Break-Even Analysis of Battery Electric Vehicles and Internal Combustion Engine Vehicles in the Indonesian Market

Halidah, Hafsah
Energy Conversion and Energy Conservation Research Center, National Research and Innovation Agency (BRIN)

Dwie Vannia Dianti
Energy Conversion and Energy Conservation Research Center, National Research and Innovation Agency (BRIN)

Eka Rakhman Priandana
Energy Conversion and Energy Conservation Research Center, National Research and Innovation Agency (BRIN)

Ganesha Tri Chandrasa
Energy Conversion and Energy Conservation Research Center, National Research and Innovation Agency (BRIN)

他

https://doi.org/10.5109/7236884

出版情報：Evergreen. 11 (3), pp.2415-2426, 2024-09. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan
バージョン：

Break-Even Analysis of Battery Electric Vehicles and Internal Combustion Engine Vehicles in the Indonesian Market

Hafsah Halidah*, Dwie Vannia Dianti, Eka Rakhman Priandana, Ganesha Tri Chandrasa, Dhea Amelia Rianjani, Nur Aryanto Aryono
Energy Conversion and Energy Conservation Research Center,
National Research and Innovation Agency (BRIN), Indonesia

*Author to whom correspondence should be addressed:
E-mail: hafsah.halidah@brin.go.id

(Received May 12, 2024: Revised July 26, 2024: Accepted August 1, 2024).

Abstract: The study explores the break-even points (BEP) for total cost of ownership of low passenger (4x2 type) Battery Electric Vehicles (BEVs) and Internal Combustion Engine (ICE) vehicles in the Indonesian market. Utilizing various assumptions, including vehicle type, annual mileage, charging modes, and fuel costs, the analysis incorporates factors such as battery prices, taxes, and government incentives. We employed a TCO model to analyze break-even points (BEPs) over a 7-year ownership duration. The Monte-Carlo simulation confirming BEPs of 5-7 years for high-power BEVs and 4-6 years years for low-power BEVs compared to their ICE counterparts. Over a 7-year TCO, battery costs play a minimal role due to manufacturer warranties, and even with a 15-year outlook, BEVs maintain a competitive TCO position, showcasing the impact of tax policies in favor of BEVs. Results indicate that lower power vehicles have relaxed thresholds, but inflation, BEV battery prices, and fuel subsidies can extend the BEP. Government incentives for BEVs under $40,000 are vital for market competition and achieving BEP, though they present long-term financial challenges. Further research on feebate programs could boost BEV adoption in Indonesia.

Keywords: battery electric vehicle; internal combustion engine; total cost of ownership; breakeven point; monte-carlo simulation; incentive; Indonesia

1. Introduction

The global effort to reduce environmental impact and dependence on fossil fuels, especially in the automotive sector, is crucial to global fuel consumption and emissions.[1)] Indonesia has proactively promoted the adoption of Battery Electric Vehicles (BEVs) as a sustainable transport alternative. This commitment is solidified through government regulations and policies, establishing a legal framework to expedite the widespread use of electric vehicles in the country.[2,3)]

Government initiatives have greatly impacted BEV adoption, with Norway leading at 95% EV sales, followed by Sweden at 60% and the Netherlands at 30%[4)]. Key drivers include early regulatory support and significant investments in EV charging infrastructure.

In August 2019, Presidential Regulation No. 55/2019 marked a pivotal shift in Indonesia's automotive industry towards electric vehicles, prioritizing environmental sustainability in road transport.[5)] In order to replace internal combustion engine (ICE) vehicles, with CO_2-free alternatives, BEVs are considered the most promising option.[6,7)] In the pursuit of decarbonization, the realization of the electric vehicle roadmap is set by the Indonesian government through the Ministry of Industry.[8)] However, BEVs face challenges in the current market due to their lower range and higher cost compared to ICE vehicles.[9)]

The price of electric vehicles is one of the factors that hinder the development of electric vehicles in Indonesia.[10,11)]. In 2022, the number of charging stations is 332 units, however, the number of registered electric cars has only reached 2,106 units.[12)] The Ministry of Industry has updated the regulation through Regulation No. 6 of 2022, emphasizing the Ministry's commitment to adapting to the industry's changing needs. The key changes in this update focus on the BEV target for 2025-2030 and the significance given to the assembly process and manufacturing in calculating local content. The adjusted BEV target reflects a more realistic outlook, considering the current pace of the BEV market (Table 1**).**

Table 1. Targets of Indonesian BEV Industry

Vehicle Type	Number of Units in Year		
	2025	2030	2035
≥4-wheel BEV	400,000	600,000	1,000,000
2 or 3-wheel BEV	6,000,000	9,000,000	12,000,000

Despite the higher upfront costs, a study found that the operational advantages of BEVs, including faster acceleration, higher energy efficiency, and lower maintenance expenses, contribute to cost recovery in approximately 5 years.[13)] Understanding the break-even point requires considering factors like manufacturer's suggested retail price, market prices for charging infrastructure, and non-rental revenue per vehicle.[14)]

Additional challenges arise from the production stage, particularly in terms of components that require large resources, such as high-voltage batteries.[15)] Through policy support and consumer-focused initiatives, Indonesia is set to contribute to global sustainability by promoting electric vehicle adoption and embracing decarbonization.

In this study, insights are derived on how incentives and regulations for BEVs have effectively lowered the overall cost compared to ICE vehicles in Indonesia. Additionally, the analysis delves into the pivotal factors contributing to this cost reduction through sensitivity analysis. The focus of this study is specifically on the low passenger vehicle type (4x2 Type), as detailed in the subsequent sections, being the most popular vehicle type in Indonesia.

The rest of this paper is organized as follows. Section 2 describes study area and current condition, consisting the vehicle market, cost of BEV, incentives for BEV, and cost to charge BEV. Section 3 provides the methods and assumptions used in the calculation. Section 4 provides results followed by a discussion. Section 5 concludes with a summary of the findings.

2. Indonesia's Current Situation

2.1. The Vehicle Market

Table 2 illustrates the vehicle market share in Indonesia for the years 2022 and 2023. The predominant vehicle type in Indonesia is the low passenger vehicle (4x2 Type), followed by affordable energy-saving cars and pickup trucks. The term "low passenger vehicle" generally refers to cars with small engine sizes, typically 1,500 cc (cubic centimeters). These cars are known for their affordability and fuel efficiency, popular choices for daily commuting.

The second category, "affordable energy-saving cars," includes low-cost, fuel-efficient vehicles that use gasoline. Pickup trucks, the third most popular type, are valued for their versatility and suitability for commercial use and rough terrains.

Table 2. Indonesian Vehicle Market Share in 2022 and 2023[16)]

Category			2022	2023*)
1	Sedan Type	Low	0.3%	0.3%
		Medium	0.5%	0.6%
		Luxury	0.0%	0.0%
2	4x2 Type	Low	46.7%	42.7%
		Medium	8.4%	9.6%
		High	0.0%	0.0%
		Luxury	1.9%	1.6%
3	4x4 Type	Low	0.1%	0.1%
		Medium	0.5%	0.7%
		Luxury	0.2%	0.2%
4	Bus		0.3%	0.4%
5	Pick up		14.0%	12.1%
6	Truck		8.9%	7.9%0
	Double Cabin 4x2 / 4x4		1.9%	2.8%
8	Affordable Energy Saving Cars (KBH2) 4x2		16.4%	20.8%
Total Market			100%	100%

*) Jan-Oct 2023

2.2. Cost of BEV passenger car

In Figure 1, we present the share of BEV sales in 2022 and 2023, based on processed data from Gaikindo[16)]. The conversion from Indonesian Rupiah (IDR) to USD is done as of December 2023 (1 USD = 15,526 IDR). The y-axis reflects prices in thousands of US Dollar (USD). In 2022, 78.2% of BEV sales were below the USD 40,000 price point, with only all variants of Wuling Air EV available at this range. The Wuling Air EV Long Range variant set the record with 6,859 sales.

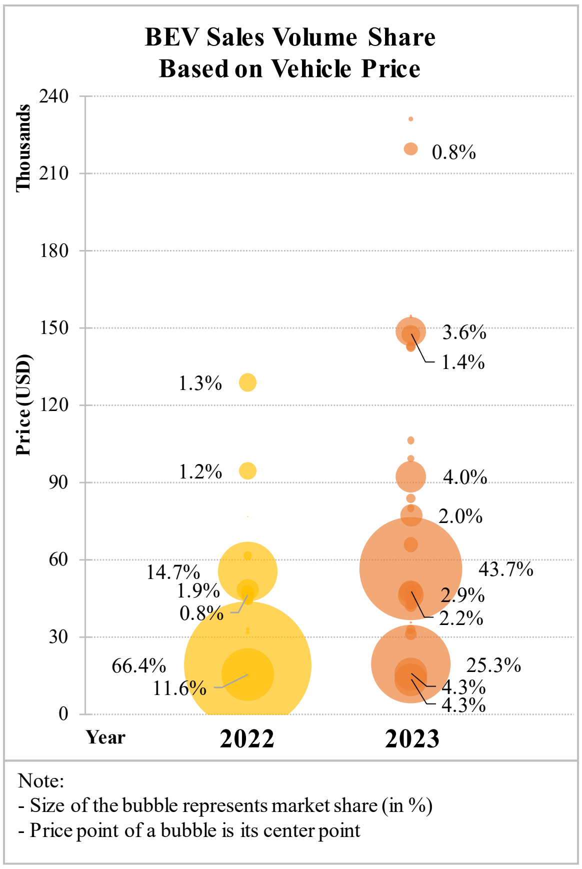


Fig. 1. 2022 and 2023 Indonesia's BEV Sales

The 2023 BEV market share appears to have shifted, with 50% of sales recorded between 40,000 – 60,000 USD and only 34.7% below 40,000 USD. The Hyundai Ioniq 5 Signature Extended holds the highest record with 5,172 sales. However, this fig is largely influenced by a specific market segment requiring vehicles with a high local content rate (a minimum of 40%) and high-end features. This market is driven by government offices and state-owned enterprises following Presidential Instruction no. 7 of 2022[17)], mandating the use of BEVs as operational vehicles nationwide. This highlights the significant impact of local content and the president's directive on officials, serving as key drivers for boosting the EV market.

Nevertheless, this does not accurately represent the price market demand for BEVs. In addition, the domestic car market demand in 2021[18)], shows that 75% of new car purchases in Indonesia fall under 30,000 USD. Therefore, the BEV price range targeting the middle market should be under 30,000 - 40,000 USD, emphasizing the need for additional variations in this range to enhance market competition.

2.3. BEV Incentives for Consumer

The incentives for BEV consumer in Indonesia are:

1) Luxury Goods Sales Tax (PPnBM) of BEV subjects to 0%

The government[19)] sets up a favorable framework to boost Low-Cost Emission Vehicles (LCEVs), particularly BEVs, in Indonesia. This regulation comes with a reduced luxury goods sales tax rate, specifically 0% for BEVs. Moreover, it introduces extra tax incentives for BEVs if there's an investment of over 5 trillion rupiahs in the BEV industry within two years of the investment or once the BEV industry starts commercial production. In contrast, traditional vehicles face much higher tax rates, ranging from 15% to 70%. The purpose of this tax incentive system is to support the development of sustainable transportation options and decrease the country's carbon footprint.

2) Exemption from BBNKB & PKB (for Renewable Energy-based Vehicles).

The government[20)] has officially waived vehicle ownership transfer fees (BBNKB) and vehicle taxes (PKB) for BEVs. This regulation applies for all BEVs except for retrofitted conversion BEVs (BEVs that were previously ICE vehicles). The PKB is paid every year, while BBNKB is only paid once by the vehicle owner.

3) Discount on additional power for home and home charging

The state electricity company (PLN) has been rolling out incentives for home electrical installation power. Single-phase customers only need to pay USD 54.75 for a maximum power capacity of 7,700 VA, while three-phase customers only need to pay USD 225.43 for a maximum power capacity of 13,200 VA. Moreover, PLN customers will receive a 30 percent discount on their electricity tariff to charge their BEVs at home, from 10 PM to 5 AM.

For BEV users to get the discount, PLN requires the home charging equipment to be connected with their charging management system, "ChargeIN". Then, PLN is able to detect the time when the charging happens. PLN also requires BEV users to install a different energy meter that connects exclusively to the home chargers. At the end of each month, the charging usage will be calculated and PLN would give some kind of bonus voucher that tops up energy to be used via the energy meter.

4) Financial aid program for the purchase of EVs with a domestic production base

The purchase of BEVs with Local Content Rate (LCR) higher than 40% can utilize a financial aid program. The subsidy quota for 4-wheeled BEV is 35,900 units and for 2-wheeled BEV is 200,000 units for the year 2023. The amount of subsidy is as follows:

- For 4-wheeled BEVs and electric buses, sales tax (PPN) are reduced from 11% to 1%[21)]
- For electric buses with local content less than 40% but more than 20%, PPN are reduced from 11% to 6%[21)]
- For 2-wheeled and retrofitted BEVs, there is a purchasing cost subsidy of USD 450.86 eligible for one ID number.[22)]

2.4. Electricity cost for BEV charging

BEV owners encounter two types of electricity costs: those associated with home charging and public charging. For home charging, the basic electricity tariffs set by PLN are shown on Table 3.

Table 3. Electricity tariff based on category and power capacity

Customer Category	Power Capacity (VA)	Tariff[*)] (USD/kWh)
Subsidized	450	0.03
	900	0.04
Non-Subsidized	900	0.08
	1,300 - 2,200	0.09
	3,500 ≤	0.11

[*)] as of October 2023

There are two customer categories: subsidized and non-subsidized customer. Subsidized customer of PLN refers to a residential electricity consumer who benefits from government subsidies on their electricity bills. The government provides subsidies to certain households to make electricity more affordable for them[23)]. The specific eligibility criteria and subsidy rates may be subject to government policies and can vary over time.

Due to the high price of BEV, we can assume that BEV owners are included in the non-subsidized category. Furthermore, as shown in the next section, the required power for portable charger which included in the vehicle purchase is around 2,000 Watt. Typically, middle to upper customers also equip their homes with air conditioning, which consumes more than 1,000 Watt. Therefore, we can assume that BEV owners subscribe to a power capacity above 3,500 VA, and the electricity cost for home charging will be USD 0.11/kWh.

For public charging, the tariff is governed by the government[24], set at USD 0.16/kWh x N, where N≤1.5. Additionally, BEV owners may face a service fee (load fee) – a fixed fee per charging session. The service fee for fast charging mode is a maximum of USD 1.42 per session, and for ultrafast charging mode, it's a maximum of USD 4.03 per session. These fees, determined by the Ministry of Energy and Mineral Resources, undergo review every 2 years or as needed.

3. Methodology

3.1. Breakeven Point Calculation

In the context of vehicle TCO, the BEP is when owning a vehicle becomes as cost-effective as alternative options. It marks the point where the financial investment in a specific vehicle type becomes comparable or more advantageous, serving as a crucial indicator for long-term cost-based decision-making.

To calculate the BEP of the comparation between BEV and ICE Vehicle ownership, first we need to calculate the TCO of the selected vehicles. The general formula of a TCO is:

$$TCO = CC + OC \tag{1}$$

CC : Capital Cost
OC : Operating Cost

Here, CC stands for all one-time expenses of vehicle ownership and can be defined as:

$$CC = MSRP - I_G - RV + C_{HC} + C_{PI} \tag{2}$$

$MSRP$: Manufacturer's suggested retail price
I_G : Government's incentive
RV : Resale Value
C_{HC} : Cost of home charging equipment
C_{PI} : Cost of additional power installation

Because of data availability, the manufacturer's suggested retail price $MSRP$ is directly subtracted with government's incentive I_G, resulting the On-The-Road (OTR) price, as shown in the next section. For Resale Value RV of ICE Vehicles, we use price data from Indonesian market. For BEV, we use data from Suttakul[25] and forecast it with any available BEV price data.

It is mentioned from section 2.3 that the PLN offers 30% home charging discount. In order to enjoy this discount, BEV owners must purchase an additional equipment C_{HC} which must be connected to PLN's charging management system. BEV owners are also assumed to increase their home power capacity, with the cost of C_{PI}, as the 89% of PLN customers still subscribe to <2,200 VA power capacity, as oppose to 2% subscribers of 3,500 VA ≤ [26].

The depreciation cost D is then defined as:

$$D = MSRP - I_G - RV \tag{3}$$

D: Depreciation cost

The operating cost OC, which is incurred annually through an ownership duration, is discounted at the discount rate r and written as:

$$OC = \sum_{n=1}^{N} \left(i_n\, C_M + i_n\, C_E + t_n\, T_V + b_n\, C_B^{d_n = w} \right) \times \frac{1}{(1+r)^n} \tag{4}$$

C_M : Cost of regular maintenance
C_E : Cost of energy consumption
T_V : Vehicle tax
i_n : Inflation factor at year n
t_n : Tax factor at year n
b_n : Battery price factor at year n
r : Discount rate
N : Ownership duration
n : Current year
$C_B^{d_n=w}$: Cost of battery, incurred once when travelled distance d in year n equals to warranty distance w

Cost of regular maintenance is usually stated by manufacturer's press release, and we forecast the annual cost based in the mileage per year. Cost of energy consumption denotes the kWh or fuel used per year. We multiply both of these with inflation factor to calculate the inflated costs.

Vehicle tax for each vehicles can be found on tax services website[27]. We multiply this tax with tax factor which assumed to be increased by 5% every year. The cost of battery only incurred once when distance travelled d on year n surpasses battery warranty distance w according to the manufacturer. This cost is weighted with the incline of battery price[28,29] which we forecasted over the years.

Regarding ownership duration, in Indonesia, people usually keep their vehicles for about 4-7 years. This brief ownership period is influenced by the frequent advancements in new car technologies, and during this short period, the resale value remains relatively high.

3.2. Sensitivity Analysis

For sensitivity analysis, we will investigate how the government incentives affect the BEP of BEV versus ICE. There are 3 types of government incentives being considered: the reduction on luxury tax, sales tax, and vehicle tax. In reality, the determination for these taxes have to consider factors such as import value, export value, replacement cost and so on. For this analysis, we use the following equation to approximate the Sales Tax S_{Tx} and

Luxury Tax L_{Tx} calculation:

$$S_{Tx} = s \times (MSRP + L_{Tx}) \quad (5)$$

$$L_{Tx} = l \times MSRP \quad (6)$$

$$OTR = MSRP + L_{Tx} \quad (7)$$

S_{Tx} : Sales Tax
s : Sales Tax percentage
L_{Tx} : Luxury tax
l : Luxury tax percentage
OTR : On the road vehicle price

We also aim to examine the impact of fuel and electricity prices (for home charging) on the BEP of BEVs compared to ICE vehicles. By analyzing various price scenarios, we will identify threshold levels at which these prices can influence consumer decisions toward purchasing BEVs. This study will provide insights into how government policies on fuel and electricity pricing can encourage the adoption of BEVs.

3.3. Assumptions

Table 5 denotes the general assumptions of the total cost of ownership calculation. Each vehicle is assumed to travel 15,000 km per year (41 km/day). The charging tariffs for BEV are according to the previous sections. Public and home charging are assumed to be used at a ratio of 20% and 80%, respectively, which is similar to usage patterns in the United States[30].

The 30% home charging discount by PLN is used in calculation. The price for home charging equipment is also listed, along with additional cost of power installation. There are 2 fuel prices considered, gas and diesel. Gas price is based on Pertamax 92's price as of October 2023, while diesel is based on Pertamina Dex's. For discount rate, we use 6%, and the inflation rate is set to be 3%[31]. For vehicle tax increase, we estimate a 5% increase per year, from available data on tax services website.

Table 5. General Assumptions

No.	Item		Value	Unit
1	Distance travelled per year		15,000	km
2	Public charging tariff		0.16	USD/kWh
3	Public charging service fee		4.03	USD/kWh
4	Home charging tariff		0.11	USD/kWh
5	Home charging discount		30%	
6	Home charging equipment		966.12	USD
7	Additional home power installation		54.75	USD
8	Fuel price	Gas	0.86	USD/L
		Diesel	1.09	USD/L
9	Discount rate		6%	
10	Inflation rate		3%	
11	Vehicle tax increase		5%	Per year
12	Ownership duration		7	year

Table 4 shows the detailed assumptions used on each

Table 4. Detailed assumptions for each vehicle

	BEV				ICE Vehicle			
Vehicle	**Hyundai Ioniq 5 signature extended**	**Wuling AirEV Long Range**	**MG 4 EV**	**Citroen Ec3**	**Toyota New Rush 1.5 GR Sport**	**Honda New HR-V SE**	**Pajero Sport Dakar Diesel**	**Honda CR-V Turbo Prestige**
OTR Price (USD)	51,655	19,290	41,859	25,441	18,775	26,800	40,313	43,128
HP	214	41	168	94	104	119	179	190
Torque (Nm)	350	110	250	150	136	145	430	240
Efficiency	8.7 km/kWh	10.0 km/kWh	9.0 km/kWh	11 km/kWh	10.5 km/l	14.9 km/l	8.2 km/l	8 km/l
Portable Charger Power	1.76 – 2.64 kW	2.2 kW	1.32 – 11 kW	3.3 kW				
Battery/tank Capacity	72.6 kWh	26.7 kWh	51 kWh	29.2 kWh	45 L	40 L	68 L	58 L
Battery price (USD)	25,763	6,441	20,929 [1)]	12,721 [1)]				
Battery Warranty (km)	160,000	120,000	160,000	140,000				
Luxury Tax	0%				20%	20%	25%	25%
Sales Tax	1%				11%			
Vehicle Tax[2)] (USD)	0				262	354	592	552

1) 50% of the vehicle price
2) Tax incurred in the first year of ownership, increased 5% yearly

vehicle. The vehicles are selected from the low passenger (4x2) type with highest sales percentage[16], with the exception of the Citroen Ec3 (BEV). The Citroen Ec3 has been recently launched, and though it hasn't registered any sales yet, its potential success is anticipated based on its price point, specifications, and positive presale reviews. Moreover, Pajero Sport Dakar and Honda CR-V are selected because they have similar horsepower (HP) with the BEV counterparts (Ioniq and MG 4 EV).

All vehicle prices are OTR prices in Jakarta, inclusive of Luxury Goods Tax (PPnBM) and Sales Tax (PPN). This table displays the government-applied tax incentives. Additionally, the Vehicle Tax (PKB), set at 0% for BEVs, is also considered. Estimated battery prices for MG 4 EV and Citroen ec3 are 50% of the vehicle price.

In order to ease vehicle owners' concerns over the high price of battery price, the BEV manufacturers give warranty on the battery, which differs for each vehicle. This warranty assures owners that they need not be concerned about purchasing a new battery until a certain distance is covered. The details of these battery warranties are also outlined in Table 4.

3.4. Monte Carlo Simulation

As the calculation spans multiple years, it is essential to consider various scenarios. There are four parameters that previously considered as constant, that may change annually: the inflation rate, the vehicle tax increase rate, the battery price decrease rate, and the fuel price increase rate. We employ 1,000 Monte Carlo simulations, using a normal distribution for each parameter, to understand how the BEP will be affected by different values of these parameters.

We analyze the historical data for each parameter to calculate the mean and standard deviations needed to run the simulation (Table 6). By simulating a large enough number of scenarios, we can assess the impact of these parameters' variability on the BEP, providing a more comprehensive view of potential outcomes.

Table 6. Parameters used in the Monte Carlo Simulations

Parameter	Mean	Standard Deviation
Inflation rate[31]	7.14%	0.04
Vehicle tax increase rate	5%	0.03
Battery price decrease rate[28,29]	9%	0.12
Fuel price increase rate[32]	9%	0.31

4. Results and Discussion

The components of the TCO for ICE vehicles and BEVs differ in several aspects. For the cost of capital (CC), ICE owners do not receive government incentives, unlike BEV owners. Additionally, owning an ICE vehicle does not involve costs for home charging equipment or additional power installations at home. In terms of operating costs (OC), BEV owners are exempt from vehicle tax, while ICE owners do not need to consider the cost of purchasing a battery. In addition, BEVs typically have lower maintenance costs compared to ICE vehicles because of their simpler battery-electric motor systems.[33]

The mapping of these differences is summarized in Table 7.

Table 7. TCO component mapping of BEV and ICE Vehicles

	CC	$MSRP$	I_G	RV	C_{HC}	C_{PI}
BEV		✓	✓	✓	✓	✓
ICE		✓		✓		
	OC	C_M	C_E	T_V	C_B	
BEV		✓	✓		✓	
ICE		✓	✓	✓		

Figure 2 shows the TCO for each selected vehicle over a 7-year ownership period. The TCO for Ioniq 5 BEV is still higher than any TCO from the selected ICE Vehicles. On the other hand, MG 4 EV shows lower TCO compared to both Pajero Sport and Honda CR-V. In lower power class, the Wuling Air EV shows the lowest TCO, followed by Toyota New Rush, Citroen ec3, and Honda New-HRV.

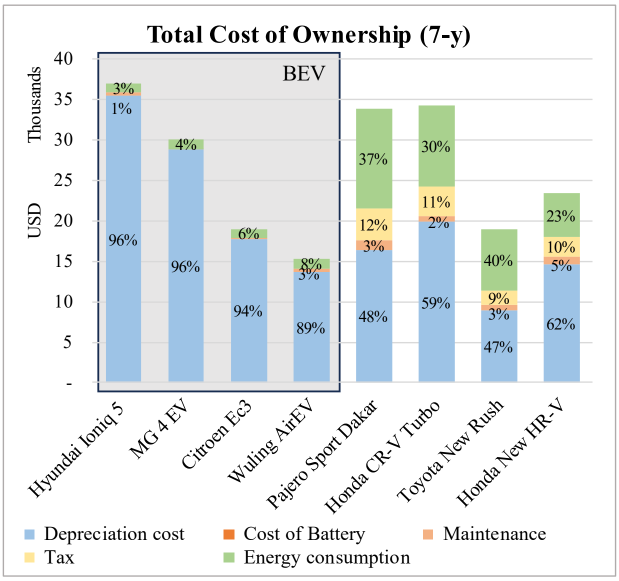


Fig. 2. 7-year TCO of selected vehicles

The TCO of BEV is dominated by its depreciation cost, account for 89-96%, as also apparent from another studies[34,35]. Penmetsa[36] discovered that 78% of fiscal incentives for electric vehicles in various countries are in the form of purchase subsidies. Many studies indicate that these subsidies play a crucial role in promoting the adoption of electric vehicles, because the benefit is provided upfront.

From Figure 2, it is apparent that the cost of battery did not contribute to the 7-year TCO. This is due to the BEV manufacturer's battery warranty. However if we prolong the ownership duration to 15 years, using Suttakul's[25] Resale Value assumption of 8% (BEV) and 15% (ICE) and forecast cost of maintenance, we see the impact of battery cost in Fig. 3.

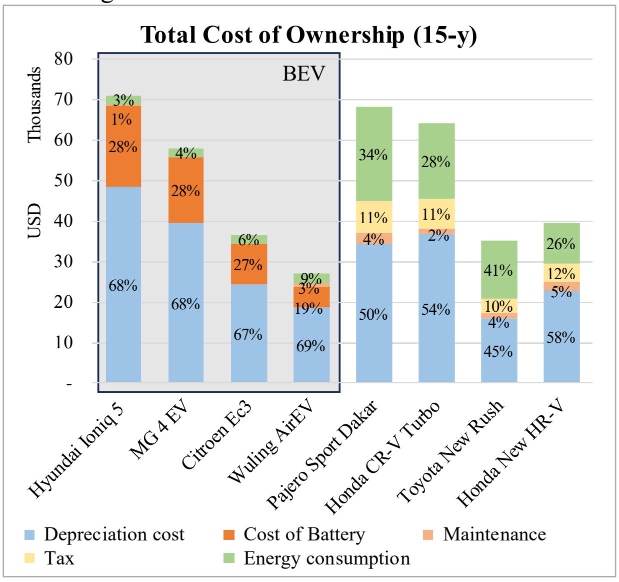


Fig. 3. 15-year TCO of selected vehicles

From Figure 3, we see 19-28% contribution from battery cost in the TCO of BEVs. However, the TCO relative positions remain the same as the 7-year TCO. The battery cost is compensated by the ever-increasing cost of maintenance, tax, and cost of energy consumption from the ICE vehicles.

For the BEP Calculation, we show the 7-year TCO as a graph of cumulative cost over the years, as shown in Fig. 4. The dashed lines are BEVs, while the solid lines are ICE vehicles. In Figure 4, we see BEPs of the higher power vehicles, with 10,000-20,000 USD differences in the depreciation cost, are around 5 - 6 years. On lower power vehicles, with 3,000-4,000 USD differences, the BEPS are around 3-5 years. These BEPs are summarized on Table 8.

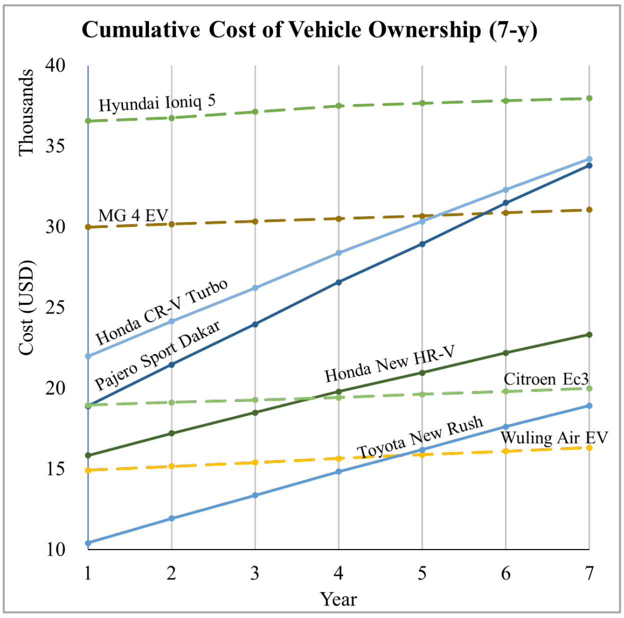


Fig. 4. Cumulative Cost of 7-year Vehicle Ownership

As seen on the TCO calculation before, the TCO of Hyundai Ioniq 5 is higher than any BEV selected. This is due to the fact that this Ioniq is the highest variants (i.e., most expensive) of Ioniq 5. On lowest variant of Ioniq 5, the BEP is 5.86 years.

Table 8. BEV and ICE 7-year BEPs on different vehicle power

BEV	ICE	BEP
MG 4 EV	Honda CR-V	5.17
MG 4 EV	Pajero Sport Dakar	5.72
Citroen ec3	Honda New HR-V	3.75
Wuling AirEV	Toyota New Rush	4.62

The 15-year TCO as a graph of cumulative cost over the years is shown on Fig. 5. Higher depreciation costs are expected due to long period of ownership of all vehicles. As seen from the previous TCO calculation, the TCO position between the vehicles are unchanged, even with the additional battery cost incurred.

The TCO of Hyundai Ioniq 5 has actually met with the TCOs of Pajero Sport Dakar and Honda CR-V at around 6.5 years. However, by year 11 it increases again due to battery costs. For TCO of Citroen Ec3 vs Honda New HR-V, the BEP is 11.15 years, which is after the purchase of new battery. The summary of BEPs is shown in Table 9.

Table 9. BEV and ICE 15-year BEPs on different vehicle power

BEV	ICE	BEP
MG 4 EV	Honda CR-V	11.23
MG 4 EV	Pajero Sport Dakar	2.61
Citroen ec3	Honda New HR-V	12.30
Wuling AirEV	Toyota New Rush	3.05

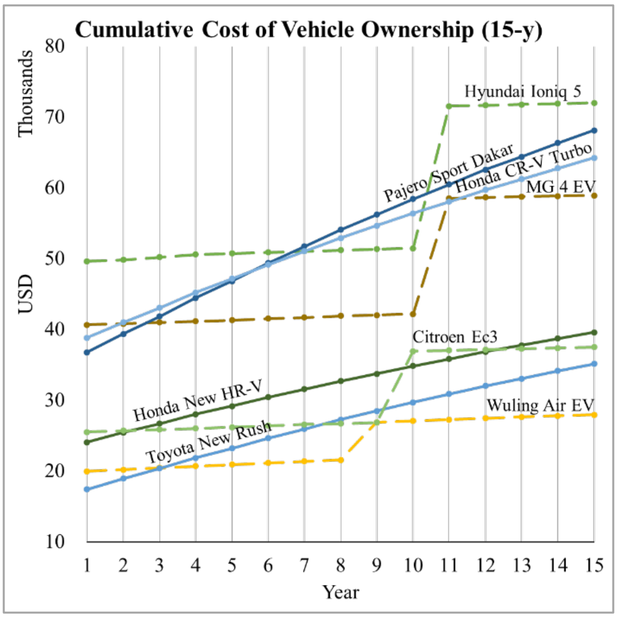


Fig. 5. Cumulative cost of 15-year Vehicle Ownership

To consider various possible scenarios, we run 1,000 Monte Carlo simulations on the 7-year BEP calculations.

Table 10 shows the resulting mean, standard deviation, and the maximum BEP with 80% probability. These results confirm the previous finding, that higher power vehicles have a BEP of 5-7 years, while lower power vehicles have a BEP of 4-6 years.

Table 10. Monte Carlo Simulations on 7-year BEP Calculations

BEV	ICE	Mean	Std Dev	BEP* 1)
MG 4 EV	Honda CR-V	5.3	0.65	5.83
MG 4 EV	Pajero Sport Dakar	5.9	0.61	6.33
Citroen ec3	Honda New HR-V	3.7	0.48	4.13
Wuling AirEV	Toyota New Rush	4.9	0.74	5.43

1)BEP* refers to the maximum BEP with 80% probability

We ran 15-year BEP simulations, shown in Table 11. Higher power vehicles have BEPs of 6-8 years, and lower power vehicles have BEPs of 5-10 years. This is due to battery purchases in years 9-11. Lower power ICE vehicles are more fuel-efficient and use cheaper gas instead of diesel.

Table 11. Monte Carlo Simulations on 15-year BEP Calculations

BEV	ICE	Mean	Std Dev	BEP* 1)
MG 4 EV	Honda CR-V	7.2	4.27	7.44
MG 4 EV	Pajero Sport Dakar	7.1	3.03	6.99
Citroen ec3	Honda New HR-V	6.0	4.72	9.94
Wuling AirEV	Toyota New Rush	5.6	2.30	5.98

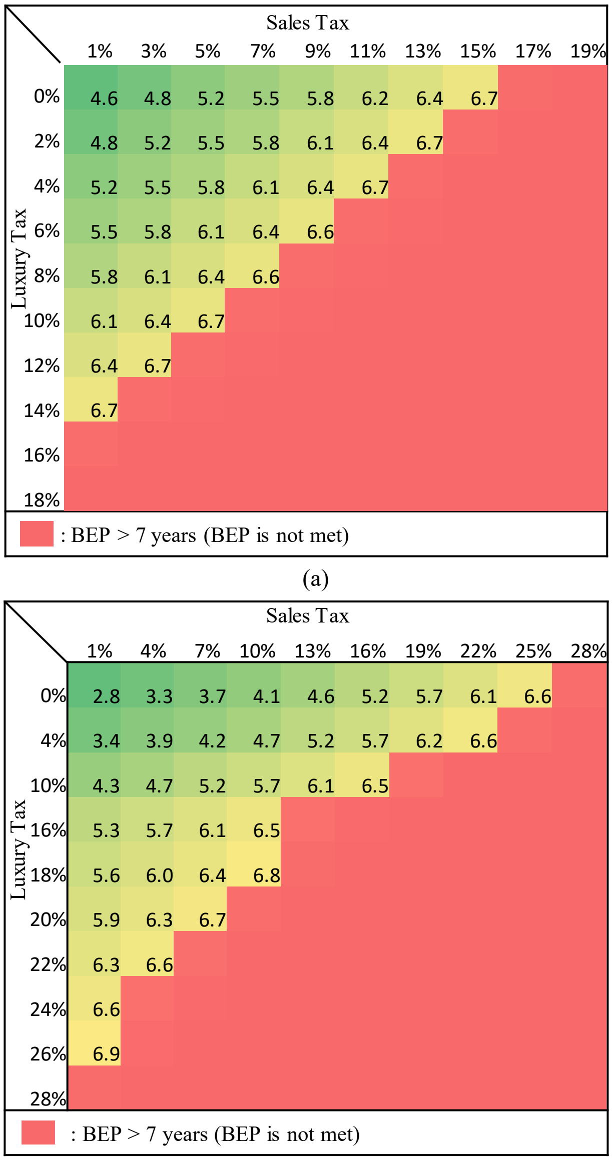
1)BEP* refers to the maximum BEP with 80% probability

Further, to investigate how the government incentives affect the BEP of BEV versus ICE, we perform sensitivity analysis. The analysis is split between higher- and lower-power vehicles, with assumptions for higher-power vehicles derived from MG 4 EV and Honda CR-V parameters, and those for lower-power vehicles based on Citroen EC3 and Honda New HR-V.

There are 3 types of government incentives being considered: luxury tax, sales tax, and vehicle tax. As both luxury and sales tax incentives target the depreciation cost, we first analyze the sensitivity of the BEP to those taxes. We consider the sales tax as the horizontal axis, and luxury tax as the vertical axis. The BEP is marked with the color scale ranging from red for over 7 years (i.e, BEP is not met), to yellow and green for minimum BEP calculated. Fig. 6 displays the sensitivity results.

We can clearly see the impact of these tax incentives on the BEP. Without incentives, sales tax would be 11% and luxury tax would be around 22-25%. On both higher- and lower-power BEV, this would cause BEP is not met. For higher-power BEV, the maximum possible tax imposition would be 15% sales tax or 14% luxury tax. For lower-power BEV it is 25% sales tax or 26% luxury tax.

For sensitivity analysis on vehicle tax, we compare this tax imposition to both BEV and the ICE counterparts. In average, the selected ICE vehicle tax on the first year of ownership is 1.37% of the OTR price. The results are shown in Fig. 7.

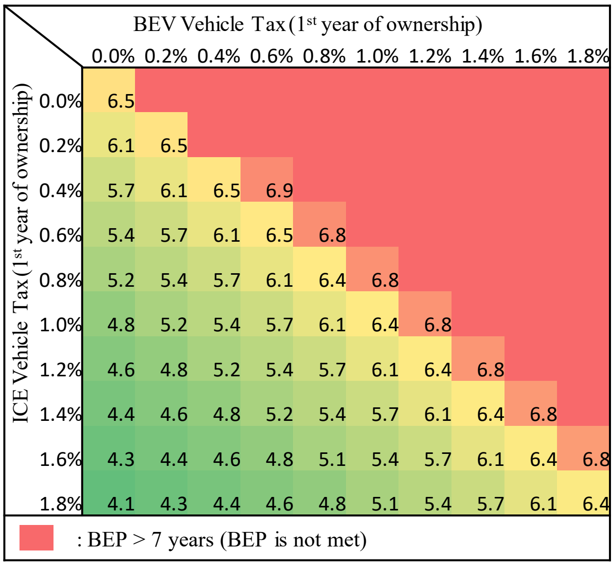


(b)

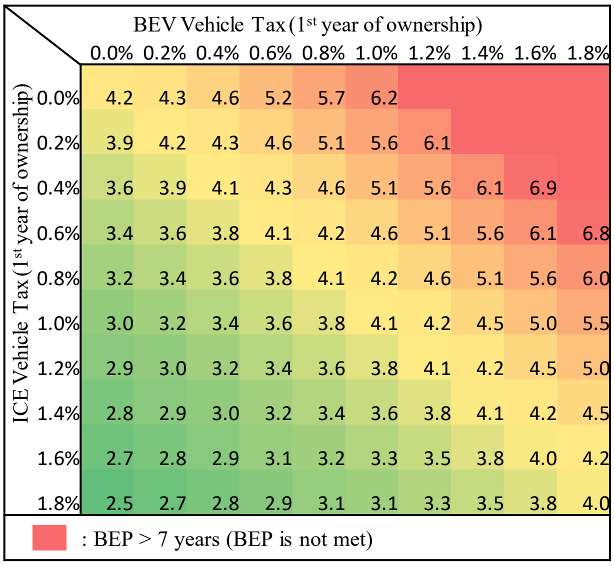
Fig. 6. Sensitivity of BEP due to sales tax and luxury tax on (a) higher-power, and (b) lower-power BEV

For higher-power vehicles, despite similar taxes on both BEV and ICE, BEV owners can achieve a BEP of less than 7 years. This becomes even more apparent for lower-power vehicles, where the BEV may be imposed with higher vehicle taxes than the ICE. These results highlight that the BEP is not overly sensitive to variations in vehicle tax.

In addition, we also investigate how vehicle price and travel distance affect the BEP. We consider the annual distance of vehicle usage as the horizontal axis, and vehicle price difference compared to the BEV price as the vertical axis. The BEV price is assumed to be higher than the ICE vehicle price.



(a)

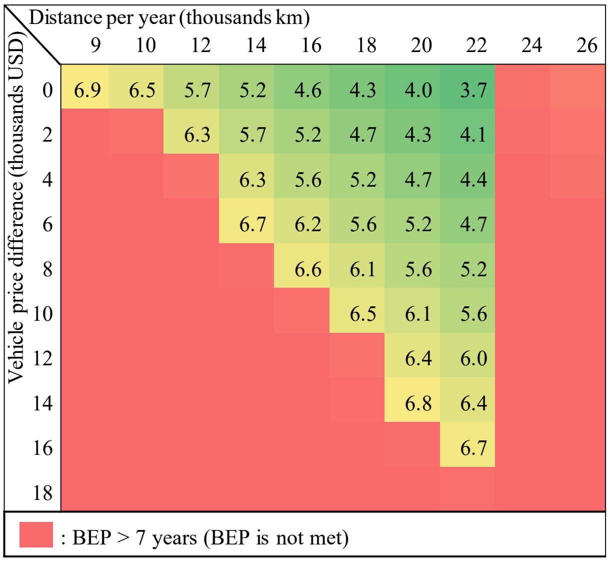


(b)

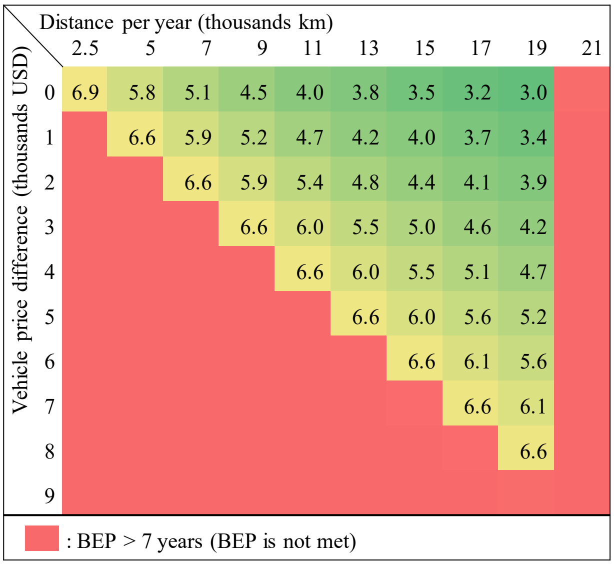
Fig. 7. Sensitivity of BEP due to vehicle tax imposed on BEV and ICE on (a) higher-power, and (b) lower-power vehicles

According to Fig. 8 (a), even if the BEV is 16,000 USD more expensive than its ICE vehicle counterpart, the owner is still likely to reach a BEP in less than 7 years, particularly with a high annual usage distance of 22,000 km. However, if the annual usage is only 9,000 km (approximately 25 km/day), the BEV cannot be more expensive than the ICE vehicle counterpart.

Figure 8 (b) displays the results of low-power BEV vs ICE Vehicle. Here we see a shorter range of price difference (0-8,000 USD), allowing less BEV options for owners to compare. The maximum annual usage distance is also lowered to 19,000 km, which is approximately 52 km/day. In general, having a higher usage distance tends to result in a lower BEP. However, this also leads to more frequent battery usage, potentially surpassing the manufacturer's warranty sooner.



(a)



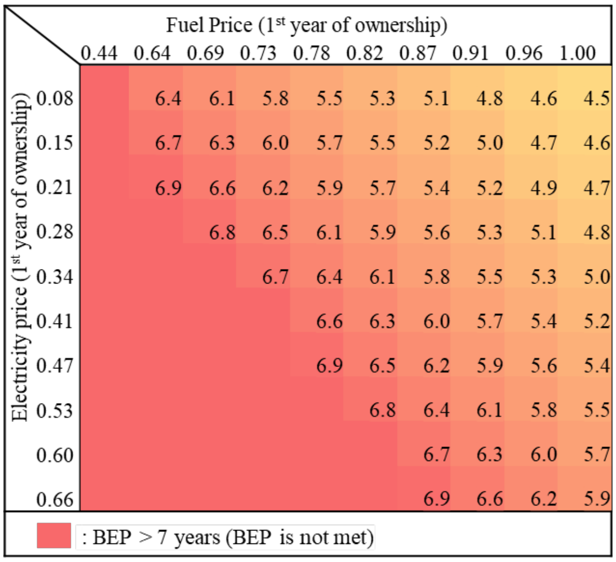
(b)

Fig. 8 Sensitivity of BEP due to price and travel distance on (a) higher-power, and (b) lower-power vehicles

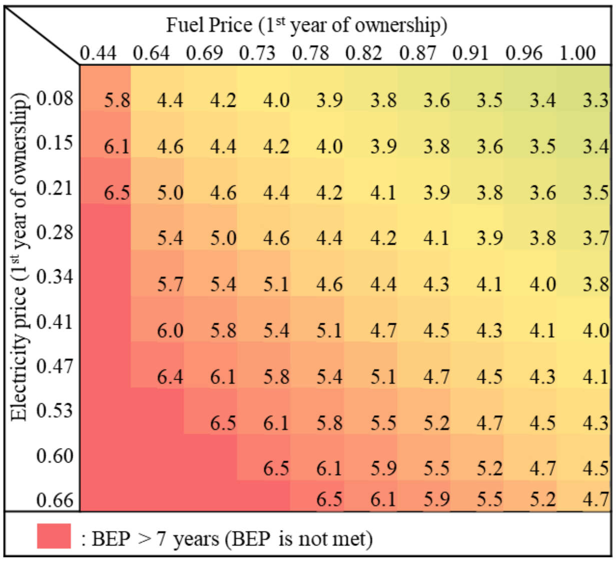
These results show that purchase subsidies are clearly crucial to the BEP, and i.e., one of the deciding factors of BEV adoption. Yet, offering purchase subsidies is financially demanding for the government, necessitating a revenue-neutral mechanism to align with long-term goals. Feebates programs are often recommended for sustained implementation[37)]. In a feebate system, buyers of low-fuel-efficient cars face fees, while those opting for fuel-efficient cars receive subsidies. Achieving an effective feebates program involves balancing the revenue generated from fees with the money spent on subsidies, even if the proportions are unequal.

Lastly, we examine the impact of fuel prices for ICE vehicles and electricity tariffs for home charging BEVs. We analyze fuel price sensitivity, ranging from the current cheapest fuel[38)], subsidized biosolar at 0.44 USD/liter, to

Pertamina Dex at 1 USD/liter. For electricity, the non-subsidized tariff is ranging from 0.08 – 0.15 USD/kWh but we consider the range up to 0.66 USD/kWh to determine the BEP threshold. Fig. 9 shows the results.



(a)



(b)

Fig. 9. Sensitivity of BEP due to fuel and electricity prices on (a) higher-power, and (b) lower-power vehicles

From Figure 9, it is apparent that with the current cheapest fuel and lowest tariff, the higher power vehicle resulted BEP not met. However, this fuel is the least used. The most commonly used fuel is Pertalite[39], priced at 0.69 USD/liter. Users of Pertalite can still achieve a BEP of under 7 years, though only marginally (6.1-6.8 years). On lower power vehicles though, they could still enjoy under 5 years of BEP if owning a BEV.

For higher power vehicles, with the current fuel price at 0.86 USD/liter, the maximum electricity tariff for BEVs to remain competitive is 0.64 per USD/kWh. If the electricity price is 0.11 USD/kWh, the minimum fuel price for ICE vehicles to maintain a cost advantage is 0.61 USD/liter. Furthermore, if the home charging tariff equals the public charging tariff at 0.16 per USD/kWh, the minimum fuel price for ICE vehicles is 0.62 USD/liter. Results for higher and lower power vehicles in comparison are presented in Table 12.

Table 12. Thresholds for fuel price vs tariff sensitivity analysis

Condition	Threshold	High Power Vehicles	Low Power Vehicles
Current fuel price (0.86 USD/l)	Max electricity tariff	0.64 USD/kWh	0.81 USD/kWh
Current electricity tariff (0.11 USD/kWh)	Minimum fuel price	0.61 USD/l	0.33 USD/l
Electricity tariff = public charging tariff (0.16 USD/kWh)	Minimum fuel price	0.62 USD/l	0.37 USD/l

The results reveal more relaxed thresholds for lower power vehicles. However, our previous Monte-Carlo analysis indicates that factors such as inflation, BEV battery prices, and fuel prices can significantly prolong the BEP if ICE vehicles in this category are fuel-efficient and the government continues to subsidize their fuel.

5. Conclusion

In our study, we developed a TCO model for low passenger BEVs and ICE vehicles in Indonesia. Analyzing factors like power, prices, mileage, charging, and fuel costs, our results show that BEP for BEV ownership is around 5 years for high-power vehicles and 4 years for low-power vehicles, both with a 7-year ownership duration. We conducted 1,000 Monte Carlo simulations, confirming BEPs of 5-7 years for higher power vehicles and 4-6 years for lower power vehicles. Extending to 15 years, BEPs are 6-8 years for higher power and 5-10 years for lower power vehicles, influenced by battery purchases and fuel efficiency. While higher power vehicles struggle with the cheapest fuel and lowest tariff, they can achieve a BEP of 6.1-6.8 years with low-cost, most-used fuel Pertalite at USD 0.69/liter. For BEVs to remain competitive, electricity tariffs must stay within specific thresholds relative to fuel prices. Our study underscores the need for government incentives, especially for BEVs under $40,000, to enhance market competition. Although battery costs don't significantly impact a 7-year TCO due to warranties, they do in a 15-year TCO, yet BEVs can still be cheaper than ICE vehicles. Purchase subsidies are crucial for achieving the BEP and promoting BEV adoption, but they pose long-term financial challenges for the government. Further studies on feebate programs could support BEV adoption targets in Indonesia. The results show relaxed thresholds for lower power vehicles, but inflation, BEV battery prices, and fuel subsidies for efficient ICE vehicles can significantly prolong the BEP.

References

1) G. Graditi, G. Langella, C. Laterza, and M. Valenti, “Conventional and electric vehicles: A complete economic and environmental comparison,” in: 2015 Int. Conf. Clean Electr. Power ICCEP, 2015: pp. 660–665. doi:10.1109/ICCEP.2015.7177590.
2) C. Harsito, Mufti Reza Aulia Putra, Daniel Aquino Purba, and T. Triyono, “Mini review of thermoelectric and their potential applications as coolant in electric vehicles to improve system efficiency,” *Evergreen*, **10** (*1*) 469–479 (2023). doi:10.5109/6782150.
3) M. Nizam, Mufti Reza Aulia Putra, and Inayati, “Heat management on lifepo4 battery pack for eddy current brake energy storage on rapid braking processes,” *Evergreen*, **9** (*2*) 451–456 (2022). doi:10.5109/4794171.
4) J. Jaeger, “These countries are adopting electric vehicles the fastest,” (2023). https://www.wri.org/insights/countries-adopting-electric-vehicles-fastest (accessed July 26, 2024).
5) V. Trivedi, A. Saxena, Mohd. Javed, P. Kumar, and V. Singh, “Design of six seater electrical vehicle (golf cart),” *Evergreen*, **10** (*2*) 953–961 (2023). doi:10.5109/6792890.
6) S. Orangi, N. Manjong, D.P. Clos, L. Usai, O.S. Burheim, and A.H. Strømman, “Historical and prospective lithium-ion battery cost trajectories from a bottom-up production modeling perspective,” *J. Energy Storage*, **76** 109800 (2024). doi:10.1016/j.est.2023.109800.
7) Abdelgader A.S. Gheidan, Mazlan Bin Abdul Wahid, Opia A. Chukwunonso, and Mohd Fairus Yasin, “Impact of internal combustion engine on energy supplyand its emission reduction via sustainable fuel source,” *Evergreen*, **9** (*3*) 830–844 (2022). doi:10.5109/4843114.
8) Kurnia Fajar Adhi Sukra, A. Sukmono, L. Shalahuddin, A. Maswan, S. Yubaidah, Didi Tri Wibowo, M. Yusuf, and Muhammad Penta Helios, “Effects of battery state of charge on fuel economy of hybrid electric vehicles: an analysis using the un ece r101 method,” *Evergreen*, **10** (*3*) 1770–1775 (2023). doi:10.5109/7151726.
9) G. Leoncini, R. Mothier, B. Michel, and M. Clausse, “A review on challenges concerning thermal management system design for medium duty electric vehicles,” *Appl. Therm. Eng.*, **236** 121464 (2024). doi:10.1016/j.applthermaleng.2023.121464.
10) D. Ji, and H. Gan, “Effects of providing total cost of ownership information on below-40 young consumers’ intent to purchase an electric vehicle: a case study in china,” *Energy Policy*, **165** 112954 (2022). doi:10.1016/j.enpol.2022.112954.
11) A. Febransyah, “Predicting purchase intention towards battery electric vehicles: a case of indonesian market,” *World Electr. Veh. J.*, **12** (*4*) 240 (2021). doi:10.3390/wevj12040240.
12) E. Djubaedah, Riza, A. Kurniasari, Nur Endah Eny S, and A. Nurrohim, “Projection of the demand for charging stations for electric passenger cars in indonesia,” *Evergreen*, **10** (*3*) 1744–1752 (2023). doi:10.5109/7151723.
13) Z. Liu, J. Song, J. Kubal, N. Susarla, K.W. Knehr, E. Islam, P. Nelson, and S. Ahmed, “Comparing total cost of ownership of battery electric vehicles and internal combustion engine vehicles,” *Energy Policy*, **158** 112564 (2021). doi:10.1016/j.enpol.2021.112564.
14) J. Jia, S. Ma, Y. Xue, and D. Kong, “Life-cycle break-even analysis of electric carsharing: a comparative study in china,” *Sustainability*, **12** (*16*) 6584 (2020). doi:10.3390/su12166584.
15) F.D. Pero, M. Delogu, and M. Pierini, “Life cycle assessment in the automotive sector: a comparative case study of internal combustion engine (ice) and electric car,” *Procedia Struct. Integr.*, **12** 521–537 (2018). doi:10.1016/j.prostr.2018.11.066.
16) “Gaikindo wholesales data,” (n.d.).
17) “Presidential Instruction no. 7 of 2022: Use of Battery-Based Electric Motorized Vehicles As Operational Service Vehicles and/OR Individual Service Vehicles for Central Government Agencies and Regional Governments,” n.d.
18) The Indonesia Ministry of Finance, “GOVERNMENT SUPPORT FOR KBLBB INDUSTRY DEVELOPMENT,” 2022.
19) “Government Regulation No. 73/2019: Taxable Luxury Goods in the Form of Motor Vehicles Subject to Luxury Goods Sales Tax.,” 2019.
20) Ministry of Internal Affairs, “Regulation of Ministry of Internal Affairs No. 6/2023: the Basis for Imposing Motor Vehicle Tax, Motor Vehicle Ownership Transfer Fee, and Heavy Equipment Tax for the Year 2023.,” n.d.
21) Ministry of Finance, “Minister of Finance Regulation (PMK) No.38 of 2023: Value Added Tax on the Delivery of Specific Battery-Based Four-Wheeled Electric Vehicles and Specific Battery-Based Bus Electric Vehicles Funded by the Government for the Fiscal Year 2023 (PMK VAT DTP Electric Vehicles).,” n.d.
22) The Ministry of Industry, “Ministry of Industry Regulation Number 21 of 2023 concerning Amendments to Minister of Industry Regulation Number 6 of 2023 on Guidelines for Government Assistance for the Purchase of Battery-Based Electric Two-Wheeled Vehicles.,” n.d.
23) P.W. Handayani, R. Nasrudin, and J.F. Rezki, “Reliable electricity access, micro-small enterprises, and poverty reduction in indonesia,” *Bull. Indones. Econ. Stud.*, **0** (*ja*) 1–48 (2023). doi:10.1080/00074918.2023.2175782.
24) The Ministry of Energy and Mineral Resources, “Minister of Energy and Mineral Resources

Regulation Number 1 of 2023 concerning Provision of Electric Charging Infrastructure for Battery-Based Electric Motorized Vehicles," n.d.

25) P. Suttakul, W. Wongsapai, T. Fongsamootr, Y. Mona, and K. Poolsawat, "Total cost of ownership of internal combustion engine and electric vehicles: a real-world comparison for the case of thailand," *Energy Rep.*, **8** 545–553 (2022). doi:10.1016/j.egyr.2022.05.213.
26) Sekretariat Perusahaan PT PLN (Persero), "Statistik PLN 2022," PT PLN (Persero), 2023.
27) "Layanan cek pajak kendaraan online," (n.d.).
28) I.-Y.L. Hsieh, M.S. Pan, Y.-M. Chiang, and W.H. Green, "Learning only buys you so much: practical limits on battery price reduction," *Appl. Energy*, **239** 218–224 (2019). doi:10.1016/j.apenergy.2019.01.138.
29) "Lithium-ion battery pack prices hit record low of $139/kwh," *BloombergNEF*, (2023).
30) J.G. Smart, and S.D. Salisbury, "Plugged In: How Americans Charge Their Electric Vehicles," Idaho National Lab. (INL), Idaho Falls, ID (United States), 2015. doi:10.2172/1369632.
31) The Central Bank, "Inflation target 2021-2024," (n.d.).
32) "DAFTAR harga bahan bakar khusus / non subsidi tmt 1 juni 2024 | pertamina," (n.d.). https://www.pertamina.com/id/news-room/announcement/daftar-harga-bahan-bakar-khusus-non-subsidi-tmt-1-juni-2024 (accessed July 24, 2024).
33) I. Veza, M.Z. Asy'ari, M. Idris, V. Epin, I.M. Rizwanul Fattah, and M. Spraggon, "Electric vehicle (ev) and driving towards sustainability: comparison between ev, hev, phev, and ice vehicles to achieve net zero emissions by 2050 from ev," *Alex. Eng. J.*, **82** 459–467 (2023). doi:10.1016/j.aej.2023.10.020.
34) K. Palmer, J.E. Tate, Z. Wadud, and J. Nellthorp, "Total cost of ownership and market share for hybrid and electric vehicles in the uk, us and japan," *Appl. Energy*, **209** 108–119 (2018). doi:10.1016/j.apenergy.2017.10.089.
35) M. Scorrano, R. Danielis, and M. Giansoldati, "Dissecting the total cost of ownership of fully electric cars in italy: the impact of annual distance travelled, home charging and urban driving," *Res. Transp. Econ.*, **80** 100799 (2020). doi:10.1016/j.retrec.2019.100799.
36) P. Penmetsa, S. Dhondia, E.K. Adanu, C. Harper, S. Nambisan, and S. Jones, "Incentives to encourage the adoption of connected and automated vehicles: lessons learned from hybrid-electric vehicle incentive programs," *Future Transp.*, **3** (*3*) 986–995 (2023). doi:10.3390/futuretransp3030054.
37) C. Brand, J. Anable, and M. Tran, "Accelerating the transformation to a low carbon passenger transport system: the role of car purchase taxes, feebates, road taxes and scrappage incentives in the uk," *Transp. Res. Part Policy Pract.*, **49** 132–148 (2013). doi:10.1016/j.tra.2013.01.010.
38) "Daftar harga bbm pertamina awal juli 2024 | databoks," (n.d.). https://databoks.katadata.co.id/datapublish/2024/07/01/daftar-harga-bbm-pertamina-awal-juli-2024 (accessed July 26, 2024).
39) "Pertalite, bbm yang paling banyak dikonsumsi masyarakat," *ESDM*, (n.d.). https://www.esdm.go.id/id/media-center/arsip-berita/pertalite-bbm-yang-paling-banyak-dikonsumsi-masyarakat (accessed July 26, 2024).