate the number of passengers leading to higher revenues for the operators.

b) Improvement of service standard: DLT as a regulator has set a plan to reform service routes and networks, promote safety standard for public transport, and connect all modes of transportation. To ensure the standard of service, the Government may consider a new business model which allows the main source of revenue of bus operators to be linked to the quality of service provided. For example, in Singapore, the bus contracting model is applied, i.e., the Government invests in all infrastructure including buses and hires private companies to run public buses through a tendering process. All bus fares are collected by the government.

c) Fair adjustment of bus fares: Most of public bus operators were facing net loss from their operation. This shows that the bus fares cannot cover the operating cost resulting in limited capacity to invest in improvement of bus infrastructure and service quality. Compared to the Sustainable Urban Transport Index on affordability, the fares of public buses in Bangkok are considered as highly affordable. There still exists the gap for adjustment of bus fares to cover all operating costs of buses as well as allow bus operators to invest in improvement of bus quality and services. To ensure affordability for low-income passengers, the government should support the service provision through subsidies, instead of keeping the fare at a low level. Fair pricing together with regular evaluation of operators' performance will lead to higher service quality which is key to encourage the use of public transport for all groups and finally leading towards an improvement of the life quality of local citizens.

Public bus electrification can be one of the promising solutions for upgrading the public bus service in Thailand. The investment on electric buses becomes more attractive. The financial analysis on TCO reveals that the TCO of an e-bus is competitive, compared to that of a diesel bus. The costs of an e-bus and batteries are decreasing further lowering the TCO of an e-bus. Moreover, since the fuel cost incurred during the operation has more impact on the TCO of ICE buses than that of an e-bus, the volatile fossil fuel prices lead to higher risks in the operation of a diesel bus and a NGV bus.

The operating lease model and integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public bus electrification in Thailand. However, since the fare is the major source of revenue for the bus operators, the current level of bus fares cannot make the bus electrification feasible. Additional financial support either from the government side or from international sources are needed. A funding volume of 1,303 – 1,983 MB is needed for make the electrification of 500 public buses feasible depending on the business model selected and the financial options provided.

Compared to the existing subsidy scheme for electric passenger cars per passenger-trip over a 15-year period (3.11 - 3.33 THB/passenger-trip [0.093 - 0.099 EUR/passenger-trip]), the support needed for public bus electrification is smaller (highest at 2.32 THB/passenger-trip [0.069 EUR/passenger-trip]). Moreover, the amount of funding required to support the electrification of 500 buses (1,303–1,983 MB) can support about 18,600–28,300 electric passenger cars, from which the number of beneficiaries is approximately 510–776 million passenger-trips. However, the number of beneficiaries of 500 public buses is 1,140 million passenger-trips, or approximately 1.47–2.24 times the number of beneficiaries from promoting electric passenger cars.

Further assessment shows that the GHG emission reduction from the electrification of 500 buses is about 43,091 tCO_2/year. The support needed for 500-public-bus electrification in all scenarios per the amount of GHG abatement are less than 16 USD/tCO_2 [EUR 14.605/ tCO_2]. The government can use this estimated

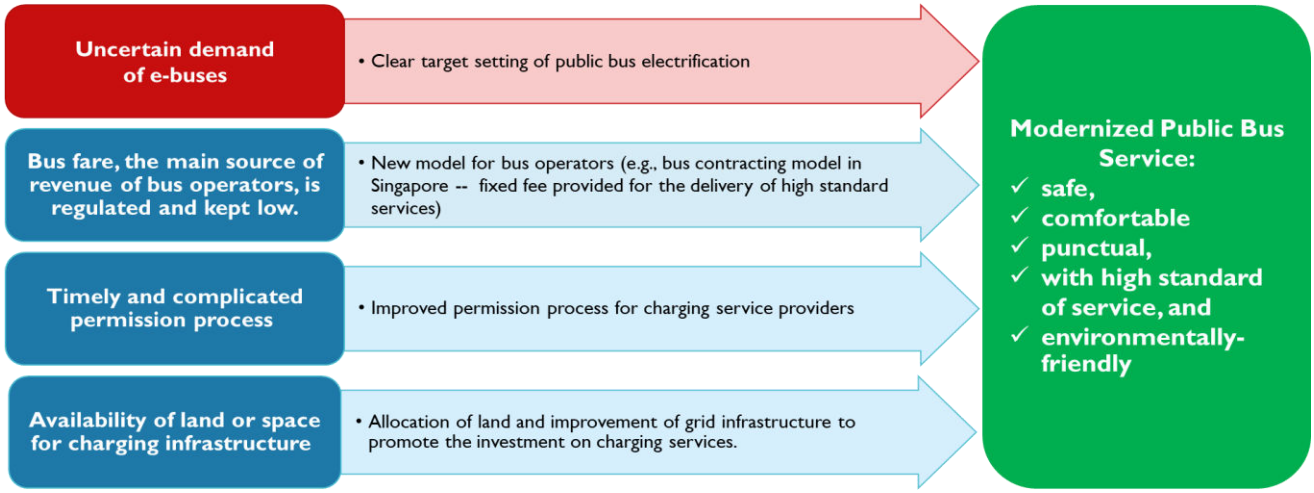
support per ton of GHG abatement as a reference to compare with the cost required to support other NDC measures for incentivizing low carbon investment to prioritize public finance support.

The implementation of public bus electrification can be divided into 2 groups depending on the types of the operators. The first group is BMTA as a state-owned enterprise. The consultation with BMTA suggests that the integrated end-to-end financing model is more suitable for the current situation of BMTA. The model can overcome the barriers that BMTA is facing on public bus electrification including the limited financial capacity to invest into new buses and the lack of skilled capacity to maintain and repair EVs. Also, it can help mitigate the risks on uncertainty of fuel supply. However, the implementation shall comply with the Public Private Partnership Act B.E.2562 (2019).

The second group is a group of private companies with direct licenses from DLT. Currently, there is a new investor from the EV and battery manufacturing sector with strong financial and technical capacities, E-Transport Holdings Co.,Ltd. entering the public bus operation business in deploying electric buses.

The proposed business models together with the financial support can remove the key financial barriers especially those for bus operators including high upfront costs, limited financial capacity, and lack of skilled capacity to maintain and repair e-buses. However, some barriers still exist, and further actions related to government policies and its roles are needed as shown in Figure 36.

Figure 36: Further needs to support public bus electrification



Source: EV document

To initiate the electrification for public buses, investment subsidy is needed for modernized public bus service over the next 15-year lifetime. The long-term development of public transport to remove overlapping routes and improve service quality especially the adoption of new models for bus operation and fair adjustment of bus fares is crucial for the sustainability of the public bus service.

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Registered offices
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Friedrich-Ebert-Allee 36+40
53113 Bonn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de

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Registered Offices
Bonn and Eschborn

Friedrich-Ebert-Allee 36+40
53113 Bonn, Germany

T +49 228 44 60-0
F +49 228 44 60-17 66

E info@giz.de
I www.giz.de