ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN855

Total Cost of Ownership of Electric Car and Internal Combustion Engine Car with Performance Normalization

[1]Adhe Budi Santoso
Department Energy System Engineering
University of Indonesia
Indonesia

[2]Bambang Priyono
Department Energy System Engineering
University of Indonesia
Indonesia

Abstract:- In the transportation sector, motorized vehicles are currently a contributor to pollution in Indonesia, producing CO2 emissions. In an effort to achieve environmentally friendly and low-carbon motorized vehicles, promoting electric cars to the public is an important strategy that is being pursued by countries throughout the world. The large target of converting ICE cars to electric cars requires a series of analyzes to accelerate efforts to convert the use of electric cars from various angles which will ultimately be successful as a promotional medium for potential electric car users. To carry out this analysis, there is one calculation method, namely calculating the total cost of ownership (TCO) of an electric car. This method has been studied in countries that are concerned with promoting the use of electric cars. In this research, we will present a calculation model for the TCO of electric cars and the TCO of conventional internal combustion engine (ICE) cars as a comparison. The cars analyzed in this research consist of several electric cars and ICE cars according to their respective performance levels, where for each electric car an analysis of several battery ownership schemes is also attempted, namely those owned by the car owner, rental batteries and those owned by the car owner. However, some components can be repaired. The calculation model will consist of capital and operational costs, namely the purchase price, resale value, government subsidies, retailer discounts, battery replacement costs, maintenance, insurance, vehicle tax and energy consumption costs. All data was obtained from literature studies and information from vehicle distributors in Indonesia. The TCO model is analyzed based on the average distance traveled, namely 20,000 km/year for 10 years of driving. The research results show that the TCO of BEVs with a rental battery scheme is cheaper than ICEs for cars with 93, 167 & 210 hp, namely 2,961; 6,227; & 5,633 (USD) and the TCO of ICE is cheaper than BEV with a rental battery scheme on cars with 40 & 95 hp, namely 796 & 5,793 USD. Several components that make up TCO costs will later be proposed to be considered for adjustment so that vehicle purchases can grow significantly. Knowledge from this research can be useful for consumers, product manufacturers, planners, and government policy makers.

Keywords:- *Electric Vehicle; Total Cost of Ownership; Indonesia; Energy Consumption; Electric Car.*

I. INTRODUCTION

Global warming and climate change are difficult human problems and have become a significant global concern in this decade. Efforts to find more sustainable solutions in various matters and aspects have been proposed to overcome this problem, such as teaching and transmitting alternative energy to surrounding communities and encouraging through research the transition to more sustainable materials to encourage the determination of transition policies to control greenhouse gases. glass. Many countries currently have set ambitious targets for controlling GHG problems, especially carbon dioxide (CO2) emissions. The transportation sector as a whole accounts for more than a quarter of global CO2 emissions [1]. Therefore, advocates for environmental conversations from every level of society in the world are promoting the electrification of transportation to decarbonize the transformation sector which mostly uses fossil fuel energy such as gasoline and diesel. Promoting electric vehicles (EVs) towards the immediate phase of reducing the number of conventional internal combustion engine (ICE) vehicles is an important strategy for countries around the world. Based on the results of an existing review or outlook, by 2025, Norway plans to place only electric vehicles in all new car markets, while China targets to make electric vehicles account for one-fifth of the domestic new car market [2]. The European Union is committed to reducing CO2 emissions by 40% by 2030 [3]. United Kingdom and California in the United States plan to end sales of ICE vehicles by 2040 [4]. Automotive manufacturers in many countries predict that electric vehicles will become the main power generator in the car market within a decade. In response to the rapid growth of electric vehicles in the future, many researchers around the world are paying attention to studying electric vehicles in various aspects such as CO2 emissions [5], energy consumption, and total cost of ownership (TCO).

The number of discussions related to EVs has existed since the oil embargo era in 1973, then continued with the number of studies on EVs increasing significantly since 2018 because EVs are used in transportation practices, as private vehicles and also public transportation. In the electric car

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN855

market, there are several electric vehicle technologies, consisting of hybrid electric vehicles (HEV), plug-in hybrid vehicles (PHEV), and battery electric vehicles (BEV). The impact of electric cars on CO2 emissions and energy consumption of each type of EV has been widely analyzed in countries that have metropolitan cities and EV promotion policies. Based on the data, in Beijing the CO2 emissions and energy consumption of EV private vehicles and EV taxis were studied [6,7]. EV taxi travel patterns in New York have also been analyzed to optimize EV feasibility [8].

Most researchers pay direct attention to studying the environmental impact, energy efficiency and the total costs that must be paid for an electric vehicle, this plays an important role in buyers' decisions in purchasing electric vehicles and the government's encouragement in determining the most appropriate policies. If comprehensive information on the overall costs over the lifetime of electric vehicles is provided, this could be useful for consumers, government policy makers in each country and product planners. In recent years, with the increasingly rapid growth of electric vehicles, the total cost of ownership of electric vehicles has been studied in countries that want to use electric vehicles as the main vehicle in their transportation sector soon [9-11]. Various TCO models have been proposed to provide more comprehensive information to Decision makers in understanding the lifetime costs of EVs. Expenditures, such as purchase price, battery costs, maintenance, insurance, vehicle tax and energy consumption costs are used in the TCO calculation model.

There are several TCO studies that have been conducted in countries with a high share of electric vehicles, such as China, the European Union, the United States, and Japan [9-12]. Because the costs and support of EVs will vary in each vehicle from a country, a TCO analysis is needed with a specific context for the conditions in that country. Apart from that, the conditions and assumptions of the TCO model will vary depending on the perspective of the research being proposed. For example, TCO research works in Italy, Germany, Sweden have presented case scenarios of government subsidized TCO models with different assumptions [11,13,10,14].

For countries taking the initiative to encourage electric vehicles in the automotive market such as Indonesia, TCO analysis will help stakeholders to better understand the total cost of electric vehicles. To the best of our knowledge, no comparison of TCO models based on different performance (EV and ICE) in Indonesia has been reported. This study proposes a comparative TCO model between Electric cars and conventional ICE. The EVs considered in this research include BEV cars with performance ratings of 40, 93, 95, 167, 210 hp. TCO analysis consists of capital and operational costs such as vehicle purchase price, battery costs, maintenance, insurance, vehicle taxes and energy consumption costs, and residual value. In this research, energy consumption costs are sourced or obtained from calculations of data on electric charging rates per kWh of electric car batteries in Indonesia and the assumed distance traveled in 1 year (20,000 km) according to the efficiency of the electric motor of each car. All expenditure data is considered appropriate to Indonesian conditions. Finally, the battery ownership case scenario is proposed as a recommendation for the government as a policy maker and manufacturer planner to encourage electric vehicles in the Indonesian car market.

II. DATA AND METHOD

A. Total Cost of Ownership

The core concept of TCO is to summarize all current and future costs of a product. When purchasing a vehicle with new technology such as an EV, the results of the TCO analysis are very important for prospective buyers to make a decision because there are several other cost variables besides the purchase price that will be charged during the use of the vehicle. TCO can be thought of as a decision-making tool in purchasing, the TCO model can help customers understand the true costs of owning a vehicle over its lifetime. At the same time, manufacturers and governments that better understand TCO can create much better planning and appropriate policies to support electric vehicles. The TCO model is very important because this method contains accurate estimates, assumptions and empirical data. The general equation for the TCO of a vehicle can be written as follows:

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

Where, CC shows capital costs while OC shows operational costs. Please note that the TCO unit used is US Dollars (USD).

CC, is the total cost of vehicle ownership which is paid once at the beginning, and can be expressed as

$$\boldsymbol{CC = MSRP - S_G - D_R + C_B} \tag{2}$$

Where, MSRP is the manufacturer's suggested retail price, S_G is the government subsidy, D_R is the retailer's discount, and C_B is the cost of the battery. The CC formula as referred to in (2) is only for calculations in the first year of electric car ownership and the C_B value is assumed to be 0, because the battery replacement will only be in the eighth year.

In the second year to the seventh year and the tenth year, CC is no longer taken into account. One of the CC parameters which is calculated again in the eighth year of electric car ownership, is CB or battery cost where the scenario used is that there is a battery replacement in the eighth year, so that CC in the eighth year can be expressed as

$$\boldsymbol{CC = C_B} \tag{3}$$

In the tenth year it is assumed that the car owner will sell his used vehicle, so the CC formula in the tenth year can be expressed as

$$\boldsymbol{CC = MSRP - R_V - S_G - D_R + C_B} \tag{4}$$

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN855

Where there is one additional parameter for RV, namely resale value, in the calculation of the ten other parameters forming CC besides RV, it is assumed to have a value of 0, because both the car price, government subsidies, retailer discounts and battery costs appear outside the tenth year.

OC, which represents the accumulated annual recurring costs over the lifetime of vehicle ownership, can be expressed as

$$\boldsymbol{OC = C_M + C_I + T_V + C_E} \tag{5}$$

Where, C_M is maintenance costs, C_I is insurance costs, T_V is vehicle tax, and C_E is energy consumption costs. The OC formula as intended in (4) is calculated every year.

In this research, we will try to analyze the TCO value of the 3 existing battery ownership schemes, which consist of: (scheme 1) owned by the car owner, (scheme 2) rented battery and (scheme 3) owned by the car owner but can be partially repaired. component.

The CC formula as intended in (3) only applies to analysis in (scheme 1) and (scheme 3), whereas for (scheme 2) the CC value is considered 0, because there is no battery replacement in the eighth year.

B. Model Parameters and Assumptions

In this study, the ownership period is assumed to be 10 years from 2024 to 2034. In addition, it is also assumed that the battery will be replaced in the 8th year of ownership. The model assumptions will be explained as follows:

➢ *Capital Costs*

The total one-time costs of purchasing a vehicle are accumulated in CC. The component of the price forming CC that experiences depreciation is the RV value, namely the resale value in the tenth year and the CB or battery cost in the eighth year when the battery is replaced, where the battery price has decreased in the year of replacement compared to the year the car was purchased (this happens in the entire scheme).

Depreciation on the value of an RV with a performance of 40 hp can be expressed as follows:

$$1st - 4th\ year = 33.89\% \tag{6}$$

$$5th - 10th\ year = 51.9\% * (6) \tag{7}$$

Depreciation on the value of an RV with a performance of 167 hp can be expressed as follows:

$$1st - 4th\ year = 3.07\% \tag{8}$$

$$5th - 10th\ year = 51.9\% * (8) \tag{9}$$

Depreciation on the value of an RV with a performance of 95 hp can be expressed as follows:

$$1st - 10th\ year = 71.83\% \tag{10}$$

Depreciation on the value of an RV with a performance of 93 hp can be expressed as follows:

$$1st - 4th\ year = 21.1\% \tag{11}$$

$$5th - 10th\ year = 51.9\% * (11) \tag{12}$$

Depreciation on the value of an RV with a performance of 210 hp can be expressed as follows:

$$1st - 4th\ year = 18.55\% \tag{13}$$

$$\boldsymbol{5th - 10th\ year = 33.89\% * (13)} \tag{14}$$

Vehicle MSRP is obtained from the selling price of new Indonesian cars in 2024, as shown in the Appendix.

SG is included in the TCO model to propose promotional options that policy makers, in this case the government, can provide for EVs. This needs to be pointed out because electric vehicles are still relatively new in the Indonesian commercial car market with unclear annual operating costs, the government's subsidy policy is very important for buyers. SG in the UK, France and Italy, ranges from 20% to 27% of the purchase price [13-16]. In this study, real data is presented on government subsidies given to several electric car brands according to their respective performance which can also be influenced by the value of domestic component levels [17].

DR is included in the TCO model to propose options to manufacturers to provide discounts to attract buyers and boost EV sales [18].

In this study, CB had a depreciation of 11.83% per year [19].

➢ *Operational Costs*

All recurring costs during the ownership period, such as annual fixed costs and other variable costs, have been included in the OC as shown in equation (5) [18]. The CM model in this research presents the required maintenance costs.

Annual recurring costs represent scheduled maintenance costs based on years of use or distance traveled. Some of these maintenance costs derived from data provided by the manufacturer are included in the CM model. BEV CM is lower than ICE vehicles for electric cars over 40 hp, but for electric cars with a performance of 40 hp the CM value is higher than ICE.

CI depends on vehicle factors such as model. There are two types of CI considered in the TCO model of this research, namely: Total loss only and all risk liability insurance where the availability of these 2 types of insurance can vary from the car model that we represent from the performance value [20].

TV shows motor vehicle tax from cars which is charged annually. The TV is based on the type of car.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN855

In this study, actual energy consumption obtained from the assumed driving distance of ICE and EV in each year by taking into account the values of liters and watt-hours per kilometer, respectively, is used to estimate CE. CE represents the cost of energy consumption based on the annualized vehicle mileage, which can be expressed as:

$$C_E = AD \times EC \times EP \tag{15}$$

Where, AD indicates the average distance traveled (km), EC is the energy consumption (L/km or Wh/km) obtained from manufacturer information, and EP is the energy price (USD/L or USD/Wh). Annual vehicle AD is assumed to be 20,000 km/year [18]. Fuel prices are based on the retail price of RON 90 in the metropolitan city of Jakarta from 2024 [21] and are projected to increase until 2034 based on the average increase in USA fuel prices over the last 45 years [22]. Electricity costs are based on the SPKLU (public electric vehicle charging station) tariff, which is 0.161 USD/kWh [23].

The data used in this study uses five EV vehicles and one ICE vehicle, EV vehicles represent 5 different performances 40 hp [24-33], 93 hp [34-41], 95 hp [42-47], 167 hp [48-55] and 210 hp [56-64] and for ICE vehicles the cost parameters were normalized following the EV comparator at each performance value. Characteristics of the six cars with BEV and ICE powertrains, are shown in the Appendix.

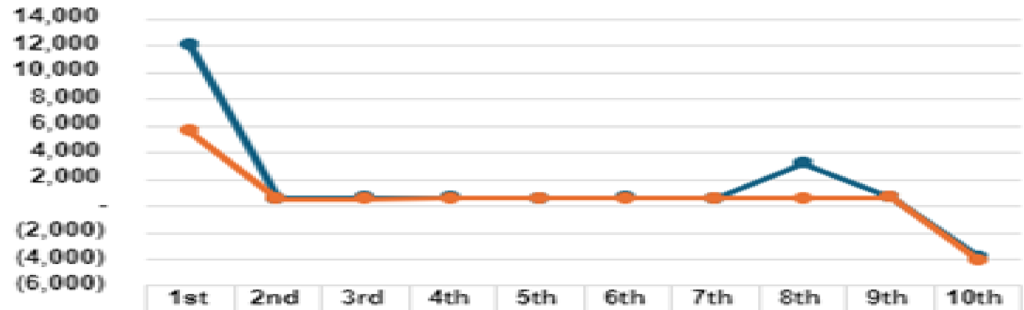
III. RESULTS AND DISCUSSION

To compare TCO between EV and conventional ICE vehicles, ICE TCO is normalized according to the performance of each existing EV.

In this study, a sensitivity analysis was carried out to estimate the influence of several parameters on the TCO model. Three case schemes to be researched and proposed, namely Scheme-1: battery ownership is owned by the car owner; Scheme-2: battery ownership is owned by the battery lessee; and Scheme-3: ownership of the battery is owned by the car owner, but the battery can be repaired only if some of the components are damaged.

A. *Scheme-1*

Figures 1, 2, 3, 4, 5 show the TCO model of 5 electric cars with different performance and 1 ICE car which is normalized to the performance of the electric car for the battery scheme owned by the car owner. The TCO of the battery is seen to have a high value in the first year in the 5 existing electric cars from ICE, because the MSRP of electric cars is still higher than ICE, in the second year to the seventh year it shows that the TCO of electric cars is 40 hp higher than ICE (Figure 1) this is inversely proportional to 4 other electric cars that have performance above 40 hp which have a lower TCO than ICE in the second to seventh years (Figures 2, 3, 4, 5). BEV TCO for cars with a performance of 40 hp to 167 hp jumped again in the 8th year due to battery replacement (Figures 1, 2, 3, 4) and cars with a performance of 210 hp only jumped in the ninth year due to the manufacturer's warranty for the battery during 8 years (Figure 5). After that, the TCO in the tenth year drops due to the appearance of a deduction, namely resale value, which arises because of the assumption that the car will be sold in the tenth year. The important point in this scenario is that the TCO of BEV is lower than that of ICE from the 2nd year until the year of battery replacement for cars with performance above 40 hp. In this context, customers can continue using the car by replacing the battery or stop investing and reselling in the eighth or ninth year.



	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
BEV Brand A (Battery Owned) (40 hp)	12,10	609	623	623	609	644	609	3,168	623	(3,79
ICE Brand A (40 hp)	5,644	532	541	575	577	558	576	586	621	(4,02

Fig 1 TCO BEV 40 hp (Battery Owned) v.s. ICE Normalized follows BEV

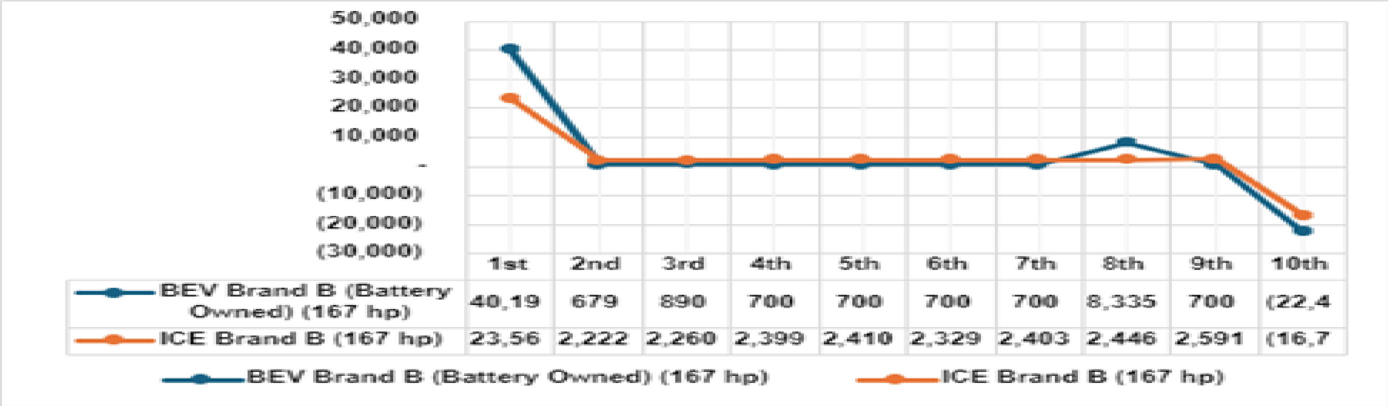


Fig 2 TCO BEV 167 hp (Battery Owned) v.s. ICE Normalized follows BEV

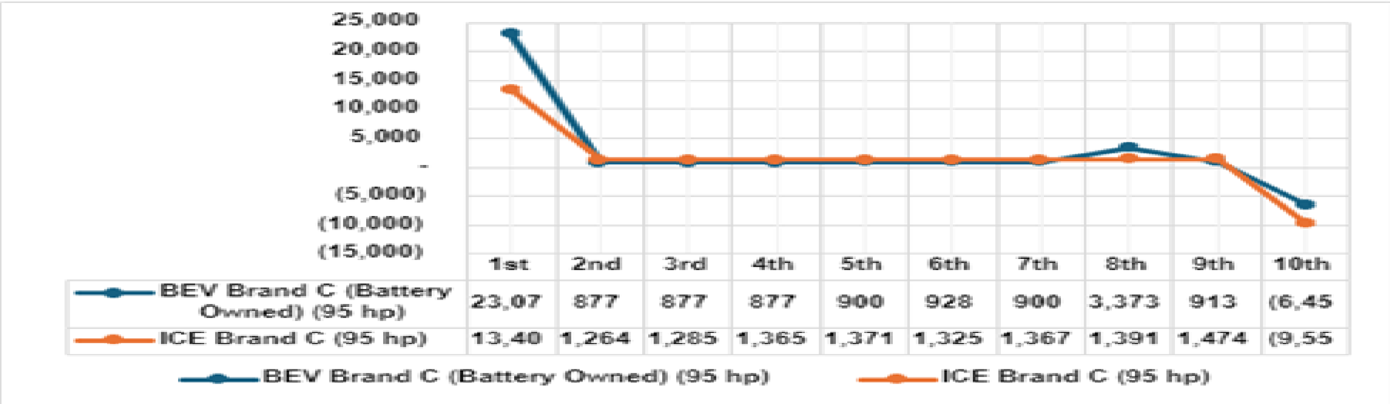


Fig 3 TCO BEV 95 hp (Battery Owned) v.s. ICE Normalized follows BEV

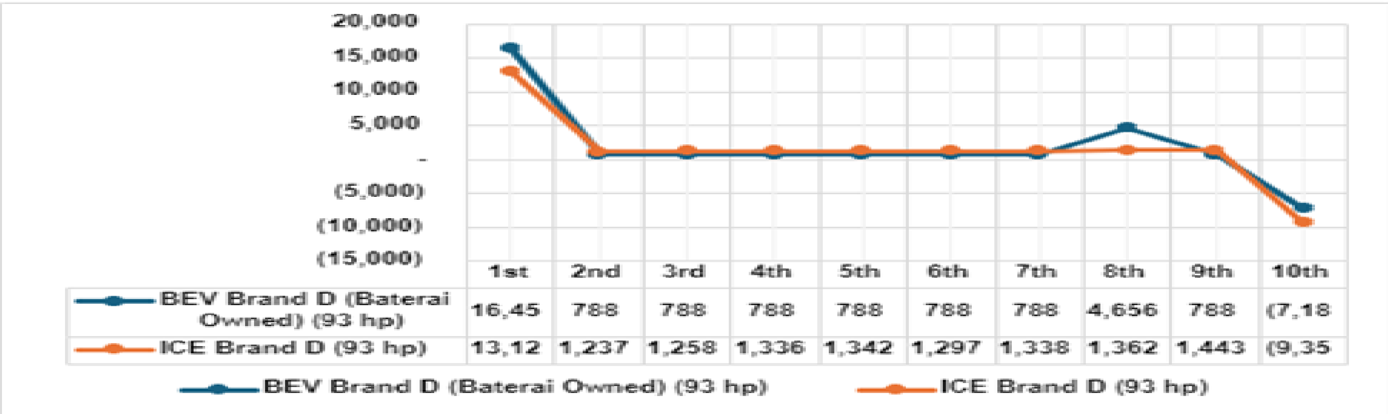


Fig 4 TCO BEV 93 hp (Battery Owned) v.s. ICE follows by BEV

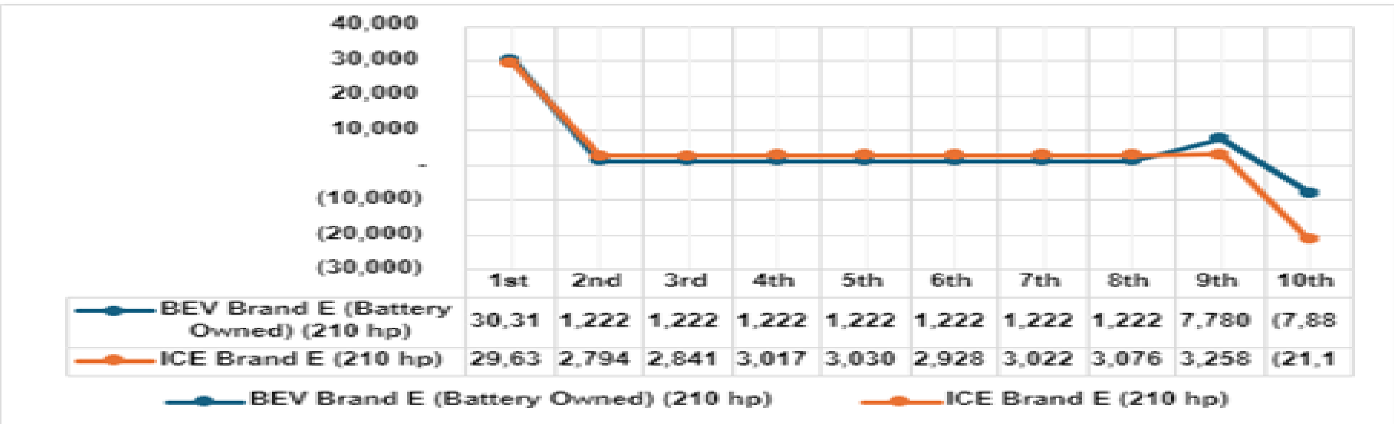


Fig 5 TCO BEV 210 hp (Battery Owned) v.s. ICE follows BEV

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN855

B. Scheme-2

Figures 6, 7, 8, 9, 10 show the TCO model of 5 electric cars with different performance and 1 ICE car normalized to the performance of the electric car for the battery scheme owned by the battery lessee. The TCO of rental batteries is seen to have a high value in the first year in 3 electric cars (brands A, B, C) and lower (brands D & E) than ICE, this higher value is because the MSRP of electric cars is still higher than ICE However, in the case of D & E brand cars there are subsidies from retailers which cause the TCO value to be lower than ICE in the first year, 4 electric cars (brands B, C, D, E) in the second to ninth year show that the TCO of electric cars above 40 hp is smaller than ICE (Figures 7, 8, 9, 10) this is different from 1 electric car which has a performance of 40 hp, the new TCO value drops lower than ICE starting in the 4th year, this is because in the second year and This third thing is because ICE cars with 40 hp performance can provide cheaper maintenance costs than BEVs (Figure 6). There is no BEV TCO displayed for cars with performance from 40 hp to 210 hp in either the eighth or ninth year because there is no battery replacement in this second phase (Figures 6, 7, 8, 9, 10). After that, the TCO for that year fell due to the emergence of a deduction, namely resale value, which appeared because of the assumption that the car would be sold that year. The important point in this scenario is that the TCO of BEVs is lower than that of ICEs from the 2nd to the ninth year for cars with performance above 40 hp and from the 4th to the ninth year for cars with a performance of 40 hp. In this context, customers can continue using the phone without changing the battery.

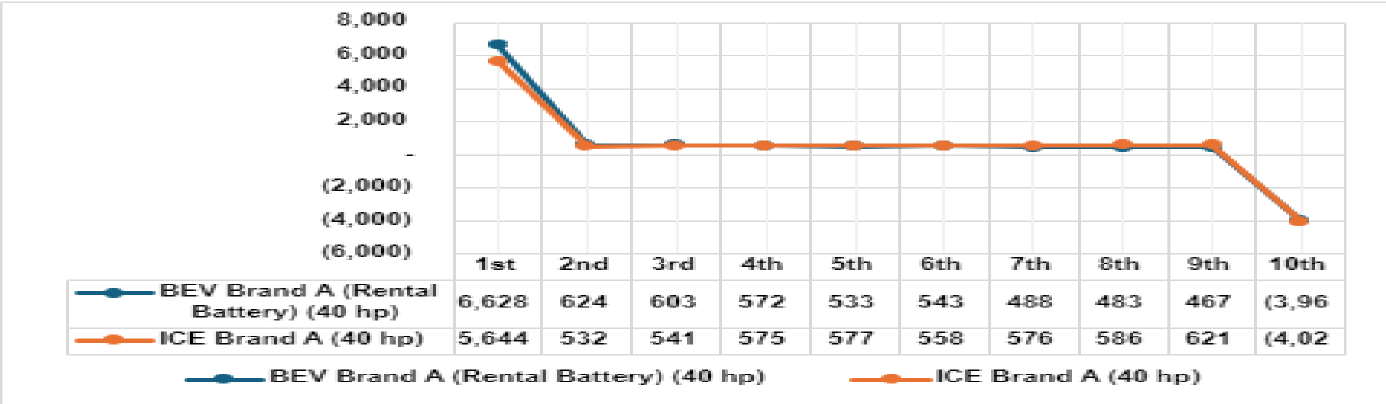


Fig 6 TCO BEV 40 hp (Rental Battery) v.s. ICE Normalized follows BEV

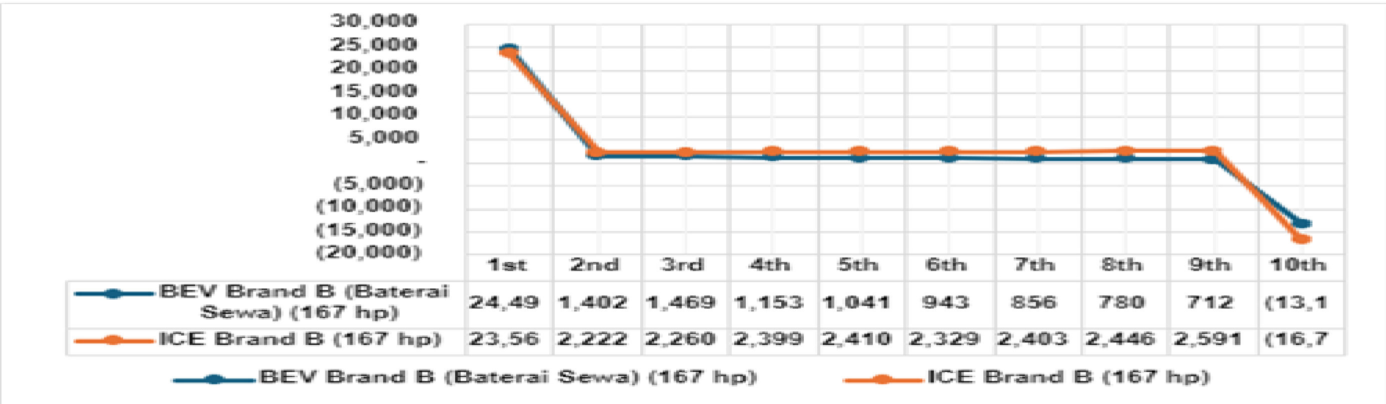


Fig 7 TCO BEV 167 hp (Rental Battery) v.s. ICE Normalized follows BEV

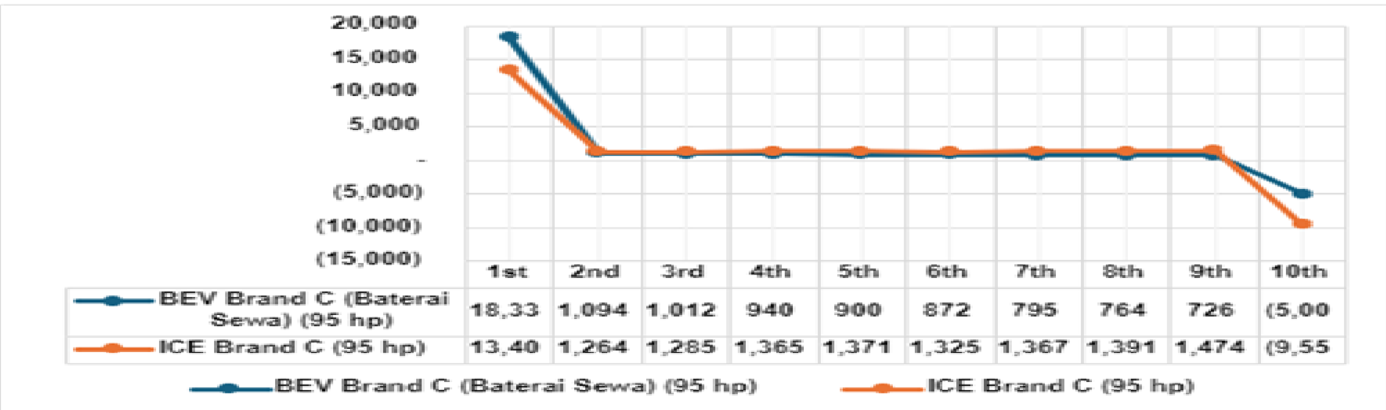


Fig 8 TCO BEV 95 hp (Rental Battery) v.s. ICE Normalized follows BEV

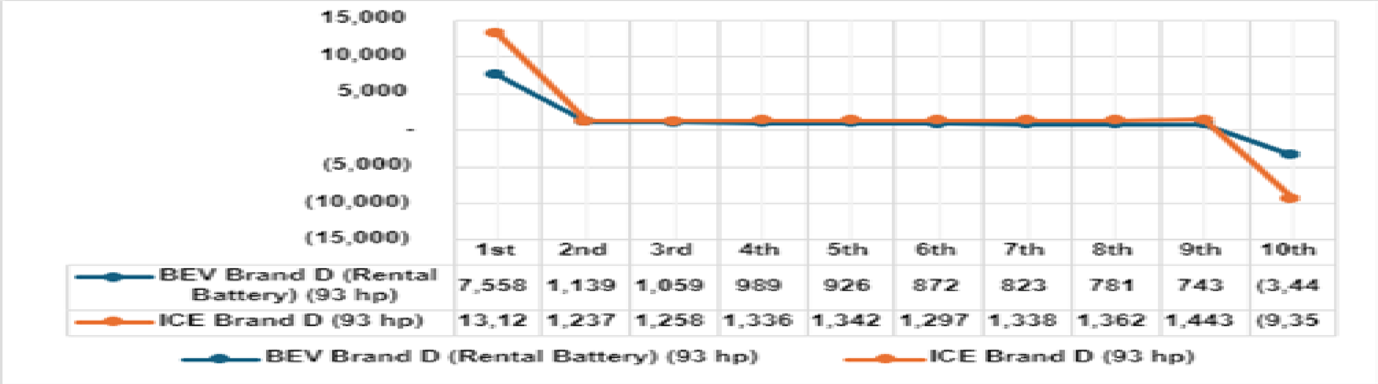


Fig 9 TCO BEV 93 hp (Rental Battery) v.s. ICE Normalized follows BEV

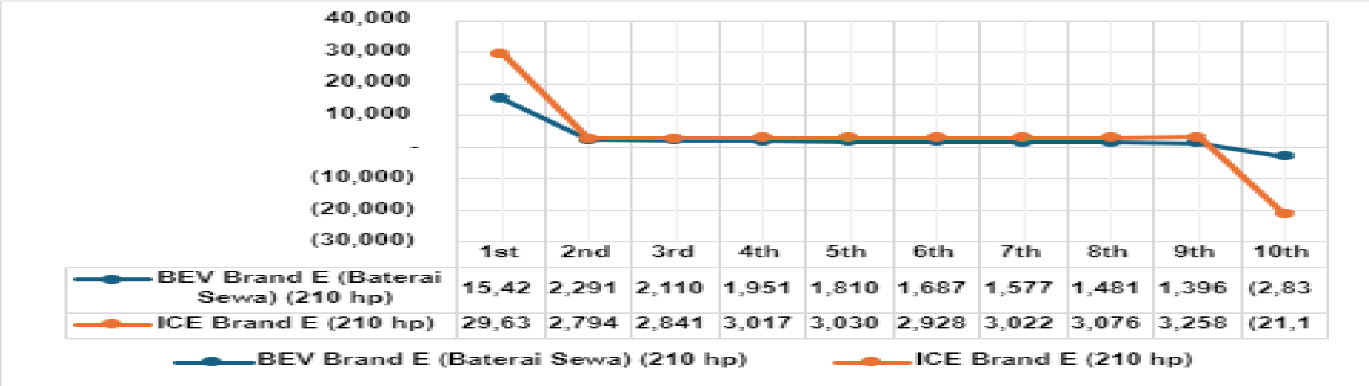


Fig 10 TCO BEV 210 hp (Rental Battery) v.s. ICE follows by BEV

C. Scheme-3

Figures 11, 12, 13, 14, 15 show the TCO model of 5 electric cars with different performance and 1 ICE car which is normalized to the performance of the electric car for the battery scheme owned by the car owner but the battery can be repaired in part. TCO in this scheme is seen to have a high value in the first year for 5 electric cars (brands A, B, C, D & E) from ICE, this higher value is because the MSRP of electric cars is still higher than ICE, TCO for 4 electric cars (brands B, C, D, E) in the second to seventh years shows that the TCO of electric cars over 40 hp is smaller than ICE (Figures 12, 13, 14, 15) this is different from 1 electric car which has a performance of 40 hp , the TCO value from the second year to the ninth year is still higher than ICE (Figure 11), this is because ICE cars with 40 hp performance can provide cheaper maintenance costs than BEVs (Figure 11). BEV TCO for cars with a performance of 40 hp to 167 hp jumped again in the 8th year due to battery replacement (Figures 11, 12, 13, 14) and cars with a performance of 210 hp only jumped in the ninth year due to the manufacturer's warranty for the battery during 8 years (Figure 5). After that, the TCO in the tenth year drops due to the appearance of a deduction, namely resale value, which arises because of the assumption that the car will be sold in the tenth year. The important point in this scenario is that the TCO of BEVs is lower than that of ICEs from year 2 to the year of battery replacement for cars with performance above 40 hp and also in this scheme the TCO value in the year of battery replacement has a smaller value than scheme-1, where Batteries can be repaired only on damaged packs. In this context, customers can continue using the car by replacing the battery or stop investing and reselling in the eighth or ninth year.

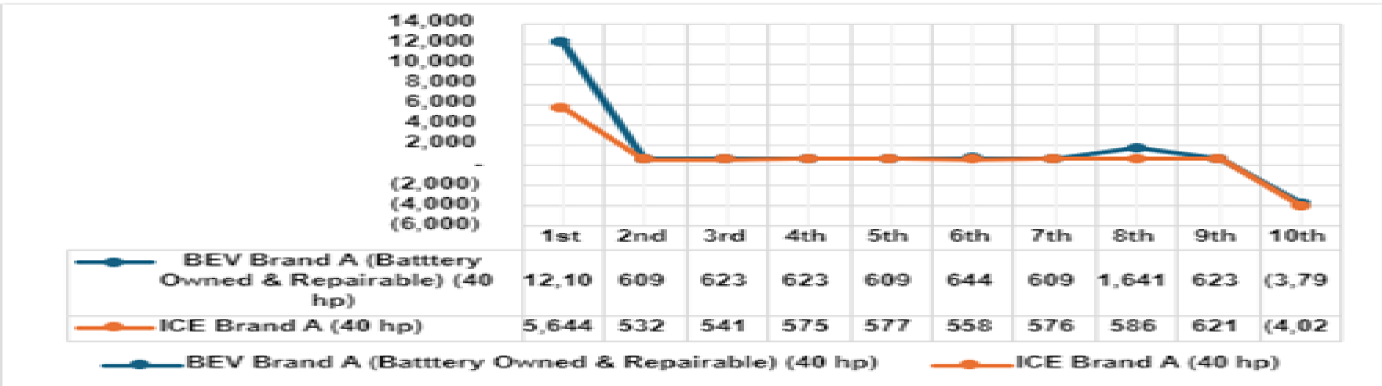


Fig 11 TCO BEV 40 hp (Battery Owned & Repairable) v.s. ICE Normalized follows BEV

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN855

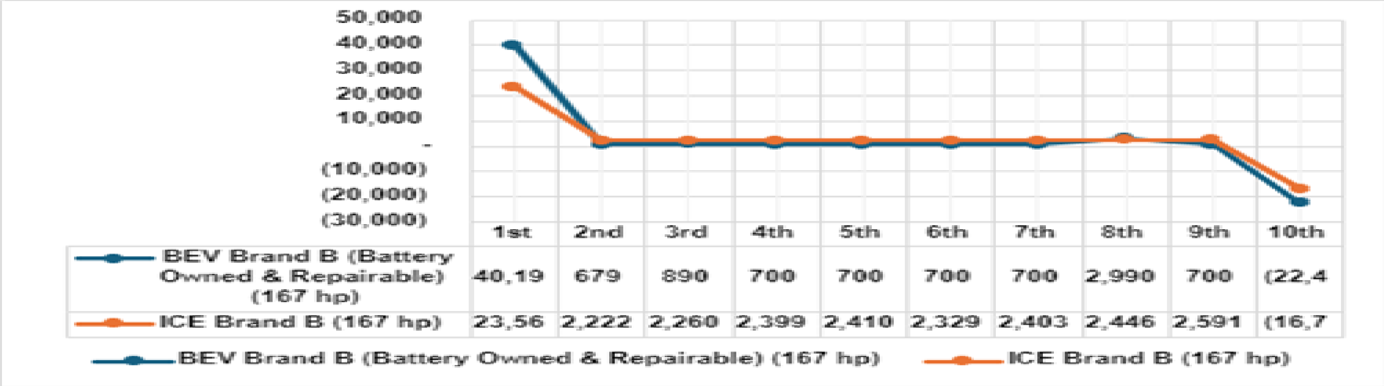


Fig 12 TCO BEV 167 hp (Battery Owned & Repairable) v.s. ICE follows by BEV

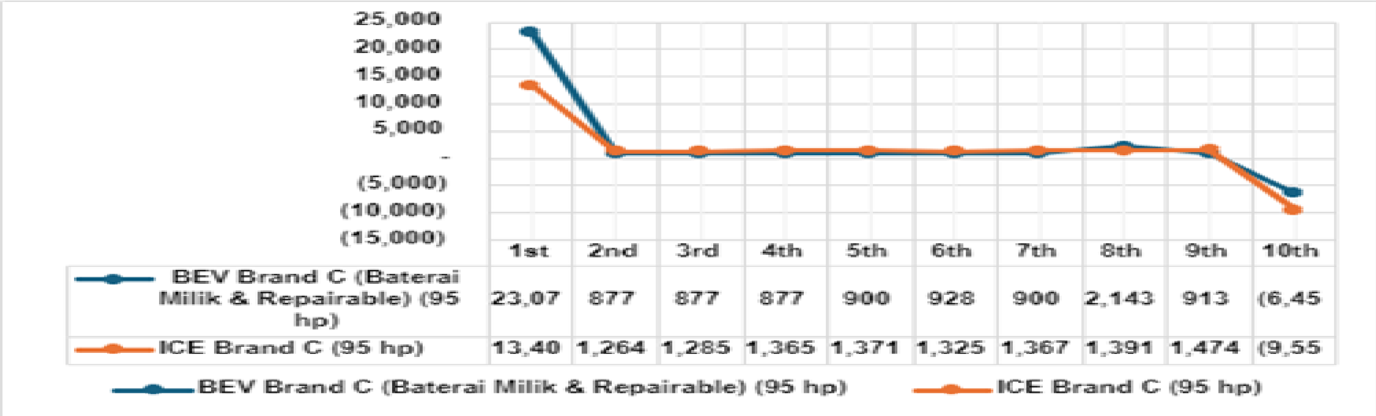


Fig 13 TCO BEV 95 hp (Battery Owned & Repairable) v.s. ICE follows by BEV

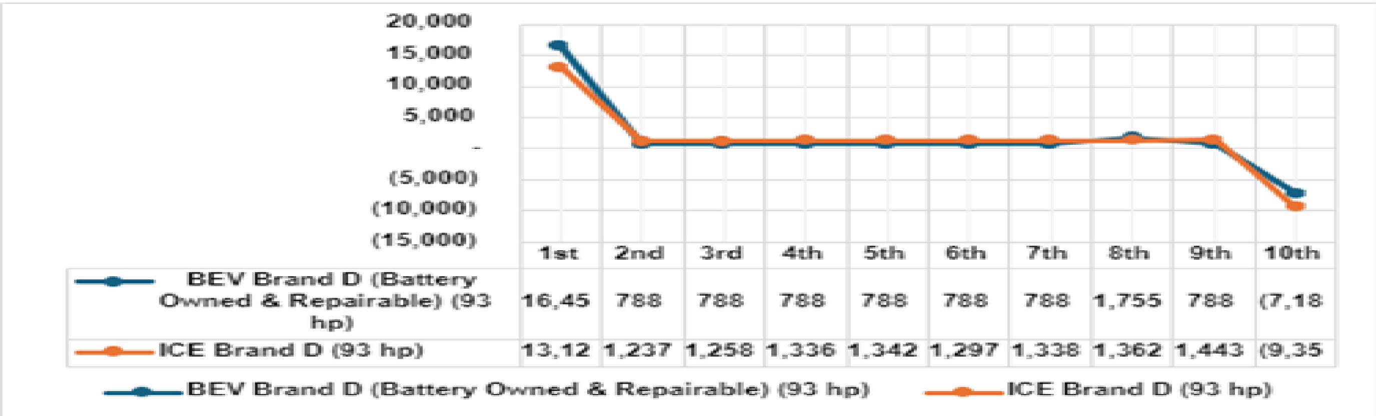


Fig 14 TCO BEV 93 hp (Battery Owned & Repairable) v.s. ICE follows by BEV

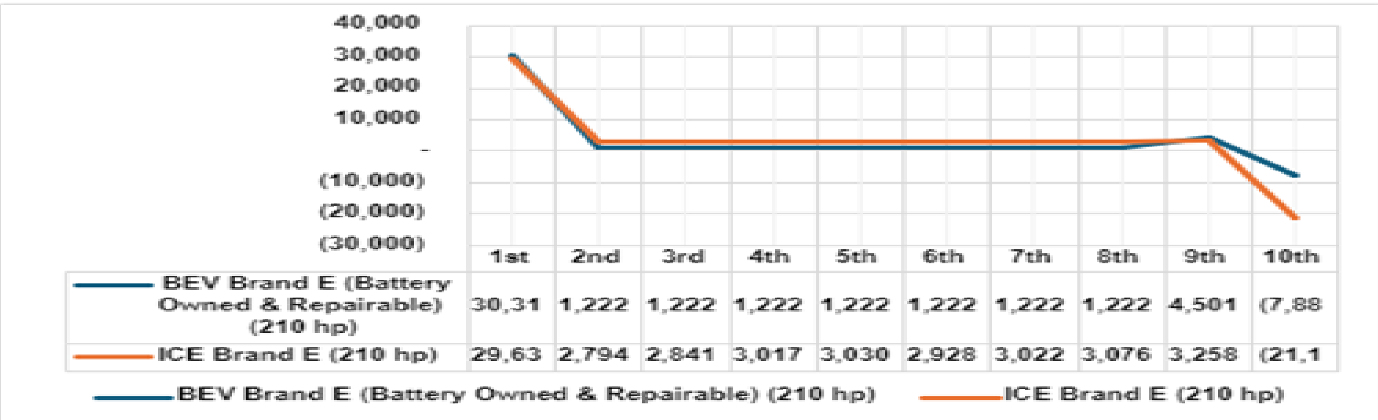


Fig 15 TCO BEV 210 hp (Battery Owned & Repairable) v.s. ICE follows by BEV

IV. CONCLUSION

➢ *This Research can be Concluded as Follows:*

- The order of the most efficient TCO values over a period of ten years, in order of the 10 most efficient is as follows: ICE 40 hp, BEV (Rental Battery) 40 hp, BEV (Rental Battery) 93 hp, BEV (Battery Owned & Repairable) 40 hp, ICE 93 hp, ICE 95 hp, BEV (Battery Owned) 40 hp, BEV (Battery Owned & Repairable) 93 hp, BEV (Battery Owned) 93 hp, BEV (Battery Rental) 167 hp.
- The comparison of TCO values for cars with 40 hp performance between ICE and BEV battery rental schemes (scheme-2) is in: cheaper MSRP value, higher retailer discounts, cheaper maintenance costs, cheaper insurance, and Cheaper energy consumption, making ICE cars 13 USD cheaper than BEVs.
- Comparison of TCO values for cars with a performance of 93 hp between BEV battery rental scheme (scheme-2) and ICE are: no burden on battery replacement in the eighth year, cheaper MSRP value, higher retailer discounts, more maintenance cheap and cheaper vehicle tax, making BEV cars 48 USD cheaper than ICE.
- Comparison of TCO values for cars with 40 hp performance between ICE and BEV battery owned & repairable scheme (scheme-3) is in: no expensive part replacement costs in the eighth year, lower MSRP value, higher retailer discount , cheaper maintenance and cheaper insurance costs, making an ICE car 132 USD cheaper than a BEV.
- Comparison of TCO values for cars with 40 hp performance between ICE and BEV battery owned scheme (scheme-1) is in: no expensive part replacement costs in the eighth year, lower MSRP value, higher retailer discounts, costs Cheaper maintenance and cheaper insurance, making an ICE car 156 USD cheaper than a BEV.
- Comparison of the TCO value for a car with a performance of 93 hp between a BEV with a battery rental scheme (scheme-2) and a BEV with a battery owned scheme (scheme-1) is that there is no charge for battery replacement in the eighth year and the MSRP is lower because the initial purchase price is not take into account the price of the battery.
- With the current policy support for BEV (battery owned), the TCO value cannot yet match that of ICE cars, ICE TCO is still 61% lower than BEV.
- The policy support needed if scheme-1 is chosen is to genericize batteries that will be used in the eighth year, government subsidies to reduce the MSRP value, encourage retailers to provide more discounts, reduce maintenance and insurance costs.
- The policy support needed if scheme-2 is chosen is to provide subsidies in an effort to reduce the MSRP value, encourage retailers to provide more discounts, reduce maintenance costs, insurance and energy consumption costs for battery renters.
- The policy support needed if scheme-3 is chosen is to genericize batteries that will be used in the eighth year, increase capacity in the form of a battery repair industry, government subsidies to reduce the MSRP value, encourage retailers to provide more discounts, reduce maintenance and insurance costs.
- Supporting electric vehicles directly against MSRP, such as government subsidies or retailer discounts, can have a significant impact reducing TCO from the first year of ownership. Scheme-2 has more sensitivity and efficiency than Scheme-3 and Scheme-1.

ACKNOWLEDGMENT

This work was supported in part by the University of Indonesia. The first author would like to thank the Department of Energy Systems Engineering, Faculty of Engineering, University of Indonesia.

REFERENCES

[1]. International Energy Agency, IEA. CO2 emissions from fuel combustion: Overview, global CO2 emissions by sector. 2020.

[2]. Chen Yuche, Wu Guoyuan, Sun Ruixiao, Dubey Abhishek, Laszka Aron, Pugliese Philip. A review and outlook of energy consumption estimation models for electric vehicles. 2020, arXiv preprint arXiv:2003. 12873.

[3]. United Nations Climate Change, UNCC. The Paris agreement. 2020.

[4]. Hertzke Patrick, Müller Nicolai, Schenk Stephanie, Wu Ting. The global electric-vehicle market is amped up and on the rise. McKinsey Cent Futur Mob 2018;1–8.

[5]. Palencia Juan C González, Araki Mikiya, Shiga Seiichi. Energy consumption and CO2 emissions reduction potential of electric-drive vehicle diffusion in a road freight vehicle fleet. Energy Procedia 2017;142:2936–41.

[6]. Hu Kezhen, Wu Jianping, Schwanen Tim. Differences in energy consumption in electric vehicles: An exploratory real-world study in Beijing. J Adv Transp 2017;2017.

[7]. Tu Wei, et al. Acceptability, energy consumption, and costs of electric vehicle for ride-hailing drivers in Beijing. Appl Energy 2019;250:147–60.

[8]. Hu Liang, Dong Jing, Lin Zhenhong, Yang Jie. Analyzing battery electric vehicle feasibility from taxi travel patterns: The case study of New York City, USA. Transp Res C 2018;87:91–104. [9]

[9]. Ouyang Danhua, Zhou Shen, Ou Xunmin. The total cost of electric vehicle ownership: A consumer-oriented study of China's post-subsidy era. Energy Policy 2021;149:112023. [10]

[10]. Letmathe Peter, Suares Maria. A consumer-oriented total cost of ownership model for different vehicle types in Germany. Trans Res D 2017;57:314–35.

[11]. Danielis Romeo, Giansoldati Marco, Rotaris Lucia. A probabilistic total cost of ownership model to evaluate the current and future prospects of electric cars uptake in Italy. Energy Policy 2018;119:268–81.
[12]. Palmer Kate, Tate James E, Wadud Zia, Nellthorp John. Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. Appl Energy 2018;209:108–19.
[13]. Scorrano Mariangela, Danielis Romeo, Giansoldati Marco. 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 2020;80:100799.
[14]. Hagman Jens, Ritzén Sofia, Stier Jenny Janhager, Susilo Yusak. Total cost of ownership and its potential implications for battery electric vehicle diffusion. Res Transp Bus Manag 2016;18:11–7.
[15]. Lévay Petra Zsuzsa, Drossinos Yannis, Thiel Christian. The effect of fiscal incentives on market penetration of electric vehicles: A pairwise comparison of total cost of ownership. Energy Policy 2017;105:524–33.
[16]. Rusich Andrea, Danielis Romeo. Total cost of ownership, social lifecycle cost and energy consumption of various automotive technologies in Italy. Res Transp Econ 2015;50:3–16.
[17]. Iom/mik, 2023, 1, 0, 0, 0, 1, https://www.cnnindonesia.com/otomotif/
[18]. Panna Sutakul, Wongkot Wongsapai, Thongchai Fongsamootr, Yuttana Mona, Kittikun poolsawat. Total cost of ownership of internalcombustion engine and electric vehiles: A real-world comparison for the case o Thailand . Energy Reports 2022.
[19]. Irena, 2021, 1, 0, 0, 0, 3, https://www.irena.org/Energy-Transition/Technology/Energy-storage-costs
[20]. Lifepal, 2024, 2, 0, 0, 0, 0, https://lifepal.co.id/plans/?area=B%20-%20DKI%20Jakarta
[21]. Pertamina, 2024, 2, 0, 0, 0, 13, https://mypertamina.id/fuels-harga
[22]. Us Inflation Calculator, 2024, 1, 0, 0, 1, 6, https://www.usinflationcalculator.com/
[23]. Kementerian ESDM, Peraturan Menteri ESDM No 1 2023
[24]. Wuling.id, 2024, 1, 0, 0, 0, 1, https://wuling.id/id/air-ev?product_id
[25]. OLX, 2024, 0, 0, 0, 0, 0, https://www.olx.co.id/item/wuling-air-ev-long-2023-cash-long-range-300-km-lite-short-iid-919816843
[26]. Bounche, 2024, 1, 0, 0, 0, 1, https://www.bounche.com/blog/agency/diskon-pajak-pertambahan-nilai-mobil-listrik-wuling-air-ev/
[27]. Selma Aulia, Aditya Maulana, Diskon Mobil Listrik Wuling Air EV Tembus, 1, 0, 0, 0, 5, https://otomotif.kompas.com/read/2023/11/13/171200915/diskon-mobil-listrik-wuling-air-ev-tembus-rp-36-juta
[28]. Antam, 2024, 1, 0, 0, 0, 2, https://www.logammulia.com/id/harga-emas-hari-ini
[29]. Ahmad Biondi, 2023, 1, 0, 0, 0, 4, https://otodriver.com/mobil-listrik/2023/jika-rusak-segini-harga-baterai-wuling-air-ev-jikddcdfrev
[30]. Dina Rayanti, 2022, 1, 0, 0, 0, 3, https://oto.detik.com/mobil/d-6451296/biaya-servis-wuling-air-ev-murahnya-bikin-heran
[31]. Bertold Ananda, 2023, 1, 0, 0, 0, 6, https://techno.okezone.com/read/2023/10/20/52/
[32]. Wulig.id, 2023, 1, 0, 0, 0, 6, https://wuling.id/id/blog/lifestyle/berapa-jauh-kemampuan-jarak-tempuh-wuling-air-ev
[33]. Oto, 2024, 1, 0, 0, 0, 2, https://www.oto.com/mobil-baru/wuling/ev
[34]. Neta, 2024, 2, 0, 0, 0, 21, neta.co.id
[35]. OLX, 2024, 0, 0, 0, 0, 0, https://www.olx.co.id/olxmobbi/item/jual-neta-v-tahun-2023-ev-mobil-full-listrik-iid-919753586
[36]. Rangga Rahadiansyah, 2024, 1, 0, 0, 0, 0, https://oto.detik.com/mobil-listrik/d-7230245/harga-mobil-listrik-neta-v-turun-rp-62-juta-sekarang-jadi-segini
[37]. Manuel Jeghesta Nainggolan, 2023, 1, 0, 0, 0, 5, https://www.suara.com/otomotif/2023/12/
[38]. Neta, 2024, 1, 0, 0, 0, 2, https://neta.co.id/id/news/biaya-kepemilikan-neta-v-hingga-100000-km
[39]. Redaksi, Jurnalis, Okezone, 2023, 1, 0, 0, 0, 7, https://otomotif.okezone.com/read/2023/12/
[40]. Neta, 2024, 1, 0, 0, 0, 2, https://neta.co.id/id/news/biaya-konsumsi-listrik-neta-v-lebih-efisien-dari-mobil-konvensional-hemat-hingga-87
[41]. Carmudi, 2024, Daya Motor Neta, 0, 0, 0, 0, 0, carmudi.co.id
[42]. BYD.Arista, 2024, 1, 0, 0, 0, 2, https://byd.arista-group.co.id/lokasi/jakarta/
[43]. Gemilang Isromi Nuar, 2023, 1, 0, 0, 0, 6, https://otodriver.com/berita/2023/bluebird-jual-25-mobil-listrik-byd-e6-bludbibcde6
[44]. Haa/haa, Tim Redaksi CNBC Indonesia, 2024, 1, 0, 0, 0, 9, https://www.cnbcindonesia.com/news/20240222070313-4-516588/sri-mulyani-bebaskan
[45]. Dicky Kurniawan, Wawan Priyanto, 2024, 1, 0, 0, 0, 0, https://otomotif.tempo.co/read/
[46]. Oto, 2024, 1, 0, 0, 0, 2, https://www.oto.com/mobil-baru/byd/dolphin/spesifikasi
[47]. Oto, 2024, Jarak tempuh pengisian penuh Dolphin, oto.com
[48]. Id-hyundai, 2024, 1, 0, 0, 0, 0, https://id-hyundai.com/mobil/hyundai-ioniq5/
[49]. OLX, 2024, 1, 0, 0, 0 ,0, https://www.olx.co.id/olxmobbi/item/ioniq-5-signature-long-range-2023-iid-919845127
[50]. Hyundai mobil, 2023, 2, 0, 0, 0, 1, https://hyundaimobil.co.id/news/details/ppn-1-khusus-untuk-hyundai-ioniq-5-berlaku-hingga-desember-2023#:~:text=10%3A52%20WIB-,PPN%201%25%20Khusus%20Untuk%20Hyundai%20Ioniq%205%20Berlaku%20Hingga%20Desember,diskon%20PPN%20menjadi%201%25%20saja
[51]. Ferry Sandi, 2023, 1, 0, 0, 0, 5, https://www.cnbcindonesia.com/news/20231228135608-4-500947/beli-ioniq-5-tak-lagi-inden-dapat-cashback-puluhan-juta
[52]. Dina Rayanti, 2023, 1, 0, 0, 0, 0, 4, https://oto.detik.com/mobil/d-6665876/bikin-penasaran-berapa-biaya-servis-hyundai-ioniq-5

[53]. Ryh/fea, 2023, 1, 0, 0, 0, 0, 8, https://www.cnnindonesia.com/otomotif/20230605185849-603-957966/biaya-pajak-ioniq-5-dan-air-ev-yang-kini-tak-perlu-dibayar-konsumen
[54]. Hyundai mobil, 2023, 1, 0, 0, 0, 2, https://hyundaimobil.co.id/news/details/lithium-ion-baterai-masa-kini-hyundai-ioniq-5
[55]. Hyundai, 2024, 1, 0, 0, 0, 0 1, https://www.hyundai.com/id/id/find-a-car/ioniq5/specification
[56]. Chery, 2024, 0, 0, 0, 0, 0, https://chery.co.id/models/omoda/types/omoda-e5
[57]. Mobil123, 2024, 0, 0, 0, 0, 0, https://www.mobil123.com/dijual/chery-omoda-5-rz-230t-dki-jakarta-citra-garden-5/14060479
[58]. Fea, 2024, 0, 0, 0, 0, 0, https://www.cnnindonesia.com/otomotif/20240206101444-603-1059165/harga-chery-omoda-e5-rp498-juta-termasuk-diskon-subsidi-mobil-listrik
[59]. CNN, 2024, 1, 0, 0, 0, 0, 8, https://www.cnnindonesia.com/otomotif/20240206101444-603-1059165/harga-chery-omoda-e5-rp498-juta-termasuk-diskon-subsidi-mobil-listrik
[60]. Radityo Herdianto, 2024, 1, 0, 0, 0, 0, 6, https://www.gridoto.com/read/224026325/segini-biaya-servis-mobil-listrik-chery-omoda-e5-sampai-5-tahun?page=all
[61]. Cermati, 2024, 1, 0, 0, 0, 0, 0, https://www.cermati.com/asuransi-mobil/t/semua?sortType=desc&carYear=2024&carBrand=chery&carSlug=chery-omoda
[62]. Redaksi okezone, 2023, 1, 0, 0, 0, 3, https://otomotif.okezone.com/read/2023/10/06/52/
[63]. Aries Aditya Putra, 2024, 1, 0, 0, 0, 0, 3, https://www.gridoto.com/read/224051584/segini-konsumsi-energi-mobil-listrik-chery-omoda-e5-seirit-apa
[64]. Mik/mik, 2024, 1, 0, 0, 0, 8, https://www.cnnindonesia.com/otomotif/20240116140654-603-1050185/ulas-spesifikasi-mobil-listrik-omoda-e5-yang-pakai-baterai-buatan-byd

APPENDIX

Powertrain	Fuel Type	Performance	Battery Capacity
BEV	Electric	40 hp	17.3 kWh
ICE	Petrol	40 hp	-
BEV	Electric	167 hp	58 kWh
ICE	Petrol	167 hp	-
BEV	Electric	95 hp	60.48 kWh
ICE	Petrol	95 hp	-
BEV	Electric	93 hp	40.7 kWh
ICE	Petrol	93 hp	-
BEV	Electric	210 hp	61.01 kWh
ICE	Petrol	210 hp	-