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Estimating the Total Cost of Ownership (TCO) of Electrified Vehicle in Indonesia

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Abstract

With the Electrified Vehicles (EVs) ventures being in the early stage, the cost-benefit analysis of the vehicles is key towards capturing the Indonesian market. As consumers, however, pricing may not only be the costs they consider; they also consider the total cost of ownership (TCO) of the cars they purchase. With that regard, this study discusses the total cost of ownership (TCO) of the EV in the Indonesian context, including calculations for HEV (Hybrid Electric Vehicle), PHEV (Plug-in Hybrid Electric Vehicle), and BEV (Battery Electric Vehicle), as well as Internal Combustion Engine (ICE) vehicles for comparisons. Specifically, this study aims to: (i) identify the monetary factors which affects total cost of ownership (TCO) of electric and conventional cars in Indonesia, (ii) construct a TCO model and calculate the value of total cost of ownership of electric and conventional cars in Indonesia, and (iii) compare the value of total cost of ownership of electric and conventional cars in Indonesia related to the relevant switching cost between EVs and ICE. Our findings suggest that generally, in Indonesia, higher usage and/or length of ownership of EVs lead to more competitive TCO compared to ICE. We also explore a comprehensive number of scenarios (e.g., total annual mileage, years of ownership, price, fuel prices, and cost incentives) in which the TCO of EV maximizes Indonesian consumer welfare.

JEL Classification: C63; L62; O14

Keywords

electrified vehicle — incentives — total cost of ownership — Indonesia

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1. INTRODUCTION

It cannot be denied that the automotive industry has contributed significantly and earned a strategic position in Indonesia's economy. Data from Central Bureau of Statistic (2017) indicates that the industry has contributed 10–11% yearly towards the non-oil and gas sector with nearly 5.6% growth every year. The automotive industry is also the third largest non-oil and gas industry after food and beverage (34%), metal goods, computer, electronics, optics, and electrical equipment industry (11%). In addition, the automotive sector has managed to create jobs for three million people. The potential of the automotive industry will keep rising in the future so far as to have contributed just as much as big automotive countries such as Japan and Thailand.

On the other hand, the high growth rates of automotive sector could potentially cause trouble in terms of energy security (the availability of fuel) and environmental issues (pollution). The government, as the policymaker, responded by issuing the National Energy Policy (PP No. 79 in 2014) which targeted the reduction of fuel consumption from 50% in 2013 to 25% in 2025. Additionally, Indonesian government also participates in the world commitment to reduce greenhouse gas emissions (COP-21, Paris) by 29% from BAU (business as usual) in 2030.

As a result, the government gradually pushes automotive industry to generate energy saving and low emission cars (environment friendly) production. The policy in motion is the Low-Cost Green Car (LCGC) in 2013, which is a program based on the incentive to cut the luxury goods sales tax (PPnBM) by 100% if complying to both technical and administrative terms (fuel efficiency above 20 km/L), comprises 85% of local content and the cost of 95 million both during the first year. Moreover, the Government Regulation no. 41 in 2013 also accommodates the Low Carbon Emission Program (LCEP), now on the implementation discussion stage, in which the luxury goods sales tax (PPnBM) would refer to the value of carbon emission.

To support the LCEP Program, the Government (in this case the Ministry of Energy and Natural Resources has formed a team consisting the Ministry itself, the Ministry of Finance, and the Ministry of Industry) to support the regulation design (Presidential Regulation) in order to aid the development of electrified vehicle (EV) in Indonesia. The aim of this Presidential Regulation is to push producers to develop an EV car as well as to urge consumers, who still use conventional cars or the internal combustion engine (ICE car), to shift into using EV, so that the increase of energy efficiency and conservation in the transportation sector could be achieved. The government will even target the sale of EV at 20% from the automotive market in 2025. In terms of its technology, the EV is comprised of three different categories, which are hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) dan battery electric vehicle (BEV). Electric Car/ Battery Electric Vehicles (BEV) are vehicles which do not require the use of fuel-based engine as a driving system, instead it utilizes electric motor as the driving system and batteries to store electricity. Meanwhile, hybrid electric vehicles (HEV) are vehicles which still utilizes fuel-based engine as a driving system as well as battery. As for Plug-in Hybrid Electric Vehicles (PHEV) which utilizes battery and electric motor as the main driving system, said vehicles still utilize fuel-based engine as a back-up driving system.

The literature on electrified vehicles in Indonesia has been growing (Ristiana et al., 2017,2019; Huda et al., 2019; Sutopo & Kadir, 2018; Purwadi et al., 2016; Sushandoyo et al., 2012). Recently, the new system and more economically efficient battery in electrical vehicle has being developed (Ristiana et al., 2017,2019). Despite the circumstances, there are still many challenges found in order to ignite EV market in Indonesia. The experience of other countries which had previously developed electric cars demonstrated that the market for electrified vehicle is still quite scarce and its sales growth has not been encouraging. For instance, in Italy, the sale of EV-type BEV only accounted for 0.01% in 2017. Similarly, in Austria, France, Switzerland, and Germany, the sale of BEV only amounted roughly 1.5% to 3% during the same year (Danielis et al., 2018). In the case of various fiscal incentives provided by the government in appealing consumers to switch to EV.

Factors analyzed in determining TCO are the factors which can be assessed through monetary terms. This study tried to include social costs which has been represented with the monetary value from the CO2 that can be reduced by EV. In order to calculate TCO, a simulation of ICE-type TCO will be made. Said ICE-type car which would be used as a comparison is the type of car with a rather large scale in Indonesia, for instance, the MVP-type with the estimated selling price of IDR200 million. This is conducted on the basis that the development of EV will be directed towards the types of cars highly demanded by Indonesian consumers.

TCO simulations are carried out for car ownership within 5, 10, and 16 years with t=1 is the year 2018 and t=16 is the year 2033. The low interest of consumers in switching to electric cars is caused by numerous factors (Coffman et al., 2017; Danielis et al., 2018) which is divided into two groups, namely:

- Monetary factors such as EV prices, tax, operating costs, parking costs, etc.
- Non-monetary factors such as mileage range, size and type of car, brand, charging time and charging infrastructure.

According to Danielis et al. (2018), monetary factors are commonly captured through total cost of ownership (TCO). TCO is defined as "TCO is defined both as a purchasing tool and a philosophy, aimed at understanding the true financial cost of buying a specific good such as a car". Furthermore, Danielis et al. (2018) described the tight connection between TCO and the level of car sales. Currently EV-type cars have a higher level of TCO compared to the TCO of ICE-type cars. Hence, the level of EV-type cars sales is still relatively lower than the sales of ICE-type cars (See Figure 1.1.).

Based on these countries, Indonesia, as one of the countries which will be developing EV market, needs to examine deeper into the comparison between EV and ICE TCO for Indonesian automotive market. Consequently, a study to identify the cost of ownership of numerous types of electrified vehicle, for instance, Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV), and Battery Electric Vehicle (BEV) needs to be conducted. Therefore, these electrified vehicles' cost of ownership can be compared with the cost of ownership of conventional or internal combustion engine (ICE) vehicles. Using the total cost of ownership (TCO) calculation, a better picture can be made in order to help consumers of electric cars in Indonesia make informed decisions by understanding when and how TCO of EV is lower than that of ICE.

2. LITERATURE REVIEW

2.1 Total Cost of Ownership (TCO) Components

According to Danielis et al. (2019), there are two components in total cost of ownership of certain commodity for consumers, which are (1) the consumer-oriented TCO that is the price to be paid by consumers to buy the aforementioned commodity (for example, the price car owners had to pay when buying a car), and (2) the society-oriented TCO that is the price to be paid by the society for the existence and use of said commodity (for example, the social cost that arises because of the use of transportation that is air pollution and noise pollution).

The difference of vehicles' TCO between countries, other than having determined by the price of buying cars, is determined by the structure of cost that is related with the price of fuel or electricity, insurance, tax and subsidy (McKinsey and Company, 2011; Lévay et al., 2017; Palmer et al., 2018). Studies have also shown that TCO for motorized vehicle depends on the pattern of vehicle use (trip type, urban vs. highway), residential density (Windisch, 2013; Wu et al., 2015), user's segment, and whether or not the vehicle is the primary vehicle or second family car (Propfe and Redelbach, 2013; Plötz et al., 2013).

Some TCO models insert components such as the price of the vehicle, import duty, PPnBM, insurance, preventive maintenance, tire substitution, car's resale value, fuel consumption, etc. Strictly for cars that are of BEV type, TCO is very dependent on battery replacement cost and the recycle or reuse from the batteries. The description of the TCO models and the comparison of it in some countries can be explained in the following sub-chapter.

2.2 Previous Researches on TCO in Several Countries

a) TCO for EV in Hawaii, USA: The TCO study for the USA was conducted for the Hawaiian Islands by Coffman et al. (2017). Generally, the TCO model in this study adopted the perspective of the consumers in evaluating the cost of purchase and operating a vehicle in a certain span of time. In this study, the researcher used TCO model without tax credit.

It is presumed that battery replacement is done after 11 years of ownership and tire replacement once in five years, while the cost of EV home charger is already comprised in the purchase price of EV (one time—upfront cost). In this TCO model, it ignores the heterogeneous attributes of every vehicle, such as the passenger capacity, acceleration, and mileage. Therefore, to minimize the heterogeneous effect from every vehicle, this analysis took into consideration the vehicle that has balanced size and function.

The result of this study is on average, present value TCO without tax credit from EV (BEV and PHEV) is US$75,000, compared to present value TCO without tax credit from others (HEV and ICE), which is only US$62,000. Moreover, Nissan Leaf (BEV) has TCO that is US$7,900 higher than the average HEV and ICE TCO. The comparison between Ford C-Max Energy (PHEV) and Ford C-Max Hybrid (HEV) that are originated based on the same manufacturing process shows that Ford C-Max Energy (PHEV) has TCO higher than Ford C-Max Hybrid (HEV). This matter also occurs to Toyota Plug-In Prius (PHEV) and Toyota Prius (HEV). Toyota Plug-In Prius (PHEV) has TCO that is US$11,000 higher than Toyota Prius' (HEV).

The same result has also been obtained from comparing present value TCO with tax credit of EV (BEV and PHEV) and present value TCO with tax credit of others (HEV and ICEV). Substantially, tax credit decreases the capital cost from EV (BEV and PHEV), but TCO for EV is still steeper than ICEV and HEV. The average TCO for EV (BEV and PHEV) is US$70,000, while the average TCO for HEV and ICEV is US$63,300.

b) TCO for EV in Belgium: The TCO study for Belgium was conducted by Messagie et al. (2013). This study measures the total cost of ownership (TCO) with the goal of evaluating the effectivity of cost from electricity-based vehicles (HEV, PHEV, and BEV) if compared with the conventional vehicles that use gasoline and diesel fuel. Consumers will consider to buy electricity-based vehicles when the price surplus between the electric-based vehicles and conventional ones are not too big. Aside from it, other factors, such as style and the shape of the vehicle, can affect the consideration in buying vehicles. However, in analysing this TCO, the variables will not be included.

In the TCO model for this study, present value from the cost that has been paid (occurred cost), for example, the cost of purchase, registration tax, vehicle road tax, maintenance cost, technical and tire replacement cost, insurance, battery renting cost, battery replacement cost, and fuel (for conventional vehicles) or electricity (for electricity-based vehicles) will be also calculated. Cost, such as battery renting cost, also happens in vehicles that have certain technology advancement.

Cost that has been paid (occurred cost) is divided into three main categories, which are cost of purchase, fuel operational cost, and non-fuel operational cost. The cost of purchase category is the initial cost and vehicle registration tax. The assumption for initial cost value includes value-added tax but does not include a price reduction due to promotions from the dealers yet. The fuel operational cost category is the price of gasoline, diesel fuel, or electricity, and the non-fuel operational cost category includes yearly road tax, insurance, maintenance cost, tire cost, technical control cost, and battery replacement cost.

This research also distinguishes segments for every vehicle. Those segments are divided into the 'small city cars' segment, 'medium cars' segment, and 'premium cars' segment. The difference between conventional ICEVs and BEVs for the 'small city cars' segment is palpable from the different ranges of fuel prices for each segment: 0.18–0.23 €/km for small gasoline cars, 0.19–0.21 €/km for small diesel cars, and 0.30–0.36 €/km for BEVs. Meanwhile, the portion of depreciation expense is higher for BEV (59%) than the gasoline-based car (34%) and diesel-based car (44%). On the other hand, the portion for fuel cost and electricity cost are lower than BEV (8%), for gasoline-based cars are on 38% and diesel-based cars 25%.

The result for 'medium cars' segment is more promising for BEV. The cost per km ranges from 0.27–0.33 €/km for gasoline-based cars, 0.28–0.31 €/km for diesel-based cars, 0.27–0.38 €/km for HEV, 0.39–0.42 €/km for BEV, and 0.45–0.50 €/km for PHEVs. In this segment, the portion of depreciation expense among all the vehicle types are uniform: 43% for gasoline-based vehicle, 51% for diesel-based vehicle, 53% for HEV, 55% for BEV, and 70% for PHEVs. Generally speaking, PHEV is still the most expensive alternative.

In the 'premium car' segment, other factors, such as brand perception, image, and appearance have more important roles than they are for the vehicles in the previous two segments. A BEV vehicle is usually offered with three-battery capacity (40 kWh, 60 kWh, and 85 kWh) so that it has a different TCO. The cost per km ranges from 0.53–0.68 €/km for gasoline-based cars, 0.52–0.66 €/km for diesel-based cars, 0.59–0.72 €/km for HEV, and 0.58–0.79 €/km for BEV. This has made BEVs the most appealing option from the perspective of costs in the 'premium cars' segment.

c) TCO for EV in some other European countries: Levay (2017) has calculated TCO for EV and ICEV for a few European countries, which are Italy, Norway, Netherlands, United Kingdom, Germany, France, Hungary, and Poland.

Data points could also be presented in the form of vehicle models to reveal the variation of possibilities in the connection of cost and sales for each and every car segment (big, medium, and small cars). This division shows that the bigger the EV car, the higher the sales and the lower the TCO when compared to the ICE counterpart. Small EV has the lowest relative sales and the highest relative TCO, while high EV has the highest relative sales and the lowest relative TCO.

The deployment of data points reveals an incredible difference in relative TCO. Small EV cars apparently have higher TCO loss than medium and big EV cars. Most data points in the picture lie above 100%, which means that small EV cars have TCO higher than their ICE counterparts. TCO from electricity-based Volkswagen e-Up is more than 150% than the TCO that comes from its gasoline-based version in all countries except Norway. On the other hand, Renault Zoe's TCO does not exceed 150% from Renault Clio's TCO in one of the countries. For medium-sized cars, only two data points that are above 150%, while the other eight are below 100%, which is EV that is cheaper (TCO-wise) than its ICE counterpart. Big EV models show the same pattern with the medium models, with the exception of Volvo V60 PHEV that is consistently above 150%, which is costlier than Model S Tesla and Mitsubishi Outlander PHEV.

d) TCO for EV in Italy: The TCO study for Italy was conducted by Danielis et al. (2018). Aiming to evaluate the present and future prospects for electric cars in Italy, this study expands probabilistic total cost of ownership (TCO) model which includes stochastic and non-stochastic variables, vehicle usage variable, and contextual assumptions.

Non-stochastic variable is divided into two groups, while stochastic variable into three components. Manufacturer's suggested retail price (MSRP) is inserted as a stochastic variable in order to seize the final price that is accepted by the consumers as a result of the discount that is given by the dealer. In the account of resale value, it is assumed that a car is only used by the first owner for 6 years, in which the residual value for the ICEV and HEV type hold 20% of the initial value, while the BEV type holds 10% of the initial value because of the advancement of new technology. However, after the year 2025, ICEV will face depreciation faster than BEV so that residual value assumptions for both types are switched.

By applying the probabilistic TCO model with 10,000 Monte Carlo simulations, this study has received the average value of TCO/km for each of the four propulsion systems. The first shows the average MSRP. It can be seen that, in Italy, 10 best-selling ICEV have retail price that is way lower than 10 best-selling BEV. BEVs are staked 2.44, 1.52, and 1.30 times more than PICEVs, D-ICEVs, and HEVs, respectively. The rest of the rows are showing TCO/km based on the annual distance traveled. BEVs always have the highest average of TCO/km, and exception has been made when 15,000 km are travelled every year and only the HEVs are involved. Because BEV is characterized by how high the initial fixed cost and the low variable cost, we have improved the AKT assumptions. The result is that BEVs are equal to the P-ICEVs, D-ICEVs, and HEVs only because the AKT is assumed approximately on 35,000, 30,000, and 22,000 km.

e) TCO for EV in the USA According to the Gilmore Research: Gilmore and Lave (2013) has calculated TCO using net present value (NPV) from every vehicle in the USA. The NPV calculation includes all costs that are tallied using USD.

The main assumption in calculating TCO for this study is that consumers estimate resale price when they are buying a vehicle. Depreciation also reflects as the biggest cost in vehicle ownership. This study also assumes that resale price in auction reflects the price that portrays the result of consumer observation.

The result shows that:

- For passenger vehicles
  TCO for diesel-based TDI (Turbocharged Direct Injection) vehicles and HEV (Hybridized Electric Gasoline Vehicle) are lower than the conventional gasoline vehicle in the discount rate ranging from 0% to 10%. An exception is made for Honda Civic, which has TCO from the conventional vehicle type and is lower than TCO that comes from the TDI or HEV type in the discount rate of 10%.
- For luxury passenger vehicles
  TCO for TDI vehicles is also lower being compared to conventional gasoline vehicle in the discount rate ranging from 0% to 10% so that it will not affect the decision from the consumers.
- For trucks
  TCO for TDI vehicles is lower than conventional gasoline vehicle in the discount rate ranging from 0% to 5% but not until 10%.

f) TCO for EV in the USA According to Arthur D. Little's Research: The study regarding the calculation of TCO in the USA was conducted by Brennan and Barder (2016). TCO is represented in dollar from the vehicle ownership cost during the period of vehicle usage and wraps all the input costs in the 20 years of a vehicle's life cycle. In this study, TCO for vehicle consists of 2 cost categories. The first cost category is the cost that is caused by the production of basic vehicle equipment. Subsequently, the second cost category is the cost that happens right after the ownership of a vehicle has shifted to the hands of a consumer.

The first cost category is called True Vehicle Cost (TVC). TVC includes all input costs that have been issued to the production of a vehicle, starting from design, technical matters, and assemblage, to warranty fee and overhead. The second cost category includes usage fee, vehicle maintenance cost, and end of ownership period fee that is related to the disposal of the vehicle.

This study concludes that BEV (Battery Electric Vehicle) is significantly more expensive to be owned and operated during the period of vehicle usage than ICEV (Internal Combustion Engine Vehicle). For compact passenger vehicle in year 2015, it has been found that BEV (US$68,492) is 44% costlier than ICEV (US$47,676). For mid-size passenger vehicle in year 2015, the difference in cost is even more visible, in which BEV (US$85,854) is 60% costlier than ICEV (US$53,649).

Furthermore, if it is analyzed in a more detailed manner, total vehicle cost (TVC) BEV is 70% higher than ICEV for compact passenger vehicle and 98% higher than ICEV for mid-size passenger vehicle. For BEV, TVC is the largest portion for the TCO. TVC for compact passenger BEV almost reaches two times its total from ICEV's, in which US$29,164 are for BEV and US$17,146 for ICEV. Meanwhile, mid-size passenger TVC reaches up to US$37,865 for BEV and US$19,114 for ICEV.

g) TCO for EV in Italy (2): Rusich and Danielis (2015) define TCO from a car as the expense of owning a car for 10 years. This study is conducting the TCO calculation for the case of Italy.

Vehicle Capital Cost is the retail price of a car reduced by subsidy. Present value of the annual operating costs includes all expenses that occur during the period of vehicle ownership. For example, annual operating costs include annual fuel cost for conventional vehicles and annual electricity cost for electric vehicles.

Annual fuel cost depends on fuel consumption per kilometer, fuel cost, and fuel efficiency. Fuel efficiency is the sum of consumed fuel for a vehicle to travel 100 kilometers. For that matter, it is obligated to estimate the total car range formula. For annual electricity cost, it is the product of estimation from the multiplication between the total amount of refuel and the cost of refuel. Other than annual fuel cost and annual electricity cost, annual operational cost also includes battery rental fee (only for a few EV models), insurance fee, maintenance and repair cost, and parking fee.

The result is that gasoline based ICEV has TCO that is way cheaper compared to the other ICEV types and also the BEV type, while hybrid diesel ICEV is the most expensive type of ICEV. For the BEV category, the BEV that uses battery rental is cheaper than the BEV that uses its own battery. Generally, hybrid ICEV has the highest TCO and then is followed by BEV.

The TCO study for Italy was also conducted by Danielis et al. (2019). TCO model from a car consists of various of expenses so that the car can be used for a few years and a few kilometers. The expenses are divided into two, which are the constant expense and the variable expense. Constant expense includes a one-time pay for buying a car, such as tax, price, and insurance, while variable expense is the expense that can change based on how high the usage intensity is and the distance travelled, such as fuel cost. Both expenses are called consumer-oriented costs. However, there is also the society-oriented cost, and it is the emission of air and noise pollution cost. Because of that, in this study, the TCO model comprises of consumer-oriented costs and society-oriented costs.

Retail price is assumed to have used real-life price based on the manufacturer's suggested retail price (MSRP), while residual value is assumed to be zero. This is because the average period for vehicle ownership in Italy is 10 years, so both ICEV's and BEV's residual value is assumed to be close to zero.

3. METHODOLOGY

This study will carry out a calculation and comparison analysis on total cost of ownership (TCO) for electrified vehicle (EV) and ICEV by adopting the models used by Coffman et al. (2017) and Danielis et al. (2018). Other than utilizing consumer-oriented, the TCO model developed in this study also attempts to consider society-oriented, which is by including the social cost for CO2 emission from ICE cars, HEV, PHEV, and BEV. CO2 emission in BEV is accounted from the CO2 emission of the generators that are used in power plants. The full models and assumptions used in this study are shown below:

3.1 TCO Model

This study generally uses the model that was used by Coffman et al. (2017) and Danielis et al. (2018) in calculating the TCO. The model that is used is shown below:

$$TCO = P + \sum_{t=1}^{N} c_t (1+r)^{-t} - R(1+r)^{-N} \quad (1)$$

In which the model's details are shown below:

1. **P is the *Initial Purchase Price***
   This study also uses the initial purchase price for one-time cost in buying cars when time (t) equals to 0. This price will also face decline over time because of existing assumptions, such as depreciation and the car's age.
2. **R is the *Resale Value***
   One of the main considerations for automobiles' consumers in Indonesia is that buying cars, for them, is also because of their resale value. Seeing this, the decline of resale value over time can also be seen as a burden in TCO calculation from the cars related to the case.
3. **r is the *discount factor***
   Discount factor also becomes a crucial component in economic calculation because with the usage of said discount factor, economic calculation that is spread at some points in time can be withdrawn and adjusted into becoming the existing value for today's worth (present value). Discount factor in this study is placed on 10% per year.
4. **Ct is the operational cost, maintenance cost and social cost**
   The last component for this calculation is how much the operational cost and the maintenance cost are for the cars related to this case.
   (a) From the calculation, maintenance cost includes:
      i. Engine costs: oil, tune-up, parts, etc.
      ii. Vehicle costs: brake pad, shockbreaker, etc.
      iii. Electric components costs
      iv. Equipment costs
   (b) From the calculation, operational cost includes:
      i. Fuel or electricity cost, etc.
      ii. Insurance costs, etc.
      iii. Tax fees.
      iv. Parking costs.
   (c) In the calculation, social cost is counted based on the CO2 emission that is produced by the usage of vehicle due to the utilization of fossil fuel in the car's fuel tank or the use of fossil fuels by power plants whose electricity is used in cars of PHEV and BEV types.
   (d) The vehicle usage cost has been taken into consideration for BEV customers, if they are travelling out of the town. This needs to be considered for those who want to own BEV inside the city, so the rental fee for ICE cars to travel out of the town needs to be considered, too, because BEV cars are not used due to their electrical power not being adequate and not being able to be recharged throughout the journey. In this matter, it has been assumed that there are at least 14 days in a year for BEV owners to rent a vehicle for long-distance travelling need so that they have to rent with a rental fee for IDR250,000 per day in the year 2018. Therefore, the total fee for it is IDR3,500,000 per year in the year 2018 and will escalate because of inflation.

   All the calculations above are carried out using the assumptions that can be explained further in this subchapter below.

3.2 Assumptions in Calculating TCO

In economic analysis, assumptions that are usually used in calculations become important in determining the sensitivity of the produced value. In this study, the basic assumptions that are going to be used are shown in the Table 3.1.

Generally, some important assumptions that are used in this study are shown below:

Table 3.1. Assumptions Used in the Study

Assumption	Value	Unit
Ownership	5, 10, 16	Year
ICE Price	200,000	000 IDR
Distance	10,000, 18,000, 25,000	Km/Year
Insurance	4.00%	From the car's price per year
Yearly Tax	1,56%	From the car's price per year
Depreciation	9,00%	From the car's price per year
Fuel Cost	Forecasting Result	IDR
Electricity Cost	Forecasting Result	IDR
HEV Battery	3,3	Kwh
PHEV Battery	8,8	Kwh
BEV Battery	13,5	Kwh
Exchange Rate as of 2027	16.507	IDR
Inflation	4%	
Discount Rate	10%	
Alternative Transportation	3,500	000 IDR/Year
ICE : HEV Initial purchase ratio	1.2	
ICE : PHEV Initial purchase ratio	1.4	
ICE : BEV Initial purchase ratio	1.5	
Parking/day	10,000	IDR
Sosial Cost ICE	37.89	IDR/KM
Sosial Cost HEV	19.07	IDR/KM
Sosial Cost PHEV	11.79	IDR/KM
Sosial Cost BEV	7.85	IDR/KM

Source: Estimations of LPEM FEB UI

1. The Assumption of Ownership Period

This study uses three scenarios in the assumption of ownership period. The 5-, 10-, and 16-year periods are used in the calculation and are also compared between the values that are produced by the three scenarios. 5-year value is considered to analyse TCO for those who want to use their car in the short term. The 10-year value is considered to calculate TCO for those who want to sell their car especially the BEV type when it is time to replace the battery. The 16-year value is the maximum limit of an insurance company to give warranty for cars that live up to 16 years.

2. The Assumption of Car Price

The assumption of car price that reaches up to IDR200 million is used to ease the simulation by considering the car market segment with the price of IDR200 million which is later used as a decision for EV cars to enter the market. It also includes the biggest market share in car usage for Indonesia. The battery capacity for PHEV and BEV are adjusted with the price of ICE cars, which is for PHEV, the battery capacity is 8.8 kWh, while for BEV, 13.5 kWh. Nevertheless, the model and dashboard that have been developed can be used for various simulations of ICE cars' desired price to adjust to the compatible battery capacity and price. The HEV, PHEV, and BEV assumed prices respectively are 1.2 x ICE's price, 1.4 x ICE's price, and 1.5 x ICE's price.

3. The Assumption of Annual Kilometers Travelled (AKT)

This study uses three scenarios in the assumption of annual kilometers travelled (AKT), which are 10,000 km per year, 18,000 km per year, and 25,000 km per year. 10 years of AKT reflects consumers with the short-distance usage of their vehicle, which is less than 30 km per day. On the other side, 18,000 AKT and 25,000 AKT are for illustrating the medium-distance usage of cars (usage is medium) and long-distance usage of cars (usage is massive). Using this assumption, the TCO that is being calculated in this study will be shown in Rupiah per km (Rp/km).

4. The Assumption of the Efficiency of Fuel Consumption in ICE, HEV, and PHEV and the Distance Travelled in Kilometer for PHEV and BEV per kWh from the Electricity in the Battery

Related to the baseline of the calculation, this study uses the assumption of batteries that are used in BEV-typed cars is 13.5 kWh and assumed to be able to travel 65 km per battery recharge.

Meanwhile, related to the efficiency of fuel for ICE, HEV, and PHEC, this study uses the empirical data from the result of experimental research that was conducted by the study team for electrified vehicle in Indonesia, which are the UI, UGM, and ITB Teams. The data is shown in Table 3.2. and Figure 3.1. until Figure 3.2.

In order to represent car users in all regions in Jakarta metropolitan area known as Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi), the sampling technique used in this survivor is multistage random sampling. In the first phase the survey area was divided into eight clusters (Central Jakarta, East Jakarta, North Jakarta, East Jakarta, South Jakarta, West Jakarta, Depok-Bogor, Tangerang and Bekasi). From each of these regional clusters, the dealer chosen as the survey location is then selected and the number of respondents in each dealer is determined proportionally. From the dealer selected as the survey location, the next (second stage), respondents (car users) were selected using systematic sampling based on the number of car users who cared for the dealer on the appointed day.

When sampling the non-users, we take individuals spread in Jabodetabek with the method of multi-stage random sampling. In the first phase the survey area was divided into eight clusters (Central Jakarta, East Jakarta, North Jakarta, East Jakarta, South Jakarta, West Jakarta, Depok-Bogor, Tangerang and Bekasi). The second stage is to choose three villages randomly in each cluster with the hope that the data collected has variations as well as random. In each kelura-

Table 3.2. The Assumption of the Efficiency of Fuel Consumption in ICE, HEV and PHEV (Km/Liter)

Study Team	ICE		HEV		PHEV	
	COROLLA 1	COROLLA 2	PRIUS 1	PRIUS 2	PRIUS 1	PRIUS 2
UI	12.5	11.1	21.6	22.0	32	36.2
ITB	10.9	10.8	21.9	22.5	41.4	42.6
UGM	10.7	10.5	23.0	21.1	54.7	68.5

Source: Kemenperind (2018)

han, non-user respondents were chosen using a systematic random sampling method in which the survey team conducted interviews from house to house, where the distance between one respondent's house to another respondent's house was made at intervals of 10 houses.

The simulation is done using the car demand function that we estimate using secondary data. We analyse the impact on the macro economy using the Input-Output model. Five scenarios in the simulation we use is S0 (Business as Usual), S1 (Policy cars acceleration EV directed only develop the car Hybrid EV N (HEV Only)), S2 (direction of development only car Plug-in Hybrid EV only (PHEV)) and S3 (the development of EV car to car Battery EV only (BEV), and S4 (the development of EV car which is combination of HEV, PHEV, BEV), as well as fiscal and environmental implications.

First, the result of the study done by the UI team shows that cars of HEV and PHEV types have fossil fuel consumption that are 46% and 65% lower than the ICE cars. Secondly, the result of the study done by the UGM team, the fossil fuel consumption for HEV and PHEV cars are 52% and 82% lower than ICE. Lastly, the study done by the ITB team says that the fossil fuel consumption for HEV and PHEV cars are 51% and 74% lower than ICE. Using these results, the TCO calculation can be carried out for ICE, HEV, and PHEV cars.

5. The Assumption of Component Replacement and Maintenance Costs

Component replacement and maintenance costs in cars follow the standard replacement technic in standard factory cars. The battery replacement for PHEV and BEV can be assumed to be happening in the 10th year. So, if the battery is broken before the 10th year, the battery is still under the warranty so that there will be no fee.

6. The Assumption of Electricity and Fuel Costs

The value in electricity and fuel prices used in this study are based on the forecasting done by the team. The value of the electricity is based on the forecasting from the country's power plants' data and U.S. Energy Information Administration. Meanwhile, the fuel price follows the movement that has been laid out by the World Bank and historical data from Pertamina. Three scenarios are used in this, which are the low fuel price scenario (10% lower than the moderate fuel price), the moderate fuel price, and also the high fuel price scenario (10% higher than the moderate fuel price).

The electricity and fuel price assumption, which are the results of forecasting, in this study can be seen in Figure 3.1. and Table 3.3.

7. The Assumptions for Exchange Rate and Inflation

This study refers to the assumptions for long-term inflation in Indonesia, which is 4%. Meanwhile, the exchange rate for Rupiah against US$ is using the forecasting result from LPEM (2018).

8. The Social Cost Calculation

From how it has been explained beforehand, social cost in this study is calculated based on the CO2 emission as a result to the usage of various means of transportation. This study uses the cost of carbon value worth USD 42 per one ton of CO2, according to the estimation by U.S. Government (Interagency Working Group, 2010). Next, this study uses the referential value from the joint study of the institution in the acceleration of electric cars in Indonesia, using the km/liter value of fuel in the shape of the average distance travelled in km/liter in the related study. The value is also multiplied with the value from the conversion of liter to gram CO2. In short, the cost of carbon value in this study can be seen in the Table 3.5.

9. Simulations and Assumptions

In the model developed in this study, it can be used to see the effect of fiscal and non-fiscal policies that are possible. For example, to look at the effect of decreasing the PPnBM, the dashboard of this study provides the option to give subsidy in decreasing or erasing PPnBM. With that, the effect of said policy on TCO can be perceived.

4. RESULTS AND DISCUSSION

As stated previously on Chapter I, that the study attempts to analyze the comparison of total cost of ownership (TCO) between conventional or ICE cars and electrified vehicles such as BEV, PHEV, and HEV. Simply, considering the main objective of the study is to compare conventional and electric cars, we will present the total cost of ownership of Internal Combustion Engine Vehicle (ICE) with a value of 1, with the TCO of BEV, PHEV, and HEV as the relative values of 1. For instance, if the TCO of BEV in a scenario amounts to 1,29 then it is assumed that the TCO of BEV approximately amounts to 29% more expensive than that of ICE. Such thing applies the other way around; if the TCO of HEV in a certain scenario equals to 0.97 then it is assumed that its TCO is 3% less expensive than that of ICE.

Generally, result and discussion will be an elaborate explanation about the many exercises we did in the case of many assumptions surrounding TCO. In other words, our presentation will be based upon the TCO values of each car, when, among other things the assumed mileage per year; year of ownership; fuel price; and others were to be changed. It can be stated that the form of our results and discussion will be something akin to sensitivity analysis by altering basic assumptions.

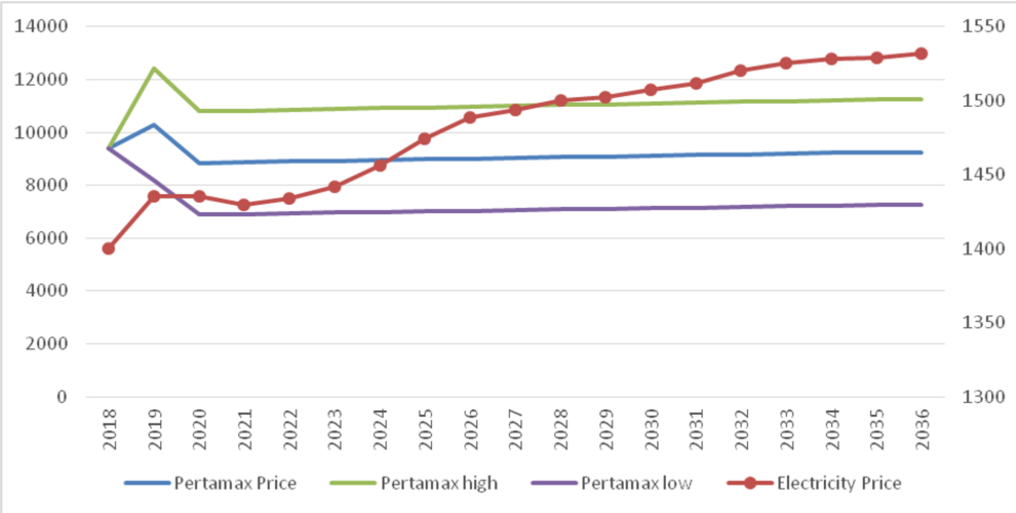


Figure 3.1. The Assumption of Electricity and *Pertamax* Costs Used in the TCO Calculation
Note: The vertical left axis is Pertamax price and vertical right is electricity's price
Source: Estimations by LPEM FEB UI

Table 3.3. The Assumption for Electricity and Fuel Costs Throughout the Years of 2018 - 2023

Year	Pertamax Price Base	Pertamax high	Pertamax low	Electricity Price
2018	9,400	9,400	9,400	1,400
2019	10,306	12,405	8,206	1,436
2020	8,845	10,799	6,892	1,436
2021	8,872	10,828	6,916	1,430
2022	8,899	10,858	6,940	1,434
2023	8,926	10,887	6,964	1,442
2024	8,953	10,917	6,989	1,456
2025	8,980	10,947	7,013	1,475
2026	9,007	10,977	7,037	1,489
2027	9,034	11,007	7,062	1,494
2028	9,061	11,037	7,086	1,501
2029	9,089	11,067	7,111	1,502
2030	9,116	11,097	7,135	1,508
2031	9,143	11,127	7,160	1,512
2032	9,171	11,157	7,185	1,520
2033	9,198	11,187	7,209	1,525

Source: Estimations by LPEM FEB UI

4.1 The Influence of Mileage and Fuel Price to TCO

The result of TCO calculation considering 5 year of ownership and the total mileage of 10.000 km indicates that ICE-type cars with the lowest TCO are IDR3.118/km (at the fuel cost 10% lower than the moderate price), IDR3.223/km (at the fuel cost 10% lower than the moderate price), and IDR3.329/km (at the fuel cost 10% lower than the moderate price). What is interesting within the assumption is that even with a lower, normal, or higher fuel cost, the TCO of PHEV will still be smaller than that of BEV and HEV. When fuel prices are low, the TCO of HEV will be 6.7% higher, PHEV will be 22% higher, and BEV will be nearly 30% higher than that of ICE. Additionally, when fuel prices are higher, the TCOs of HEV, PHEV, and BEV will only amount to 3.4%, 16.5%, and 21% above that of ICE respectively. In conclusion, fuel prices have a significant role contribution to TCO. The more expensive fuel costs, the smaller the TCO differences between HEV, PHEV, and BEV towards that of ICE. (See Figure 4.1).

The second TCO calculation combines the variables namely 5 years of ownership and 18.000 km of AKT. Assuming that the fuel prices are low then TCO of HEV (IDR1.986) will still be 0.1% lower than that of ICE (IDR1.988). However, PHEV is still considered as 11% (IDR2.203) and BEV 19% more costly than that of (IDR2.368). With the assumption that the fuel is at a moderate level, TCO of HEV (IDR2.044) will still be underneath that of ICE (IDR2.093), PHEV (IDR2.240), and BEV (IDR2.368). Considering the second combination, it can be concluded that the total cost of ownership for HEV will be the lowest compared to those of ICE and other EV, meaning that in a moderate mileage, the ownership of a HEV will be the most efficient among others and its TCO is, among others, lower with the shorter mileage.

The third combination of TCO calculation combines the variables of 5 years of ownership and 25.000 km AKT. With the assumption of low fuel cost, the TCO of HEV (IDR1.536) is 5% lower than TCO of ICE. Meanwhile, PHEV (IDR1.661) and BEV (IDR1.785) have each 3% and 10% higher percentage compared to the TCO of ICE. With the assumption of fuel prices standing at a moderate cost, TCO of HEV (IDR1.593) is towering 7% higher than PHEV (IDR1.698) which is already 1% beneath that of ICE. However, BEV (IDR1.785) still holds a taller percentage of 4% compared to ICE. Additionally, assuming that the fuel prices are higher than normal, TCO of HEV would be (IDR1.651),

Table 3.4. The Assumption for Exchange Rate

Year	USD to IDR
2018	14,633
2019	14,428
2020	14,400
2021	13,800
2022	13,750
2023	14,033
2024	15,562
2025	15,157
2026	15,283
2027	16,507
2028	16,276
2029	16,244
2030	15,567
2031	15,511
2032	15,830
2033	17,555

Source: LPEM (2018)

Table 3.5. The Assumption of the Cost of Carbon Value Calculation

Total emission	ICE	HEV	PHEV	BEV
Fuel Emission	1,610,932	810,954	388,987	-
Electrification Emission	-	-	112,403	333,965
Emission Total (per year)	1,610,932	810,954	501,390	333,965
Emission Total (gr/km)	64.44	32.44	20.06	13.36
Cost of carbon (IDR/km)	37.89	19.07	11.79	7.85

Source: Compiled by the writer

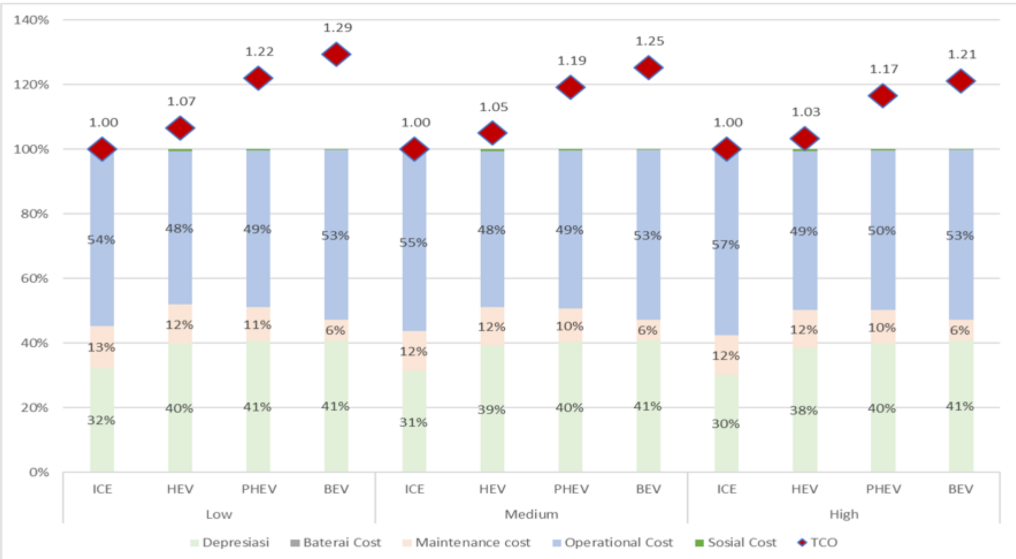


Figure 4.1. Comparison between TCO Ratio in ICE, HEV, PHEV dan BEV and 10.000 AKT per Year
Source: Estimations by LPEM FEB UI

PHEV (IDR1.735) and BEV (IDR1.785), which is already below TCO of ICE (IDR1.821). In this combination, it can be concluded that the total cost of ownership for HEVis still, among others, the lowest than those of ICE and EV. In other words, a hybrid vehicle would be the most efficient car to own in terms of riding in further distances, yet the cost difference between HEV and PHEV is not the most drastic. Hence the ownership of PHEV is still a considerable choice for the consumers. Meanwhile, if the fuel cost were to be 10% more expensive than its normal price, the cost of owning a BEV becomes significantly lower compared to owning an ICE.

The outcome of the calculation as described above indicates that the larger the number of AKT, the more it stipulates the fact that electrified vehicles have the tendency of becoming more economical than ICE. AKT number has quite a significant impact in reducing the cost of ownership. In the initial assumption (10.000 km/year), we can observe that TCO for EVs are still relatively higher than that of the ICE. It can be stated that if EVs were to be used for shorter distances, then EV would not be as economical compared to ICE. In a moderate assumption (18.000 km/year), we can observe then that HEV in every fuel cost price scenario can compete with ICE in terms of its economic value while PHEV and BEV still could not reach a value below 1. Another interesting detail can be observed in the assumption of heavy use (25.000 km/year) which is the fact that TCO for EV was seen to become more competitive, especially in the

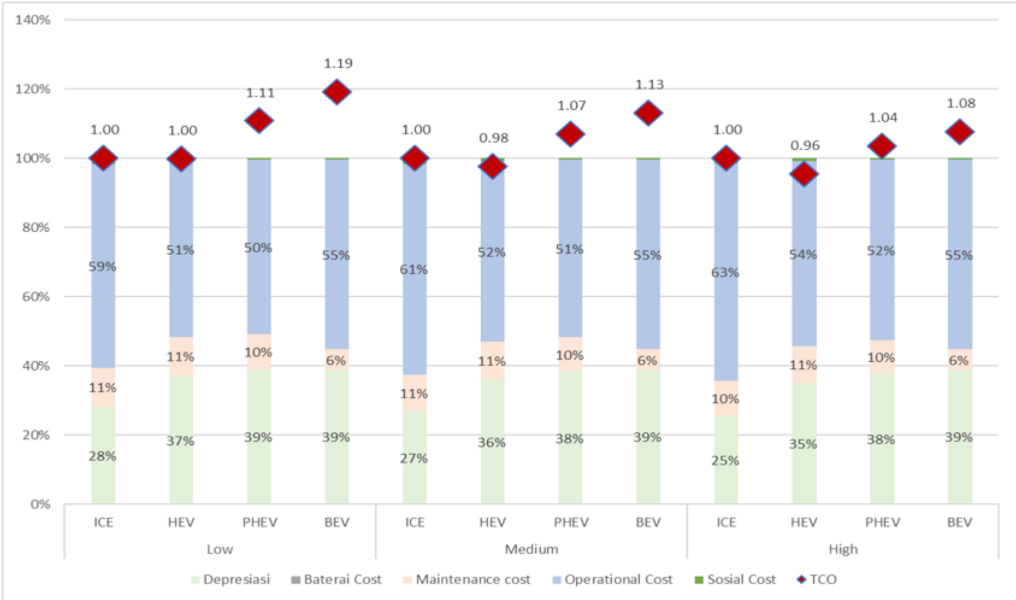


Figure 4.2. Comparison between TCO Ratio in ICE, HEV, PHEV dan BEV and 18.000 AKT per Year
Source: Estimations by LPEM FEB UI

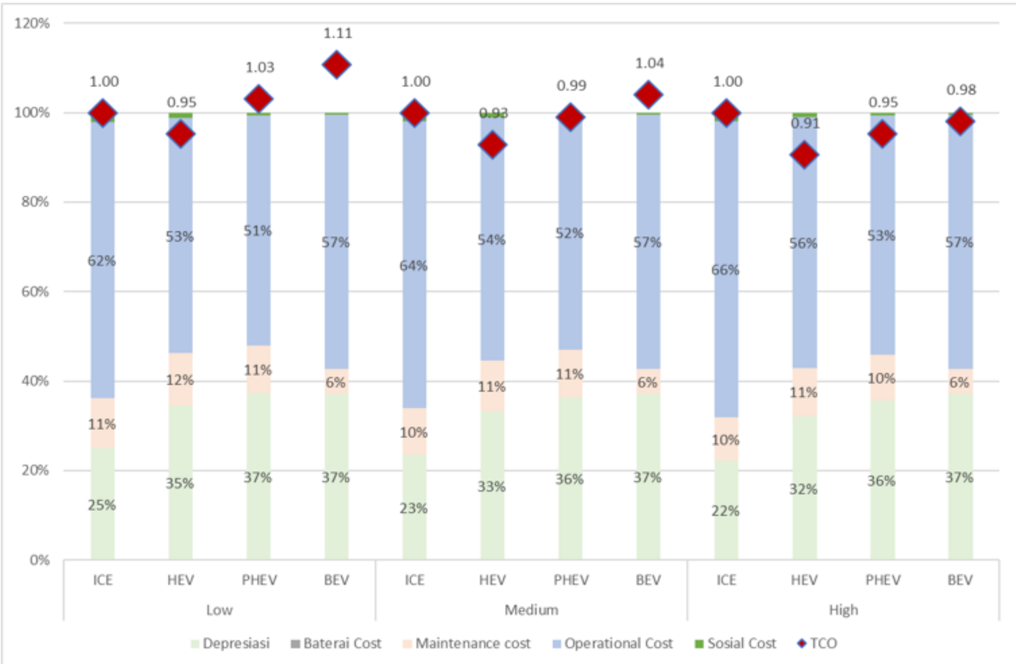


Figure 4.3. Comparison between TCO Ratio in ICE, HEV, PHEV dan BEV and 25.000 AKT per Year
Source: Estimations by LPEM FEB UI

assumption of medium and high fuel prices. This could be set as a good motivation to accelerate the national production of electric cars. The data on car users can be a useful instrument for the government to utilize when considering this matter. To target consumers, both businesses and the government may be able to target and provide incentive for users who drives great distances yearly. It is good to accelerate EV market in Indonesia. For instance, a strategic cooperation with taxi companies and/or other ride-hailing companies is one way to introduce EV to the appropriate parties.

4.2 The Influence of Duration of Car Ownership

To see the influence of car ownership duration (5 years (moderate), 10 years (long), 16 years (very long)), we have conducted a simulation to calculate TCO by altering the assumption of car ownership duration. It should be noted that in this analysis, we always apply 3 fuel price scenarios given the importance of fuel to operate ICE-type cars (as well as their impact on TCO balance). Thus, readers would be able to receive a more intuitive picture when oil prices increase and/or decrease in the simulation.

The result of our simulations are as follows. We set all other key assumptions on a moderate level; meaning the moderate distance used would be 18.000 km per year. From the results, there are several things which can be understood. In terms of alterations in car ownership assumption, in general we can state that the long-term usage of EV is indeed economical yet not as significant. Observing the three images, it is easy to conclude that a 5-year (and above) usage of EV, the TCO value for HEV is the only one as economical as that of ICE.

Changing the duration of car ownership to 10 years resulted in TCO ratio for all EV. Even so, the obvious change lies in the fact that PHEV and BEV were still likely to be more expensive than ICE. The same result can be seen when the duration of car ownership was to be increased to 16 years, with the decline of EV TCOs, though the ratio of PHEV and HEV were generally still less economical than that of ICE. On the exception one scenario which is the 16-year ownership scenario with high fuel price (right side of the last picture), in which PHEV became as economical as ICE.

One thing that is needed to be emphasized is that even with the shortest span of ownership (5 years with 18.000 km of AKT), the TCO ratio for HEV is as equal as, if not lower than, that of ICE. This indicates a good result for the acceleration of national electric car. Although, in general it is safe to say that the duration of car ownership still can not be considered as a key instrument to encourage consumers in considering electrified cars.

Moreover, in terms of composition of cost itself, it is obvious that in general the duration of car use will increase the amount of maintenance costs for all types of cars available. Furthermore, operational costs experienced a decline the longer the duration of car ownership. It may well be argued that the change of ownership duration contributed in the cost composition of a vehicle and stakeholders can see as well as adjust policies when conducting incentives in terms of cost composition.

Among all the simulations used to determine the cost of ownership for ICE and EV as presented, it can be argued that in general with 5 and 10 years of ownership, possession of HEV is the most rational choice than the possession of any other cars as mentioned previously when the annual distance traveled is within a moderate or high rate. Indeed, in terms of a shorter annual distance traveled TCO of conventional car (ICE) may be lower, yet the difference between its TCO with that of Hybrid Vehicle (HEV) is not as drastic, only amounting to 1–7% depending on fuel price assumptions. However, with a moderate mileage and a high type of ownership, the possession of HEV becomes the most reasonable for its low TCO. The percentage difference for HEV and ICE's TCOs may be able to reach 2–19%, depending on ownership period and fuel cost assumption in the future. PHEV and BEV have a lower TCO than that of conventional car with a higher annual mileage and the assumption of normal and high fuel price both for 5 and 10 years of ownership. The percentage difference between PHEV and BEV amounted to 1–5%.

4.3 The Influence of Duration of Car Ownership

The cost of fuel has a significant role in establishing the cost of car usage. For this reason, this study conducts multiple simulations using variations of different level of fuel prices; low, medium, and high. To observe the impact of fuel prices itself, we conducted a simulation by altering the assumptions above, namely those related to car ownership and AKT.

As seen in Figure 4.5., a significant increase in fuel prices can be seen to reduce TCO of EV. This occurs consistently in all scenarios both in the AKT and/or the duration of ownership. Therefore, it may as well be said that fuel prices can be a relatively influential instrument for policy makers and market players to encourage people in using electrified vehicles. Related government agencies can carry out policies to raise incentives for using EV by increasing fuel prices on a regular basis, combined with other incentives.

4.4 Car Ownership

The reason for the high value of TCO for EV, especially those of plug-in hybrid (PHEV) and battery electric-type (BEV) is due to its higher initial price compared to that of ICE. As a result, price becomes quite influential towards the high and low total cost of ownership for EV. There are several strategies, one of many is a government intervention through the subsidy and tax exemption (the elimination of PPnBM) which would result in a more affordable price.

If a simulation to decrease TCO through the elimination of PPnBM were to be done, a simulation of 5-year ownership and close as well as moderate average distance will be carried out. With the implementation of PPnBM elimination when the average mileage is close, TCO of EV declined drastically to only 3–9% compared to without any subsidy, although its TCO could still be higher than that of ICE with every fuel price assumption. However, if the implementation of PPnBM elimination with a moderate average mileage was to be carried out, then TCO of EV will be 7–8% lower than that of a ICE especially in a high fuel price scenario. Therefore, the policy of eliminating PPnBM becomes effective with further distance, added with high fuel price in the future though it still cannot compensate the use of car at a closer distance. Hence, there should be other instruments added so that TCO of EV can at least be as equal to that of ICE in order to attract consumers (See Figure 4.6).

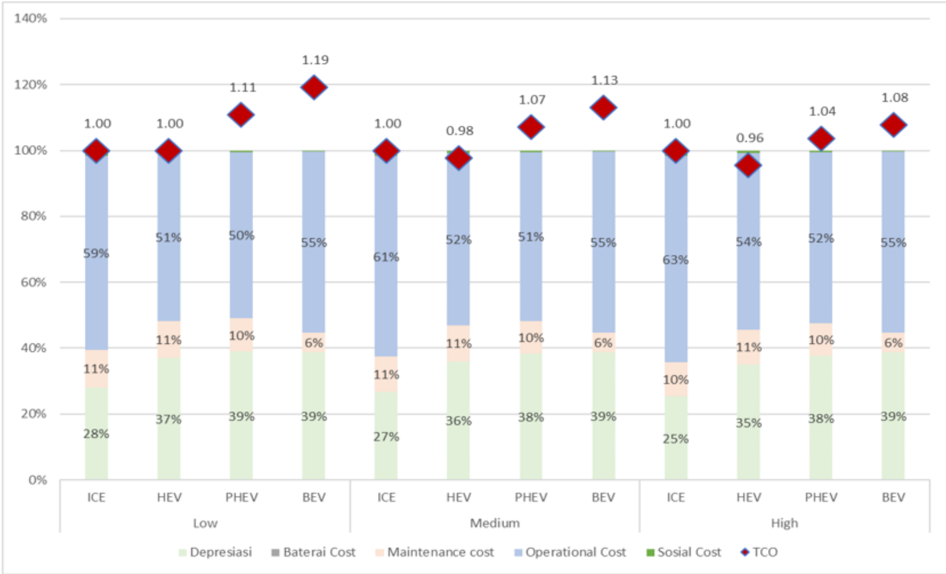
Considering the results above, the subsidy for EV price is one of the most significant instruments to affect the comparison of ICE and EV's TCOs. Even with the subsidy of only 10%, HEV and PHEV can already be as competitive as conventional cars when fuel prices are at medium and high.

Meanwhile, all of the EV are considered as competitive at a high fuel price in the simulation with the subsidy of 20%. Furthermore, all EV are also considered to be as competitive in all level of fuel price if the subsidy were to amount to 30% out of the total car cost.

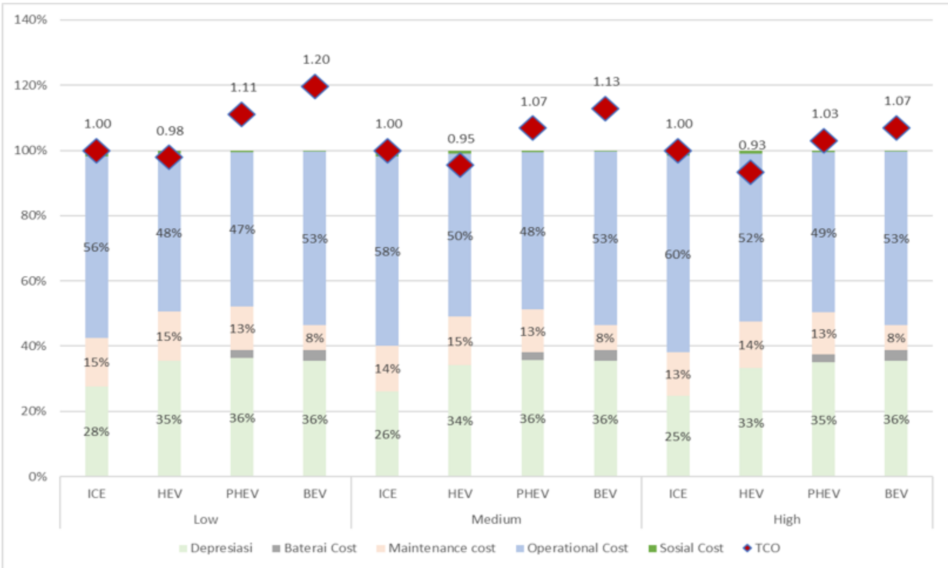
In conclusion, the amount of PPnBM given for EV can be one of the basic alternative policies to target consumer demand. On the other hand, the cost needed to be borne by the government must also be considered.

4.5 The Influence of the Subsidy of Parking Cost

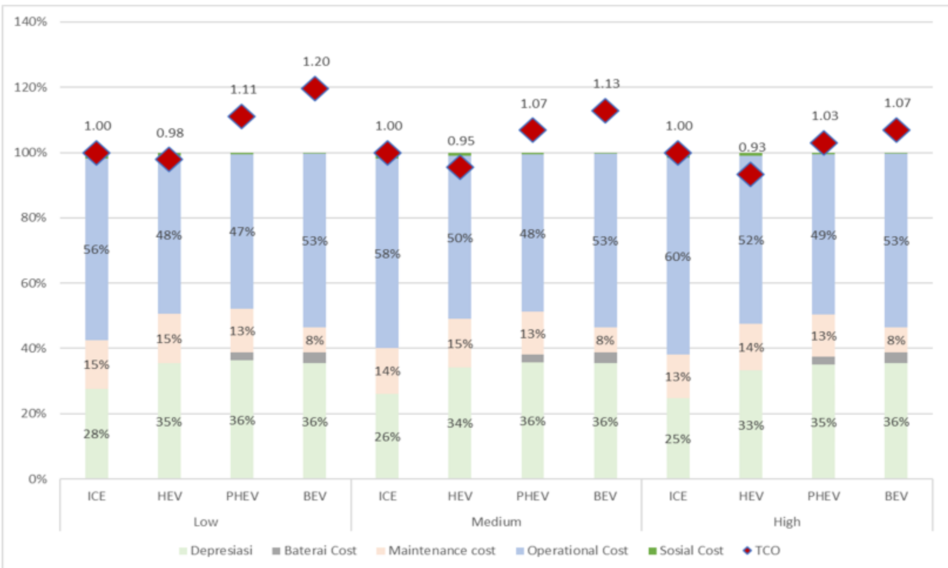
Another subsidy that can be exercised by the government is the subsidy of EV parking expense. An example of subsidy that may be applied is the exemption of EV parking fee for (100%), and or a half-price (50%) discount for all types of EV. This policy may be applied to appeal consumers in



(i)



(ii)



(iii)

Figure 4.4. Comparison of TCO Ratio among 5, 10, dan 16 Years of Ownership
Source: Estimations by LPEM FEB UI

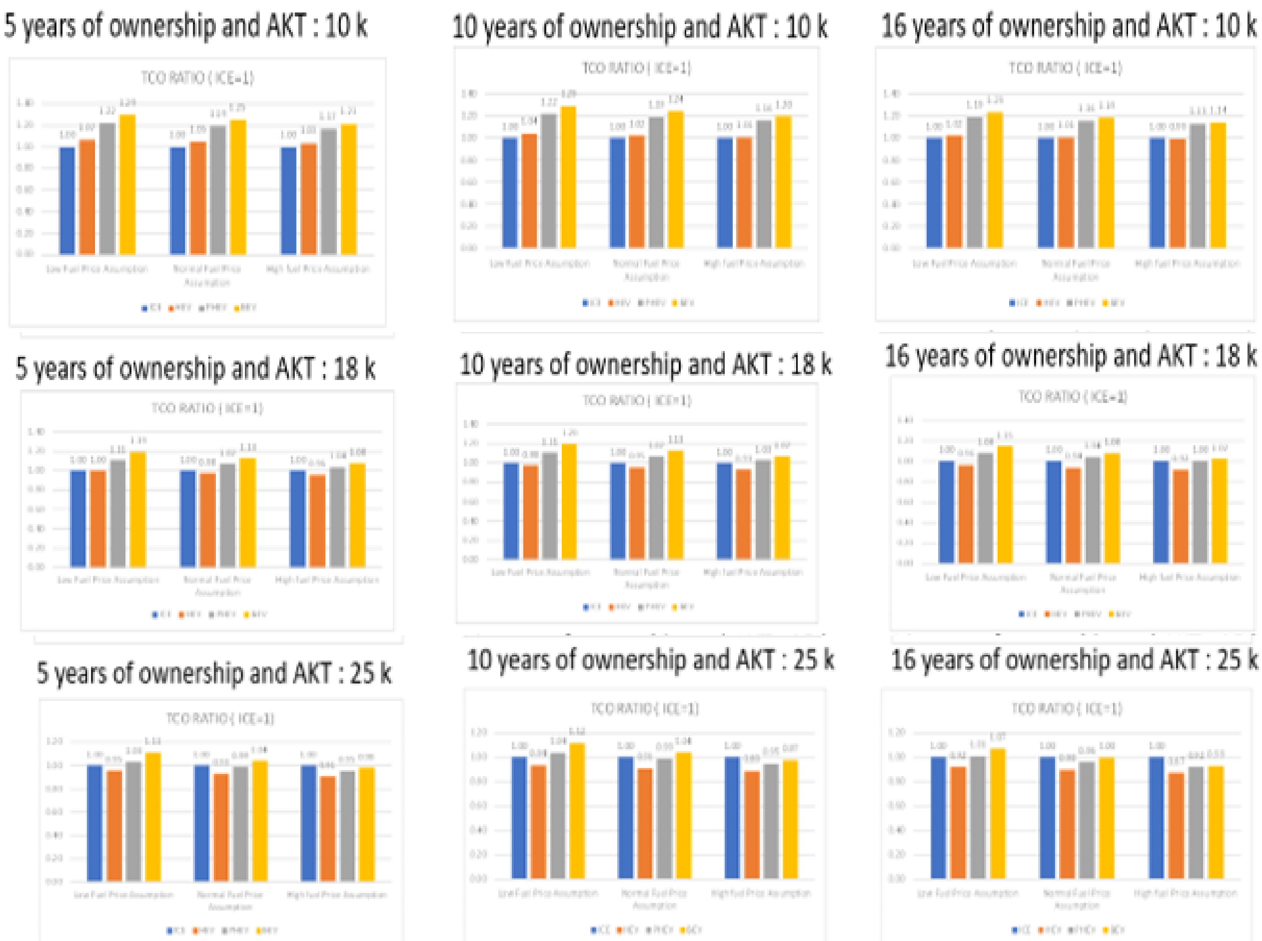


Figure 4.5. Comparison of TCO Ratio base on Year of Ownership and AKT
Source: Estimations by LPEM

using EV. Comparison between the moderate value without any parking subsidy, a 50% subsidy, and a full subsidy are as follows.

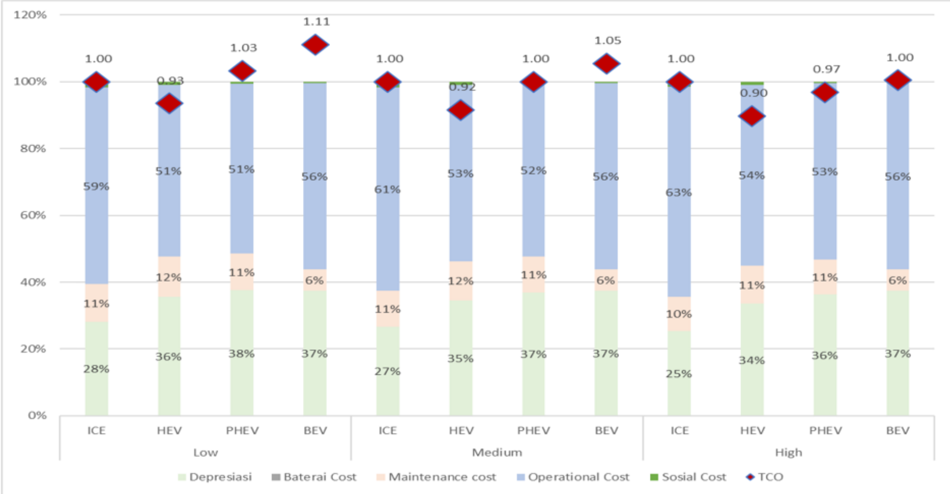
Generally, it can be observed that the exemption of parking causes PHEV to be more competitive in the high fuel price scenario with only half-price exemption (discount). Meanwhile, with full exemption of parking cost, PHEV is able to compete in both medium and high fuel price scenario whereas BEV is able to do the exact same only on the high fuel price scenario

5. CONCLUSION

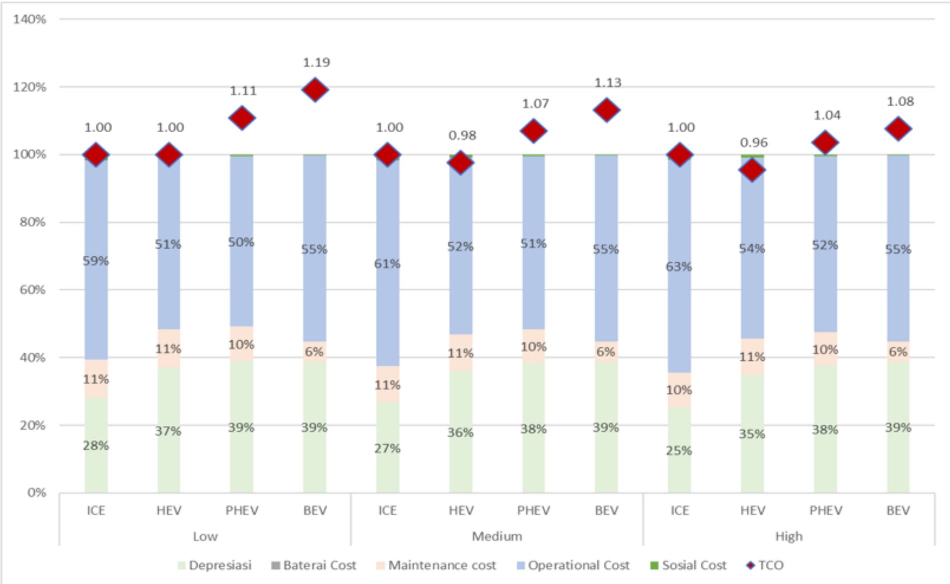
Based on literature review and analysis that have been conducted in this study, it can be concluded that TCO for electrified vehicle tends to decline while the technology battery for electrified cars climbs higher. In terms of operational cost, HEV and PHEV have lower operational cost than ICE and BEV, while in terms of the maintenance cost and social cost, BEV has the lowest TCO. Generally, BEV still has the highest TCO because the price of a BEV car is relatively very expensive compared to the ICE, HEV, and PHEV.

Generally, the longer and the higher the frequency of the vehicle, the more competitive TCO for HEV, PHEV, and BEV compared to the TCO for ICE. The TCO for BEV are close to the TCO for ICE when the usage of the car is up to 25,000 km travelled per year.

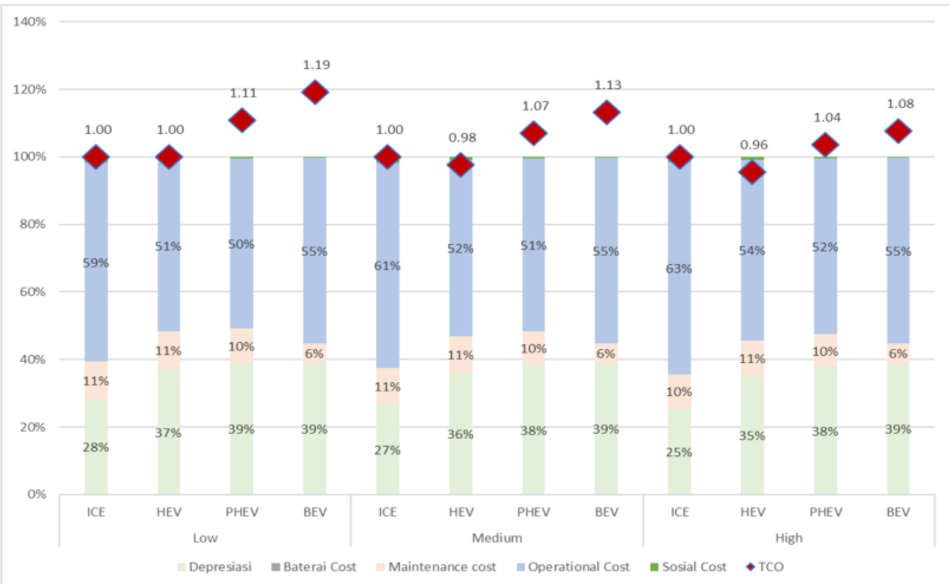
If the fuel price rises, BEV cars will have a lower TCO and BEV will become more appealing for the customers. The reduction for PPnBM will result in TCO for PHEV and HEV closing in to ICE's. Even the of exemption of PPnBM and the rising the fossil fuel price will give PHEV and BEV a lower TCO than ICE's.



(i : 10% tax reduction)

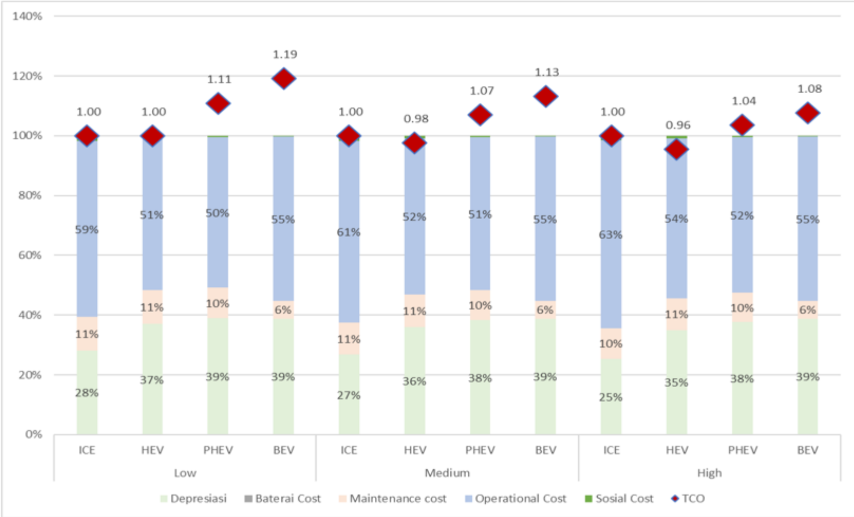


(ii : 20% tax reduction)

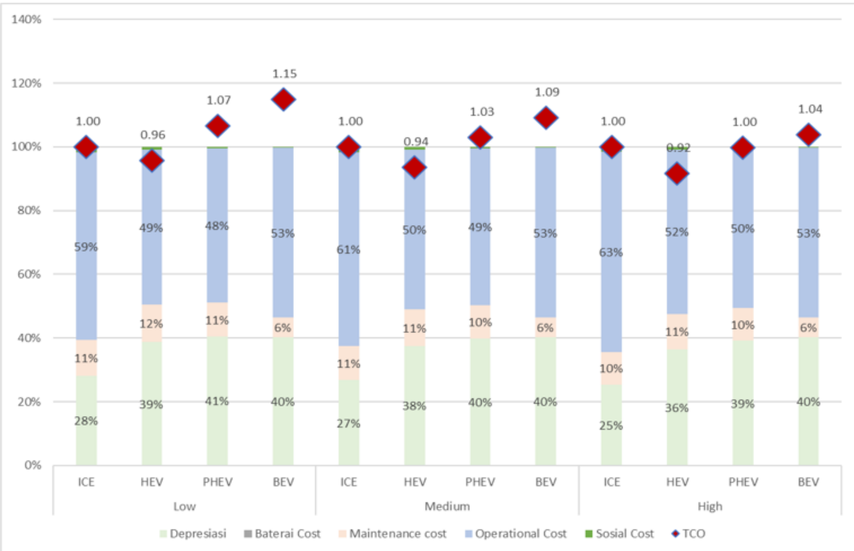


(iii : 30% tax reduction)

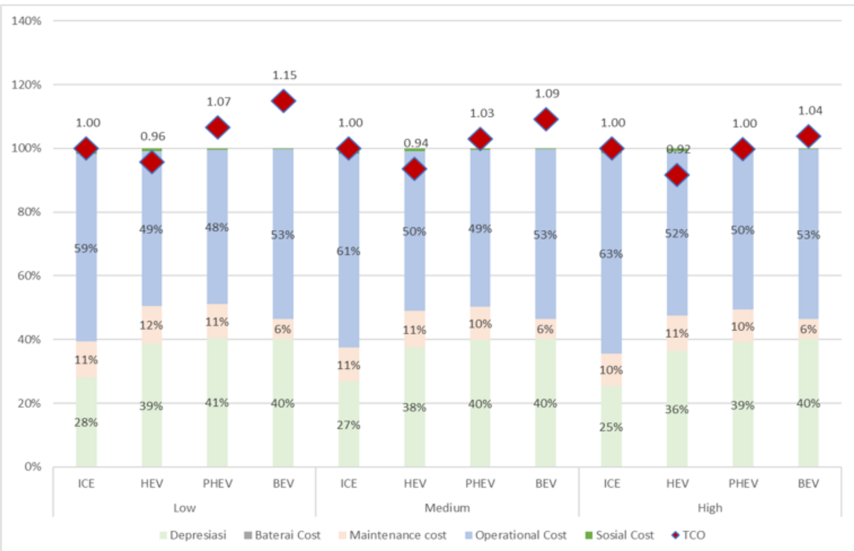
Figure 4.6. Comparison of TCO Ratio in Electric Vehicle Subsidy of 10, 20, and 30 percent
Source: Estimations by LPEM FEB UI



(i: no parking cost subsidy)



(ii : 50% parking cost subsidy)



(iii : 100% parking cost subsidy)

Figure 4.7. Comparison of TCO Ratio in Parking Cost Subsidy of 0, 50, and 100 percent

Source: Estimations by LPEM FEB UI

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