Cost-benefit analysis of alternative vehicle technologies for the urban bus system in Thailand

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ABSTRACT

Environmental impacts from the transport sector have been a critical issue in urban areas for more than two decades. Bangkok, the capital city of Thailand, is one of the biggest megacities in developing countries that is also concerned with this issue. In order to reduce air pollution and mitigate greenhouse gases (GHG) emission, the Bangkok Mass Transit Authority (BMTA) initiated a policy to promote alternative clean technology vehicles by replacing the conventional diesel buses, with compressed natural gas (CNG) buses and electric buses. This paper discusses the economic feasibility for Bangkok, Thailand by the total cost of ownership (TCO) and cost-benefit analysis (CBA) for three alternative technologies for the bus system in Bangkok: diesel, CNG, and electric buses. The TCO of electric vehicles was 8% higher than CNG buses, but it was 10% lower than diesel buses. However, the operating cost of electric buses, including energy costs, operating cost, tax and insurance, was higher than the others. The study showed that in Bangkok's conditions, the net present value (NPV) for electric buses was 2 times higher than diesel buses, but it was 6% lower than that of compressed natural gas buses, when externality costs were excluded. However, when external costs of pollution were included, the NPV of electric buses was 2.5 times higher than diesel buses and 13% higher than CNG buses.

Keywords: Bus system, Electric vehicle, Externality costs, Total cost of ownership, Cost-benefit analysis

1. INTRODUCTION

For more than two decades, environmental impacts from the transport sector have been a critical issue in urban areas, such as health impacts and climate change. Selecting appropriate alternative technologies to cope with these problems is an important responsibility of governments around the world. Bangkok, the capital of Thailand, is one of the megacities in developing countries. It had more than 15 million inhabitants with a travel demand of 22,220 trips per day by bus system in 2017 [1]. Similar to other cities in low-income developing countries, the bus system plays a crucial role in passenger public transport, while other public transport systems, e.g. mass rapid transit (MRT), are under construction.

Currently, the bus system in Bangkok mainly uses diesel and compressed natural gas (CNG). This high fossil fuel consumption results in a high level of greenhouse gases (GHG) emission and local air pollutants, such as sulfur 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). In 2016, the transport sector in Bangkok emitted more than 13.76 million tons of CO_2 ($MtCO_2$) [2]. Moreover, in 2018, Bangkok had a very high PM2.5

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concentration, ranging from 54 to 87 micrograms per cubic metre [3].

In order to reduce air pollution in urban areas, various alternative technologies for urban bus systems have been introduced to replace the conventional internal combustion engine bus, including hybrid electric bus, electric bus, fuel cell bus.

The Bangkok Mass Transit Authority (BMTA), in order to improve air quality and mitigate GHG emission, initiated a policy to promote alternative clean technology vehicles by replacing conventional diesel buses with CNG and electric buses (eBus). According to the government policy, BMTA has purchased 489 CNG buses and plans to purchase 200 electric buses to replace old diesel buses [4, 5].

Electric buses have become commercially available recently and seem to be a promising vehicle technology to improve air quality and also mitigate GHG emissions in urban areas. The development of battery technology has helped to raise the potential of eBuses to be a solution for conventional mass public transport. However, even though the technology is still being developed, the total costs to operate eBuses on a large-scale are relatively expensive compared to the conventional diesel technology. Since the range of vehicles depends on the battery technology, the operational range of buses needs to be well managed in terms of route plan and charging. Moreover, eBuses require dedicated charging equipment and infrastructure for their operation.

TCO has been identified as one of the main barriers in the implementation of eBuses [6]. There are many studies on TCO in European public transportation. The results show that eBus cost per km is still higher than conventional internal combustion engine (ICE) buses, due to high battery replacement costs [7],[8]. Even one that shows lower TCO of eBus than a diesel bus, the influence factors are fuel cost and maintenance cost per km and distance per year, operational years, and investment cost [9],[10]. However, when the annual average external costs for eBuses were accounted for by TCO, the eBus was found to be more beneficial than the ICE buses [11]. According to the results of the transport and environment study in 2018 [12], the eBuses already offer better TCO than diesel buses, when the external costs (air pollution, noise, and GHG emissions) are included as well as in India [13] and China [14].

Cost-benefit analysis (CBA) is a systematic approach to estimate the strengths and weaknesses of alternatives used to determine options, which provide the best approach to achieve benefits while preserving savings. CBA may be used to compare completed or potential courses of actions, or estimate (or evaluate) the value against the cost of a decision, project, or policy. It is commonly used in commercial transactions, business or policy decisions (particularly public policy), and project investments. [15] The economic benefit for alternative vehicles were investigated by employing CBA using primary data (real driving data) [16] or secondary data [17-18].

Therefore, this study aims to analyse the costs and benefits of CNG and eBuses compared to conventional diesel buses in the next 20 years. The financial analysis studies total cost of ownership (TCO) and the benefits of saving energy and environmental impacts' reduction.

2. METHODOLOGY

2.1 Scope of study and key assumptions

In this study, the costs and benefits of substituting the current 2,000 conventional diesel buses of the BMTA by alternative bus technologies, e.g., CNG and eBuses in the next 20 years are analyzed. The costs of investment include capital cost of buses, infrastructure costs and operation and maintenance (O&M) costs, e.g., fuel cost, vehicle maintenance, salary of employee, etc. The income from bus services is considered as benefits in financial analysis, while benefits of GHG, e.g., carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) and other local pollution mitigates, such as carbon monoxide (CO), oxide of nitrogen (NOx), volatile organic compounds (VOC) and particulate matter (PM), reduction by alternative technologies are also estimated in the economic analysis. The total benefit is calculated by the sum of revenue (tickets sold, other revenues i.e., advertisement, rental) without value added tax (VAT), with 6.5% growth rate, and residual value at the end of the project period. This paper assumed the residual value as 10% at the end of the lifetime and the depreciation rate is calculated as a straight-line method (SL) for buses (20 years lifetime) and infrastructure (30 years lifetime). Finally, the reduction in GHG emission and pollution is considered as benefits, for economic analysis that results from replacing diesel buses with alternative buses. Data and key assumptions of bus operation and related costs from various sources are presented in Table 1.

2.2 Cost-benefit analysis

In the study, financial and economic analyses are carried out to determine appropriate bus technologies to substitute conventional diesel buses for BMTA. For this purpose, TCO analysis was employed to estimate the total annual cost of bus operation. Financial benefits of bus operation were calculated from the income of bus services, which assumed that the same buses are operated by a different technology. For economic analysis, benefits of bus operation by each alternative technology were estimated from the costs of GHG and pollution reduction, compared to conventional diesel buses. All technology options were then compared by Net Present Value (NPV), Interest Rate of Return (IRR) and Benefits/Costs ratio (B/C ratio) to analyse appropriate technology for BMTA's bus system in the next 20 years.

2.2.1 Total cost of ownership calculations

The TCO of the bus system was divided into two parts: vehicle and infrastructure, as presented in Eq. (1). TCO of a vehicle can be calculated by Eq. (2), which includes purchasing cost (capital cost) of vehicle, annual fuel cost, annual registration fee of vehicle, annual personnel salary and annual maintenance cost and replacement cost of major vehicle parts. For infrastructure, TCO included capital cost, annual personnel salary and annual maintenance cost and replacement cost, as presented in Eq. (3).

$$TCO_{bus} = TCO_{veh} + TCO_{inf} \tag{1}$$

where TCO_{bus} is the annual TCO of bus system (THB), TCO_{veh} is the annual TCO of vehicle (THB), and TCO_{inf} is the annual TCO of infrastructure (THB).

$$TCO_{veh} = \sum_{i=1}^{i}\sum_{j=1}^{j}\left[\left(C_{veh,i,j} + \left(\frac{VKT_{i,j}\cdot P_j}{F_{i,j}}\right) + Rg_{i,j} + S_{i,j} + M_{i,j} + Rp_{i,j}\right)\cdot N_{i,j}\right] \tag{2}$$

where C_{veh} is the capital cost of vehicle (THB/vehicle), F is the fuel economy of the vehicle (km/litre or km/kWh or km/kg), VKT is the annual average vehicle kilometre of travel of the vehicle (km/vehicle), P is the fuel price (THB/litre or THB/kWh or THB/kg), Rg is the annual registration fee of vehicle (THB/vehicle), S_{veh} is the annual average salary of the vehicle (THB/vehicle), M is

Table 1. Data and key assumptions

	Diesel Bus	CNG Bus	Electric Bus	Remark	Sources
Bus operation					
Average annual travel distance (km/year)		91,250			BMTA
Fuel Economy	1.54 km/litre	1.67 km/kg	1.46 kWh/km		BMTA
Well-to-wheel emission factor (g/km)					IPCC
CO_2	2,073	1,963	589		
N_2O	0.017	0.004	n/a		
CH_4	0.141	1.768	n/a		
NO_x	22.63	21.22	1.28		
PM (PM10 and PM2.5)	0.39	0.08	0.02		
VOC	5.66	0.18	n/a		
Lifespan of bus (years)	20	20	20		
Costs of bus operation (Baht)					
Capital cost	5,200,000	3,459,182	12,607,500		BMTA
Operating costs					
- Fuel	27.96 /litre	16.01 /kg	3.30 /kWh	Annual growth rate 2.5% per year	PTT (2019), MEA (2019)
- Annual personnel salary		600,000 /year/bus		Annual growth rate 6.5% per year	BMTA
Maintenance costs					
- Annual maintenance	6.72 /km	Year 1-5 : 3.70 /km	Year 1-5 : 2.61 /km		BMTA
		After year 5 : 6.54 /km	After year 5 : 5.09 /km		
- Replacement	310,000 (every 5 years)	310,000 (every 5 years)	5,000,000 (at 10th year)		BMTA
- Other costs		29,030 /year		Annual registration tax, insurance fee	BMTA
Discount rate		6.87%			Prime Rate (MOR), BOT (2019)

Table 1. (Continue) Data and key assumptions

Costs of infrastructure (Baht)					
Capital cost			67,000,000		BMTA
Operating costs			38,400 /year/bus	Annual growth rate 6.5% per year	BMTA
Maintenance costs			First 10 years: 5% of capital cost, after 10 years: 10% of capita cost		
Discount rate		6.87%			BOT, 2019
	Diesel Bus	**CNG Bus**	**Electric Bus**	**Remark**	**Sources**
Costs of pollutants at 2019 price (per ton of emission)					
CO_2		3,189			
N_2O		289			
CH_4		25			
NOx		12,512			
PM (PM10 and PM2.5)		151,277			
VOC		6,238			
Benefits (per year)					
Ticket sold		1,872,450			BMTA
Other revenue		887,568			BMTA
Depreciation rate		10%			Assumption by authors

2.2.2 Benefits of alternative technologies

Reduction of GHG emission and other local pollutants is a benefit of adopting alternative bus technologies by replacing conventional diesel in the bus system. Therefore, the total amount of each emission from applying each vehicle technology was assessed by using Eq. (4). Furthermore, emission reduction of alternative bus technologies compared to conventional technology was also calculated. Avoided cost of emission reduction was considered as a benefit of the alternative technologies that can be calculated by Eq. (5).

$$E = \sum_{i=1}^{m}\sum_{j=1}^{n}[A_{i,j} \cdot EF_j] \quad (4)$$

where E is emission (g), A is total travel distance of vehicle (km) and EF is emission factor of fuel (g/km).

$$C_{avd} = \sum_{k=1}^{K} G_k \cdot C_{e,k} \quad (5)$$

where C_{avd} is total avoided cost of emission (THB), G is emission reduction (ton), C_e is cost of emission (THB/ton), k is type of emission, and K is number of emissions.

2.2.3 Net present value, internal rate of return, and benefit-cost ratio

The time value of money is an important approach, which plays a key role in making financial decisions. It is the assessment of cash flows and financial movements of different time periods in the same time area. This approach can be used to evaluate the effect of loss of value or of money over time [19]. Therefore, the NPV of all costs and benefits of vehicle and infrastructure of each bus technology was calculated by using Eq. (6).

$$NPV = \sum_{t=0}^{t} CF_t/(1+r)^t - C_0 \qquad (6)$$

where *NPV* is the net present value (THB), CF_t is net cash flows in a period of time (THB), C_0 is total initial capital cost (THB), *r* is discount rate (%), and *t* is time period (year).

IRR is normally used to estimate the profitability of potential investments of the technology. It is a discount rate *r* that makes the *NPV* of all cash flows equal to "zero". Formula to determine IRR can be presented in Eq. (7).

$$\sum_{t=0}^{t} FV_t/(1+r)^t - C_0 = 0 \qquad (7)$$

A benefit-cost ratio (BCR) is an indicator used to show the relationship between the relative costs and benefits of each technology option, as shown in Eq. (8). If a project has a BCR greater than "1.0", the project is expected to deliver a positive NPV of the investment.

$$BCR = \sum_{t=0}^{t} \frac{B_t}{(1+r)^t} / \sum_{t=0}^{t} \frac{C_t}{(1+r)^t} \qquad (8)$$

where *BCR* is the benefit-cost ratio, *B* is benefits of project (THB) and *C* is costs of project (THB).

2.3 Scenario Analysis

In this study, CBA was divided into two parts: financial analysis and economic analysis. Continued use of conventional diesel buses for the BMTA bus system was defined as a reference case (dBUS scenario) or business-as-usual (BAU). Substitution of conventional diesel buses with CNG and eBuses were determined as alternative scenarios, i.e. cBUS scenario and eBUS scenario, respectively.

In financial analysis, costs and benefits of each scenario were estimated and compared. In alternative scenarios, it was assumed that CNG and eBuses would replace 500 diesel buses every five years. The alternative technologies would then replace all 2,000 diesel buses by 2035. Mix of bus technologies in the bus system fleet until 2040 is illustrated in Figure 1. Charging stations of eBuses would be invested in every five years according to the number of vehicles. Additionally, the eBUS scenario was further divided into two scenarios: include and exclude investment of charging stations.

For economic analysis, costs and benefits of alternative scenarios (cBUS and eBUS) compared with reference scenarios (dBUS) were determined. Replacement of alternative technologies and infrastructure investment were assumed as well as in the financial analysis.

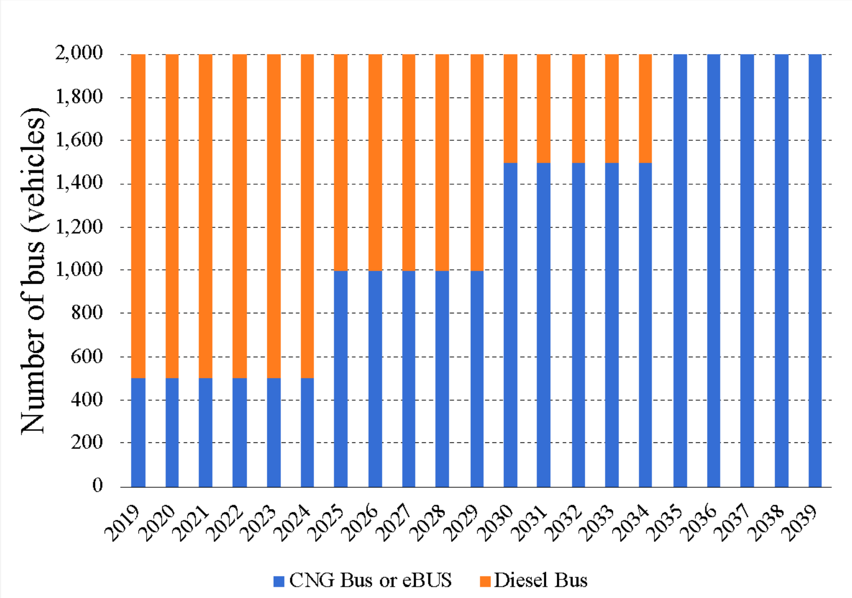


Figure 1. Number of bus technologies in alternative scenarios (cBUS and eBUS)

3. RESULTS AND DISCUSSION

3.1 Energy consumption and emissions

In Figure 2, the results of energy consumption presented that the diesel bus consumed 6,853 ktoe per year constantly. In cBUS scenario, when the CNG bus is introduced in the bus system the energy consumption grows to be 7,473 ktoe per year in 2020 and reaches 9,333 ktoe per year in 2035, respectively. This is because the energy efficiency of the CNG bus is lower than the conventional diesel bus. In contrast, for eBUS scenarios, the energy consumption would reduce when conventional diesel buses would be replaced by eBuses, due to their high energy efficiency. The energy consumption is expected to reduce by about 5,325 ktoe per year compared to dBUS scenario in next 20 years.

Figure 3 shows total emission by scenario and emission reduction in each scenario compared to dBUS scenario. The results present that alternative technologies could reduce emissions from the bus transport system compared to the conventional diesel bus, where eBus has higher potential of emission reduction than CNG bus. The VOC, NOx, PM and GHG emissions decrease for both scenarios at different levels. Substitution of eBuses and CNG buses could help to reduce GHG emission by about 272 kt of CO_2eq and 12 kt of CO_2eq in 2039, respectively. In cBUS scenario, by 2039, CNG buses could help to reduce VOC, NOx and PM about 1.00 kt of VOC, 0.26 kt of NOx and 52.92 t of PM, respectively, whereas eBuses could reduce about 1.03 kt of VOC, 3.90 kt of NOx and 67.52 t of PM.

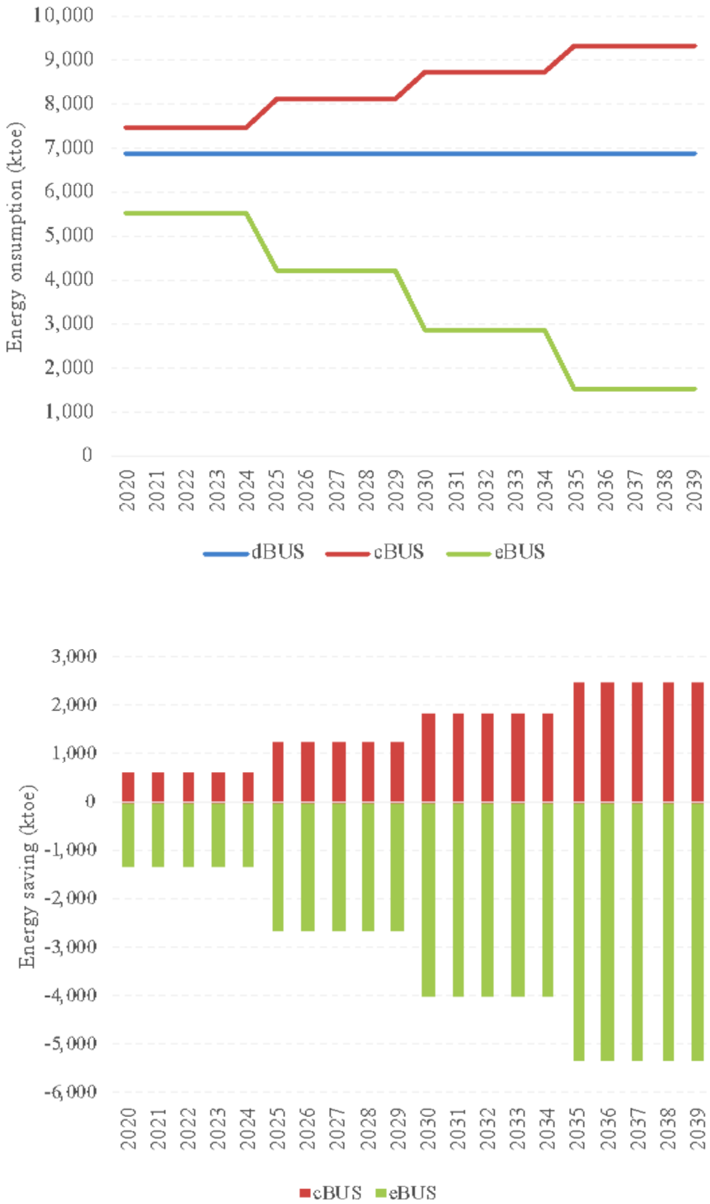
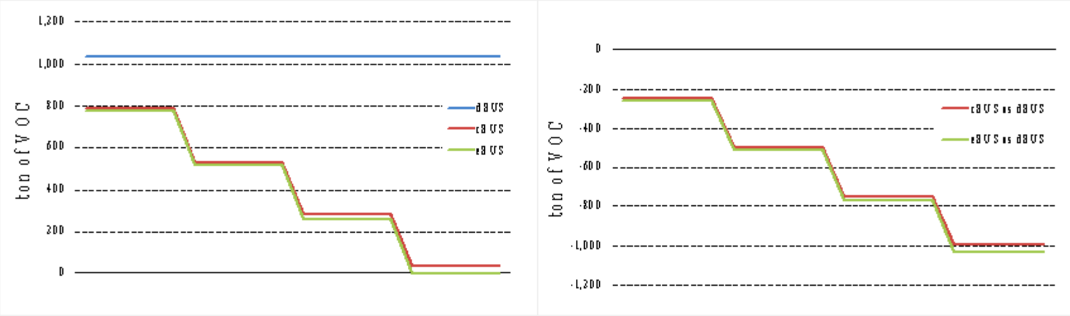
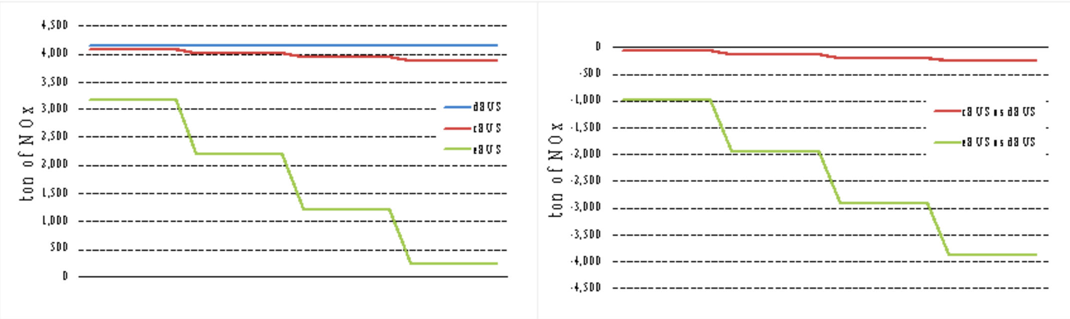


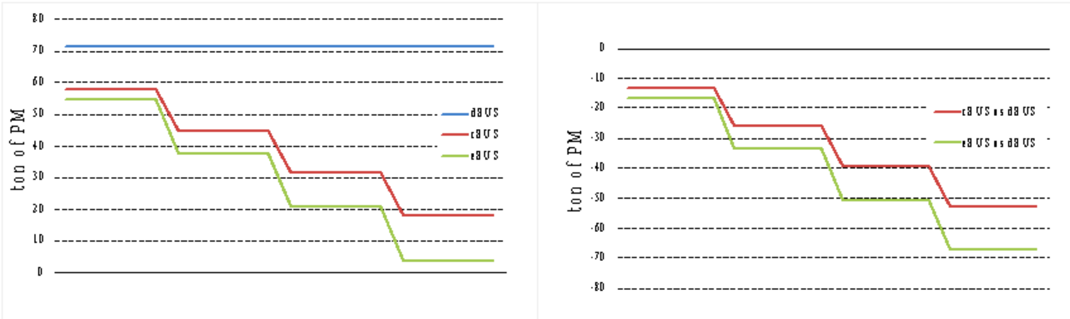
Figure 2. Energy consumption and energy saving by scenario



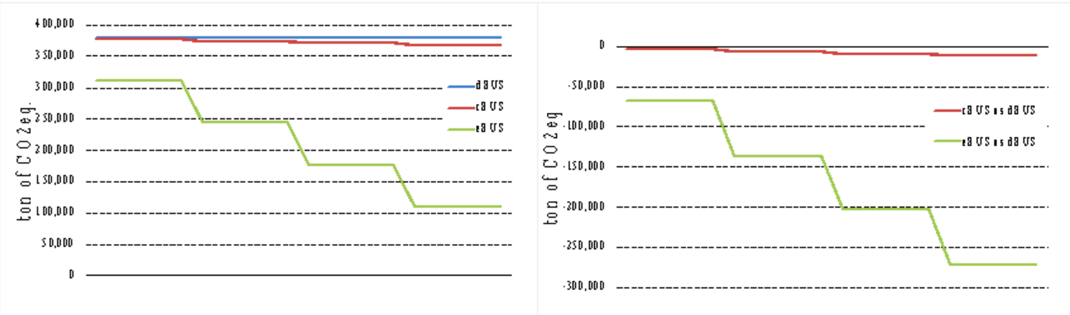
(a) GHG



(b) NOx



(c) PM



(d) VOC

Figure 3. Total emission and emission reduction of GHG, NOx, PM and VOC

3.2 Total cost of ownership

Figure 4 presents the estimation of TCO in each scenario. The NPV of capital cost (bus procurement and infrastructure investment) and annual costs such as fuel costs and O&M costs are also estimated by factoring with the 6.87% discount rate for 20 years.

In the dBUS scenario, the NPV of TCO is about 87,949 million THB or 24.10 THB/km for a functional unit of 250 km per day. The results also show that half of TCO is shared by fuel cost, while O&M and capital costs share about 43.22% and 6.75%, respectively. The TCO of the cBUS scenario is about 72,751 million THB (19.93 THB/km), where almost half of TCO in cBUS scenario is shared by O&M costs, whereas 44.48% and 6.34% are shared by fuel cost and capital cost, respectively. For the eBUS scenario, the TCO of 78,757 million THB (21.58 THB/km) is shared by O&M fuel, capital and infrastructure costs by around 44.96%, 32.86%, 17.35% and 1.04%, respectively.

Both cBUS and eBUS scenarios have lower TCO than that of dBUS scenarios accounting for 18% and 11%, respectively. This is because of lower fuel cost (operating cost) and maintenance cost of CNG and eBuses. CNG and electricity prices are relatively lower than diesel prices and maintenance costs of electric vehicles is about 35% lower than internal combustion engine vehicles. However, the eBUS scenario has the highest capital cost for vehicles due to the high upfront price of eBus. Moreover, the eBUS scenario has additional costs of capital cost and maintenance cost of infrastructure (charging station), while diesel and CNG buses require no investment in the infrastructure.

As can be inferred from the huge variations in cost components, highlighted in Figure 4, there is a definite need to reduce the high capital expenses of bus procurement and infrastructure investment. Most obviously it is also needed to raise the initial funds for the procurement for eBuses and charging station investment for eBus. The revenue model should target the other recurring expenses, mainly O&M and electricity. Even though the estimation is kept as the BAU case, definite savings can be accrued to procure a bus in the following cycle. There is great potential to explore a strong financial model, based on O&M and fuel savings of alternative technologies, especially eBus.

3.3 External costs of pollution

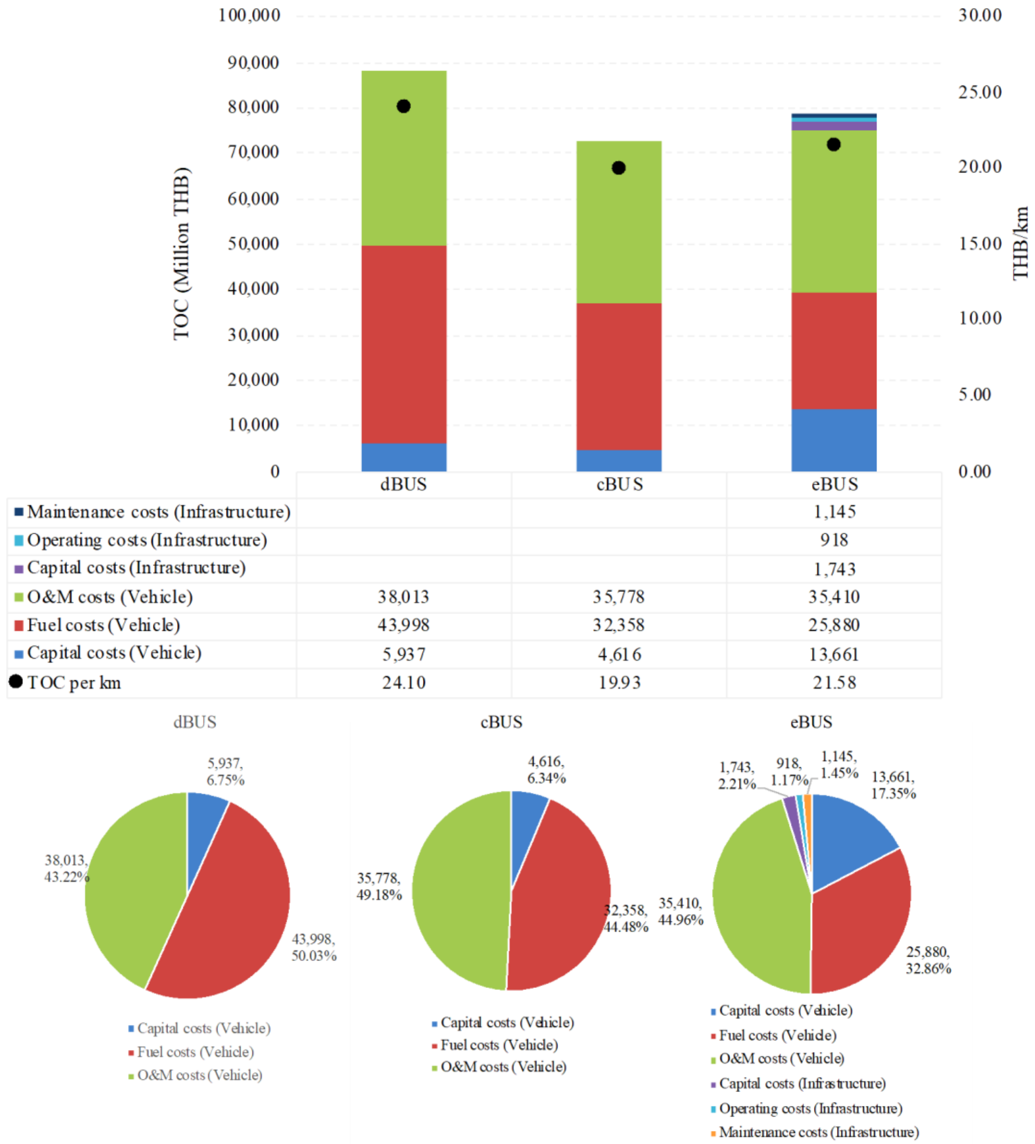
The NPV of external cost of environmental pollution is separately calculated in each scenario. Additional breakdown for external costs categories is presented in Table 2. Due to high energy consumption, the dBUS scenario has the highest total emission costs of 16,935 million THB among all scenarios. In cBUS scenario, substituting the conventional diesel buses with CNG buses could help to reduce emission costs by 387 million THB. With zero tail pipe emission of eBus and Thailand’s current national electricity grid mix, we could save environmental costs by about 6,914 million THB by substituting diesel buses with eBuses. The electricity grid mix will have a huge effect on the cost of environmental pollution. The saving cost will increase if the electricity grid mix has a higher share of renewable energy sources, i.e. solar power, wind power and biomass. In contrast, environmental costs could be less than the current situation if power plants use more fossil fuel for power generation.

The cost saved from the environmental impact by substituting alternative technologies for conventional diesel buses was considered as benefits of alternative scenarios (cBUS and eBUS scenarios) for further calculation of CBA in the next section.

3.4 NPV, IRR, BCR analysis results

In this study, the CBA is divided into two approaches: (1) financial analysis, which excludes external cost of environmental pollution and (2) economic analysis, which considers avoided cost of environmental pollutions as a benefit of alternative bus technologies, i.e. CNG bus and electric bus.

Figure 5 presents the NPV of all scenarios during the 20-year project lifetime. The results presented that the cBUS scenario will reach positive NPV at year 7.5, the eBUS scenario including and excluding the charging station costs will reach that at year 11.5 and 10.5, respectively, and the diesel bus will reach that at year 12.5.



	dBUS	cBUS	eBUS
Maintenance costs (Infrastructure)			1,145
Operating costs (Infrastructure)			918
Capital costs (Infrastructure)			1,743
O&M costs (Vehicle)	38,013	35,778	35,410
Fuel costs (Vehicle)	43,998	32,358	25,880
Capital costs (Vehicle)	5,937	4,616	13,661
TOC per km	24.10	19.93	21.58

Figure 4. NPV of TCO for all scenarios by cost category

Table 2. Net present value of external cost of pollution and reduction cost of cBUS and eBUS scenarios compared with dBUS scenario (THB)

Emissions	dBUS	cBUS		eBUS	
	External cost	**External cost**	**Saving cost**	**External cost**	**Saving cost**
CO_2	16,020	15,543	477	9,593	6,428
CH_4	0.009	0.007	0.002	0.004	0.005
N_2O	0.012	0.064	-0.052	0.005	0.007
VOC	86	39	46	38	48
NOX	686	662	24	323	363
PM	143	303	-160	67	76
Total	**16,935**	**16,548**	**387**	**10,020**	**6,914**

Note: All emissions costs were calculated on the wheel-to-wheel basis. Emissions related to battery production for electric vehicles (EV) were not included [20].

For economic analysis, the NPVs of costs and benefits during the project lifetime for all scenarios are presented in Figure 6. The results presented that the dBUS scenario will reach positive NPV at year 12.5, while the cBUS scenario will reach positive NPV at year 7. The eBUS scenario will take longer to reach positive NPV at year 8 that excludes charging station costs and at year 11 includes charging station costs.

The analysis of NPV, IRR and BCR for each bus alternative considered is shown in Table 3. According to the NPV method, the CNG bus value with a 6.85% discount rate is determined as the best financial option with 27,579 million THB. With the same discount rate, the eBus value without a charging station is 27,478 million THB, followed by the eBus value with a charging station at 24,116 million THB. Finally, the diesel bus with 11,938 million THB is the last financial option. Similarly, the IRR of the cBUS scenario is 37%, better than eBus (with and without charging station) with IRR values being 21% and 19%, respectively and IRR of diesel bus being 17%. However, the BCR for all cases was accepted as more than 1. The cBUS scenario is found to be the most financially viable option for alternative technology selection.

However, when the pollution reduction was accounted for the benefits, the NPV values for eBUS scenarios increased to be 30,587 and 34,393 million THB, while the cBUS scenario decreased to 26,966 million. Higher NPV of both cases of eBUS were also affected to increase the BCR and IRR of these scenarios.

Technology assessments, which ignore environmental externality, are incomplete because these are actual costs paid by people, not just the emitter [21]. When including externality costs (GHG emission and air pollution reduction) in this study, the impact of technologies was changed. The eBuses have lower external costs compared to diesel and CNG buses. Diesel and CNG buses have large externality because they have significantly higher air pollution damages than others. CNG buses emit higher GHG and air pollutants than diesel buses, contributing further to higher external costs. The ratio between external and ownership costs are 45%, 28% and less than 1% for diesel buses, CNG buses, and eBuses with charging stations, respectively.

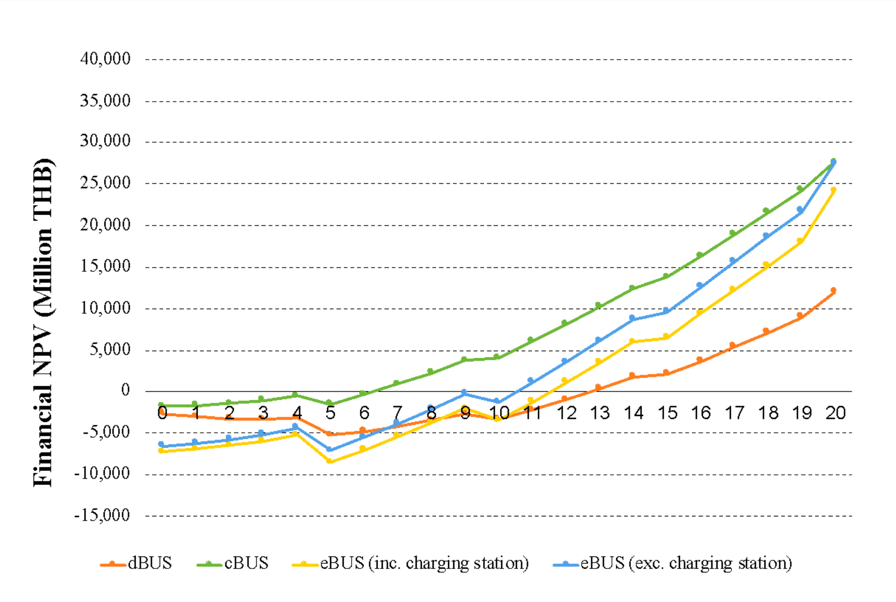


Figure 5. Net present values as 2019 THB for all buses considered during the project's lifetime excluding externality benefits

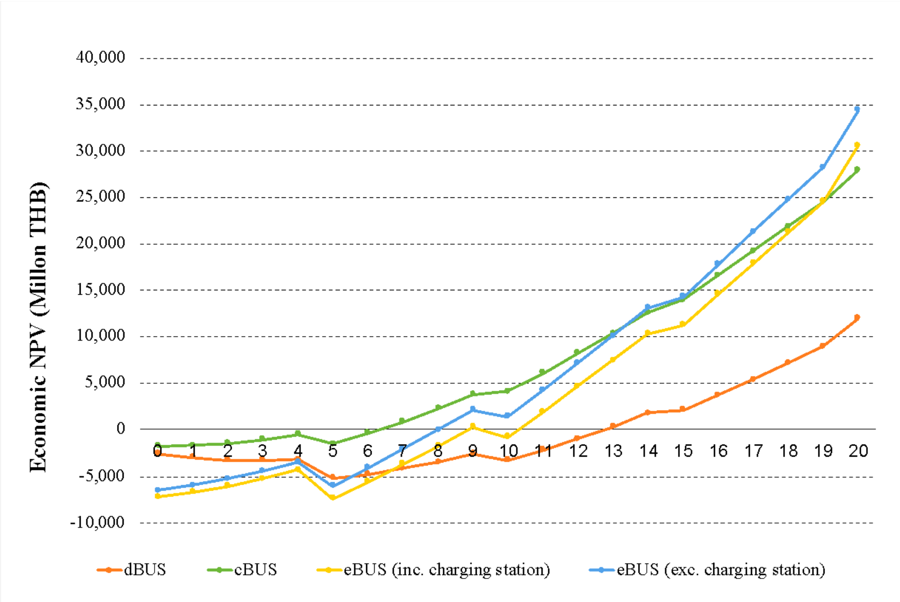


Figure 6. Net present values as 2019 THB for all buses considered during the project's lifetime including externality benefits

Table 3. Results of NPV, IRR, and BCR analysis

	dBUS	**cBUS**	**eBUS (Inc. charging station)**	**eBUS (Exc. charging station)**	**Evaluation Criteria**
Financial (Exc. externality)					
NPV (Million THB)	11,938	27,579	24,116	27,478	NPV <0, not accepted
B/C Ratio	1.13	1.38	1.31	1.37	B/C <1, not accepted
IRR	17%	37%	19%	21%	IRR < 6.85%, not accepted
Economics (Incl. externality)					
NPV (Million THB)	11,938	26,966	30,587	34,393	NPV <0, not accepted
B/C Ratio	1.13	1.38	1.39	1.46	B/C <1, not accepted
IRR	17%	37%	22%	24%	IRR < 6.85%, not accepted

4. CONCLUSIONS

Urban transport is a major contributor to local air pollution and greenhouse gas emission. Bus systems play an important role for urban transport systems for low- and middle-income cities in developing countries, because they offer the most affordable, cost-effective, space-efficient and environmentally friendly transport mode. However, with conventional ICE technology, buses are seem as energy inefficient vehicles and major sources of pollution in many developing countries. Electric vehicles seem to be the promising technology to replace the conventional bus technology for improving the energy efficiency and reducing air pollution in urban areas.

Results from this research present that, in Bangkok, the electric buses have lower cost-benefit than that of CNG buses from a financial point of view. The main reason is because of high investment costs in upfront price of electric buses and charging station costs. The results also show the operation costs with an increasing electrification rate, as fuel and maintenance costs are substantially lower than their diesel and CNG bus costs. The results prove that electric public bus operation expenses (including the charging station costs and battery replacement) are substantially less than the ones for the diesel and CNG buses. The eBus is better than the CNG bus when oil displacement and climate change impact were considered.

It can be seen that the price of buses and electric charge stations is the main reason that the investment cost of the electric buses project is higher than other types of buses. Therefore, in order to reduce the investment costs of electric buses, the government should implement policies and measures to reduce vehicle price of electric buses by subsidy for vehicle upfront price in short term period and promoting domestic electric vehicle industry, include tax incentives for entrepreneurs, reducing import tax on machinery, as well as promoting the research and development in long term. In addition, the study shows that electric bus technology can greatly reduce the environmental impact in urban areas. Therefore, the additional benefits of environmental impact reduction should be considered for electric bus promotion projects.

6. ACKNOWLEDGEMENT

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