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Projection of the Demand for Charging Stations for Electric Passenger Cars in Indonesia

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Abstract: Indonesian Government has paid serious attention to using electric vehicles (EV). The high price of EV was considered to be one of the reasons for the slow growth of EV in Indonesia. As of year 2022, the number of charging stations is 332 units; however, the number of registered electric cars has only reached 2,106 units. This paper discussed estimating the number of future electric charging stations based on the growth of electric passenger cars until 2040. The Gompertz function model was used to forecast the quantity of passenger cars. The number of passenger cars was calculated using car ownership as a proxy based on per capita income. Furthermore, three different scenarios were used to predict the number of EV: the Business As Usual (BAU) scenario, the Moderate scenario (MOD) model (used for global growth conditions for electric cars), and the Advanced scenario (ADV) model (used for optimistic conditions). The demand for charging stations was determined using a ratio of 1:10 between charging stations and electric passenger cars. Under the BAU scenario, the demand for charging stations in Indonesia will increase from 7,953 units in 2025 to 202,424 units in 2040. Meanwhile, if the conditions for the development of electric passenger cars align with worldwide trends in MOD scenario, the need for charging stations will increase from 18,511 units in 2025 to 561,741 units in 2040. In the ADV scenario, if Indonesia completely pushes EV, it will require around 33,427 charging stations in 2025 and 967,427 units in 2040. However, this scenario is overly optimistic because charging stations must be built nearly twice as many as the world target (MOD) and four times as much as the BAU target. This requirement will be difficult to meet because the availability of power plants to deliver power needs also be taken into consideration.

Keywords: electric cars, demand, charging station, Gompertz function model

1. Introduction

The energy crisis, global warming, and environmental degradation are the most critical issues confronting all emerging nations at this time. Therefore, many researchers and industries are currently competing to develop energy-efficient and environmentally friendly technologies[1)]. Net Zero Emission (NZE) has become one of many countries goals in developing cleaner energy infrastructure, where the energy sector is currently responsible for 73.2% of CO_2 gas emissions (including 16.6% from the transportation sector)[2)]. The majority of automobiles on the road today are propelled by Internal Combustion Engines (ICE), which all use petroleum oil as an energy source during the combustion process[3)]. Vehicles powered by combustion engines emit greenhouse gases[4)]. If fossil fuels are continuously combusted, CO_2 emissions will increase[5)]. The research findings indicate that the utilization of an ICE in a gasoline-powered vehicle results in the emission of 167 g of carbon dioxide (CO_2) gas per km. Similarly, a diesel vehicle emits 134 g of CO_2, a hybrid vehicle emits 145 g, and an EV emits 114 g of CO_2[6)]. The high enthusiasm for the NZE has become the urgency for many developing countries in developing their land transportation systems into electric vehicles (EV).

One of the advantages of using EV based-on renewable energy is to reduce emissions, However, another issue that may arise is the safety issue caused by the very low sound made by EV, in which pedestrians may have difficulties identifying the EV's presence, which can cause an accident[7)]. The conversion of ICE vehicles, both two-wheeled and four-wheeled, into EV or Battery Electric vehicles (BEV) is one solution that is being pursued in many countries. In addition, research has been conducted on energy management systems for electric two-wheeled vehicles in order to fulfill the power requirements and achieve optimal energy efficiency[8]. In the year 2022, the global sales of EV reached about 10 million units. China remained the largest market for EV, accounting for 59% of global sales. Europe came in second rank with 25% of total sales. The United States came in third rank, contributing for 9.3% of global sales[9]. California and Canada have targeted to stop selling ICE cars and sell EV only by 2035. Even the Netherlands, Sweden, Denmark, and several other European countries, as well as China, will start doing so much earlier in 2030[10]. The acceleration of this target was made by providing regulations and special business schemes to facilitate the penetration of the ecosystem, both EV and charging stations. For example, the Netherlands subsidizes the purchase of new EV and exempts purchase taxes until 2024. Purely EV are entirely free from purchase tax until 2024, and the owners will get a tax fee of €360 per car in 2025[11].

In Indonesia, Presidential Decree No. 55 of 201912 facilitates the acceleration of the EV program, particularly BEV[12]. ICE motorcycles have grown rapidly in Indonesia over the last decade. Electric motorcycle conversion is the best way to replace ICE motorcycles in this country in order to reduce emissions[13]. With the issuance of Presidential Regulation No. 55, the number of EV in Indonesia has increased dramatically, from 1,419 units in 2019 to 14,400 units in November 2021, with a share of 85% by electric motorcyles[14]. According to The Association of Indonesia Automotive Industries (GAIKINDO) data, the automotive manufacturing sector in Indonesia ranks as the second largest in Southeast Asia, having produced over 1.5 million cars in the year 2022. Moreover, the motorcycle manufacturing industry in the region has achieved significant prominence, boasting a staggering output volume of over 6 million units in the year 2021. This observation suggests that Indonesia have the potential to emerge as a prominent EV production center[15]. In addition, the electric company strongly encourages the acceleration of the increase in the number of EV in Indonesia in order to overcome oversupply from excess electricity production. However, the price of EV, the supply chain of EV's component such as battery, inverter, etc, the independence of industries, and the lack of public charging facilities are the main factors that may influence the public's decision to switch to EV[16]. One of the primary challenges currently confronting Indonesia pertains to the scarcity of domestic battery manufacturers, which has caused higher battery costs within the country. Safety is an additional factor to consider when evaluating EV[16].

According to the projections made by the Ministry of Energy and Mineral Resources (ESDM), Indonesia was expected to have a total of 2,700,000 EV consisting of two-wheeled and three-wheeled vehicles by the year 2021. These EV were anticipated to be facilitated by a network of 170,000 charging stations. However, that forecast lacks empirical evidence to substantiate its claims. As of the year 2021, the total number of EV units sold in Indonesia amounted to a mere 1,465,000, accompanied by a meager count of 148 successfully established charging stations[16].

The public charging station facilities, in generally divided into three levels, are following[16]:

- Level 1: a public charging station with a capacity of 1 kW and a charging duration of 20 h for a distance of 200 km.
- Level 2: a public charging station with a capacity of 3-20 kW and a charging duration of 5 h for a distance of 200 km.
- Level 3; that is, a public charging station with a capacity of up to 50 kW and a charging duration of 30 min for a distance of 200 km.

To support the accelerated growth of EV in Indonesia, the government's roadmap calls for the installation of at least 25,364 level 3 charging stations by 2030[16].

The availability of comprehensive academic literature on EV technology in Indonesia, particularly pertaining to charging stations, is limited. Existing sources primarily consist of magazines, news publications, and government reports, which provide valuable insights but lack the rigor and depth often associated with scientific studies. Consequently, accessing scholarly research specifically focused on charging stations in Indonesia poses a challenge. Hence, the primary objective of this study is to present a complete scholarly review article on the necessity of establishing public charging stations in Indonesia.

The novelty of this study is the forecast of the demand for charging stations based on the projected number of passenger cars that the general public can purchase by including the credit component as an incentive or convenience in purchasing electric car.

2. Forecasting Model

Azmi et al.,[17] attempted to investigate numerous modeling methodologies commonly used by other researcher, some of which are based on consumer preferences for pricing, fuel consumption, comfort, performance, reliability, safety, as well as brand and image. There are also those based on demographic, economical, and environmental factors, government involvement, and future infrastructure readiness, such as the study of transportation modeling in Malaysia. They also forecasted the number of electric and hybrid vehicles in Malaysia through 2040. They use dynamic system modeling by integrating population expandable income and vehicle price reduction policy. As a result, Hybrid Electric Vehicle (HEV) is expected to reach 1.43 million units in 2040, whereas EV is expected to be 43,000 units. They didn't figure out how many charging stations would be needed to power electric passenger cars until 2040[17].

Presently, many researchers are conducting research on the estimation of electric passenger cars ownership. In the field of automotive prediction literature, it is customary to employ the Gompertz function as a modeling tool for predicting vehicle ownership. This approach is particularly prevalent when economic variables, such as per capita income or per capita Gross Domestic Product (GDP), are utilized as the primary explanatory factors[18]. Xiaolei Li, et. Al., compared the Gompertz model with the Logistic model in making predictions of EV ownership in China[19]. Torok et al., employed the Gompertz function to forecast the growth rates of passenger vehicles in Hungary. This projection was based on historical trends in human-driven vehicle ownership statistics, which were analyzed in relation to predicted per capita GDP[20]. S. Ayyadi et Al., utilized three models, namely Gompertz, Logistic, and Bass, to make predictions on the diffusion of EV in the Moroccan market[21]. Yong Zhang *et al.* estimate the market demand for electric cars in China using singular spectrum analysis (SSA) and vector autoregressive (VAR) methods, where sales history data from the previous eight years and consumer preferences are used to get predictions[22]. Nele Rietmann *et al.* projected EV inventories in 26 countries by 2035, along with the estimated CO2 and electricity demand reduction, using a logistic growth model and sales data from 2010-2018 [23]. The projection of passenger car ownership is calculated based on an econometric model that relates per capita ownership to per capita income presented by M. Sommer et al.[24], A. Nurrohim and H. Sakugawa[25], and N. Singh et al[26].

In this paper, The Gompertz function was used to determine how many public charging stations will require based on the expected number of electric cars sold in Indonesia. The Gompertz model employs a time series mathematical model that considers GDP per capita and historical data on the number of cars per population into account[18]. The projection's results can be utilized for further research of the number of plugs required, location dispersion, the reliability of the electricity network, and its economy. Furthermore, it is intended that the findings of this study would help the government establish regulatory schemes between the government and the private sector, as well as stock units, components, and their derivatives for manufacturers.

2.1 Methodology

The number of public charging stations needed is directly proportional to the number of electric passenger cars. For that, projecting the number of electric passenger cars is an important thing to do.

This research has been limited by the projected demand for a level 3 public charging station that is specifically designed for electric passenger cars. The designed model illustrates the Gompertz function-representable relationship between car ownership per capita and per capita income. This model has been empirically examined in 26 countries with incomes ranging from the lowest to the highest income for over three decades, with positive results. The Gompertz Function model calculates passenger car ownership per capita using per capita income expressed as GDP per capita in Purchasing Power Parity (PPP).

$$V_{t*} = \gamma e^{ae^{\beta GDPt}} \tag{1}$$

Vt* is the long-run equilibrium level for the ratio of passenger cars to population, GDP is the income/capita, γ is the saturation level, α and β are negative parameters defining the curvature of the function, and t is the time. The parameters used for the above calculations are 0.62 for saturation level γ, -6.42 for α, and -0.21 for β.

In order to account for lags in the adjustment of vehicle ownership to per-capita income, a partial adjustment function V_t is postulated:

$$V_t = V_{t-1} + \theta(Vt^* - V_{t-1}) \tag{2}$$

where, θ is the speed of adjustment (0 < θ < 1). The lags reflect the adjustment of vehicle ownership to increase GDP per capita arising from the necessary buildup of saving to afford the purchase. In this case, θ is 0.0014.

Due to the ease of the credit system in purchasing passenger cars in Indonesia, a Correction Factor is inserted to adjust the speed and ratio of car ownership. The correction factor is used to synchronize the actual data and the model in the calculation of passenger cars. So, Eq. 2 becomes as follows

$$V_t = \delta\, V_t \tag{3}$$

The correction factor δ started in 2003 with a value of 1.07 and decreased gradually to 1.02 in the base year (2020). As for the projections for 2021 to 2035, the correction factor δ is 1.02. The correction factor in the projection is taken to remain at 1.02 because throughout the last four years (2017-2020), it has been constant at that number.

2.2 History Data and Assumption

The data used in gompertz modeling are historical data from the last 30 years (1990-2020). As shown in **Table 1**, population data is obtained from the Central Bureau of Statistics (BPS), and GDP per capita (PPP US$ 2017) is derived from World Bank data. In the meantime, the number of passenger cars is derived from Ministry of Transportation and BPS data as shown in **Fig. 1**.

Table 1. Indonesia's population and GDP/Capita 1990-2020

Year	Population[27] (Million People)	GDP/Cap[28] (PPPs 2010 US$)	Number of pass. Cars[29] (Thousand Units)
1990	179.4	4,533	1,313.2
2000	206.3	5,689	3,038.3
2010	237.6	8,287	8,891.0
2020	269.6	11,445	15,798.7

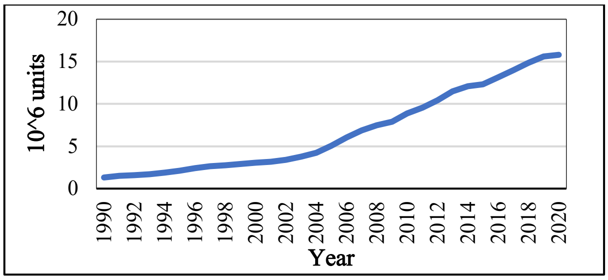


Fig 1. Development of the number of passenger cars in Indonesia 1990-2020

The synchronization results between historical data and model of car ownership data and per capita income from 1990 to 2020 can be seen in **Fig 2**.

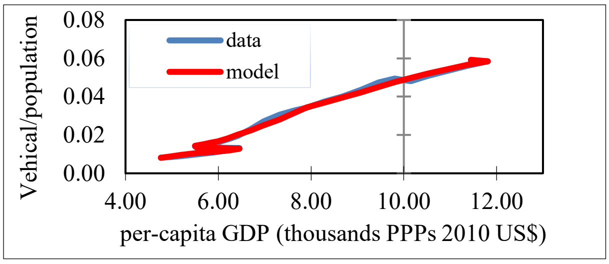


Fig 2. Data and Model of Car Ownership Based on Long-run Gompertz Functions for Historical Data 1990-2020

The graphic above shows that the results of evaluating the Gompertz function with historical data modeling are identical, indicating that the stated Gompertz function can be utilized in subsequent modeling.

Furthermore, the calculation of the projected number of passenger cars for 2021 – 2040 refers to the long-term real GDP estimate estimated by the Organization for Economic Co-operation and Development (OECD). while the population projection uses projection data issued by BPS. Based on the projected GDP and population, income per capita can be calculated as shown in **Table 2.** Then these data can be used to calculate the number of passenger car ownership as a Gomperz function.

Table 2. Projection of Indonesia's population and GDP/Capita

Year	Population [30] (Million People)	GDP (PPPs) [31] (Million 2010 US$)	GDP/Cap (PPPs 2010 US$)
2021	272.2	3,310,046	11,608
2025	282.5	4,233,448	14,140
2030	294.1	5,309,205	17,332
2035	304.2	6,387,423	20,277
2040	312.5	7,506,742	23,295

2.3 Scenario

The period of the simulation model for this study is twenty years, starting from 2021 to 2040, and 2020 is chosen as the base year.

The projection was carried out until 2040 by considering three scenarios are as follows:

- The BAU scenario as a pessimistic scenario. This scenario only considers current socio-economic conditions without considering the possibility of fundamental energy policy changes. Government policies related to energy and EV are not working as expected. The development of electric cars, level 3 public charging station type, and other technologies follows the market mechanism. In this scenario, it is presumed that the price of electric passenger cars is still expensive, so only a select group of consumers can afford them.
- The Moderate Scenario (MOD) referring to global vehicle growth. In this scenario, the number of electric cars grows at the same rate as the world average or global trend. According to projections, the proportion of electric cars in new car sales is anticipated to be 8% in 2025, 24% in 2030, 42% in 2035, and 53% in 2040[32].
- The Advanced Scenario (ADV) as an optimistic scenario. This scenario assumes that the number of electric passenger cars will attain the same production target as ICE vehicles. In this scenario, it is assumed that the involvement of government policies and incentives is significant.

For the electric passenger cars penetration scenario, it is assumed that it only occurs in producing new cars, not including modifications of old cars that are converted into electric cars.

2.4 Ratio of EV per public charging station

The rise in sales of EV is accompanied by a corresponding increase in the availability of public charging infrastructure. Consumers have a strong expectation for convenient and cost-effective access to charging services that are comparable to the ease of refuelling an ICE vehicle. Publicly accessible fast chargers could encourage consumers with no access to private chargers to purchase electric car. Fast charging stations can accommodate more electric car than slower charging stations.

The forecast of the demand for charging stations is conducted by utilising global average data from 2021, which pertains to the ratio between the number of public charging stations and the capacity of each fast charging station to accommodate EV. This ratio is estimated to be roughly 1:10. In other terms, each fast charging station unit can accommodate ten electric passenger cars[33].

3. Result and Discussion

3.1 The growth of passenger cars population

Based on historical data, the growth of passenger car number in the period 1990-2020 about of 8.64% or an increase from 1.3 million units to 15.8 million units. From 2010 to 2020, the number of passenger car sales grew at a rate of nearly 6% annually, the highest rate of growth over the past decade.

The simulation for estimating the ratio of passenger cars per population to GDP per capita for the period 2021-2040 was undertaken using the same methodology as the calculation performed for the period 1990-2020. The projection results are shown in **Fig. 3,** where the modeling result line based on the Gomperzt function simulation matches with the simulation result line based on historical data, indicating that the modeling was done accurately. Per capita income is frequently used as an indicator of a country or region's prosperity and level of development. The government can use per capita income as a guide for economic policy making because it can monitor economic development in society. Based on the graphical representation, there is a positive correlation between the rise in GDP per capita and the proportion of individuals owning passenger cars in Indonesia. This observation suggests an improvement in the general economic condition of the Indonesian people.

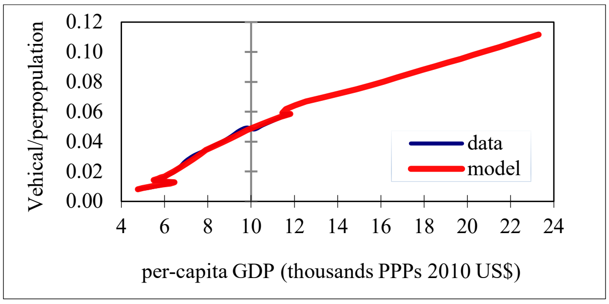


Fig 3. Projected Passenger Car Ownership Ratio Based on GDP per Capita (Gomperz Function)

The projected number of passenger cars from 2021 to 2040 is calculated using the Gomperzt function, which yields an increase of approximately 3.7% per year, or, in other words, the number of passenger cars in 2021 is projected to be 16.8 million units and will reach 34,9 million units in 2040, as depicted in **Fig. 4**.

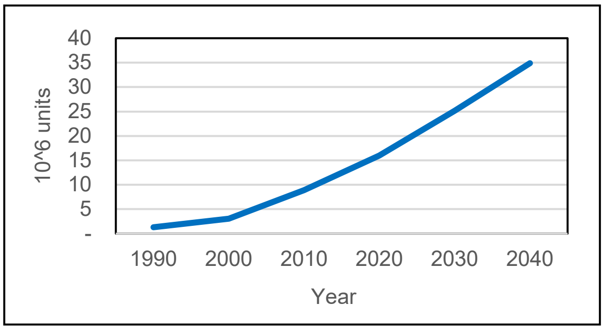


Fig 4. Development of the Number of Passenger Cars in Indonesia 1990 - 2040 (1990-2020 Historical Data, 2021-2040 Projected Figures)

3.2 Projected Number of Electric Cars

As previously stated, the predicted quantity of EV in this study is passenger cars, and only new vehicle types are considered in modeling, excluding modified cars converted from ICE types to electric cars. The results of modeling using three scenarios, namely BAU, MOD, and ADV, are shown in **Fig. 5.**

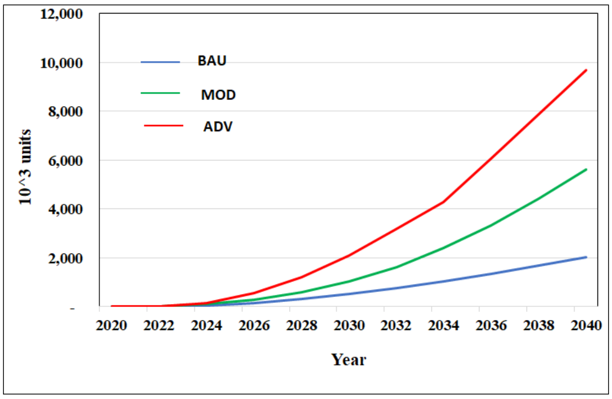


Fig 5. Projected number of electric passenger cars in Indonesia

3.2.1 BAU Scenario

In the BAU scenario, the market mechanism drives the increase in the quantity of electric cars. It is believed that the price of electric cars is still extremely high, particularly above 400 million rupiah, so that just specific segments of the population can afford to buy electric cars. In this situation, the scenario predicts that electric car penetration will grow gradually, with sales limited to middle and upper-class EV. According to the simulation results, the growth of electric passenger cars in 2025 will be 4% of new passenger car sales, or 38,005 units. Because sales of EV are restricted to prices above Rp. 400 million, electric passenger car penetration is relatively slow[34]. In 2025, the total number of electric passenger cars on the road is expected to be roughly 0.4% of the total number of passenger cars on the road, or 79,259 units. In 2030, the number is projected to increase to 543.119 units, and in 2040, to 2.02 million units, or 5.8% of all passenger cars in operation.

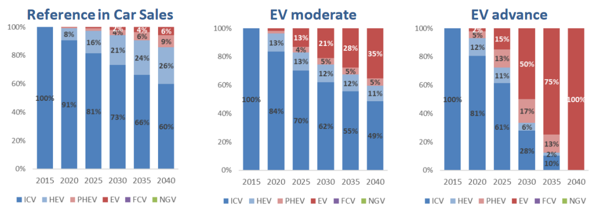
3.2.2 MOD Scenario

This scenario follows the trend as projected at the global level. Global projections vary widely, ranging from low to high. For example, Exon Mobil predicts the number of electric cars in 2040 will be around 100 million, OPEC predicts 266 million, and Bloomberg New Energy Finance predicts 530 million units. In this study, based on the MOD scenario, the number of electric cars sales in 2025 is expected to reach roughly 8%, or 185.1 thousand units. In 2030, sales are projected to increase by 24%, or up to 1.1 million units, and by 2040, sales are projected to reach 53%, or up to 5.6 million units.

3.2.3 ADV Scenario

In 2019, the government launched its ambition to create an integrated EV sector ecosystem. By offering incentives to the BEV industry, the government encourages the growth of the electric car technology industry. The referred to incentives include import duty incentives on the import of battery-based EV that are completely knockdown (CKD) or incompletely knockdown (IKD) or main components for a specified quantity and time period. Additional incentives include Sales Tax on Luxury Goods (PPnBM) incentives. The government also offers incentives for the production of public charging station equipment, export financing incentives, fiscal incentives for research and development, parking rates, charging costs, the installation of public charging stations, competency certification for BEV human resources, and product certification and technical standards for BEV industrial companies[35]. One of the quantitative targets is the manufacture of 400 thousand EV based on four-wheel batteries or more in 2025; 600 thousand units in 2030; and one million units in 2035, with 90% of the units projected to be passenger cars. In terms of production, the sales of electric passenger cars, specifically BEV, in 2025, 2030, and 2040 are 334.3 thousand units, 2.1 million units, and 9.6 million units, respectively.

In comparison to the research conducted by S. Kimura et al.,[36], our study also examined similar scenarios, including the reference scenario (representing BAU conditions without any policy interventions) and the MOD scenario (based on estimates provided by the ESDM). In addition, the ADV scenario (which assumes that ICE cars would no longer be sold by 2040). They were assumed that the proportion of electric car sales in the year 2040 under the BAU scenario is 6%, while it is projected to be 35% under the MOD scenario. In the ADV scenario, electric car sales are expected to account for 100% of total vehicle sales, as depicted in **Fig 6**.



EV = electric vehicle, FCV = fuel-cell vehicle, GDP = gross domestic product, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.

Fig. 6 Sales Share by Powertrain for References, Moderate and advance Scenario[36]

Another researcher, Ardy Gamawanto et al.[37], estimated the projected population of EV in Indonesia until 2030 by combining the government's target simulation results and Kimura's scenario simulation results. The results indicate that the estimated number of EV in Indonesia in 2030 under the BAU scenario is approximately 17,119 units, under the MOD scenario it is 21,435 units, and under the ADV scenario it is 72,856 units.

3.3 Demand for Charging Stations in Indonesia

ICE vehicle owners have convenient access to filling facilities that are widely distributed across several locations. However, this is not applicable to individuals who utilize EV, as the availability of electric charging infrastructure remains limited and is currently in the developmental phase.

Charging at home is not as simple as it appears; the main issue is the lengthy charging period. Additionally, the existing power capacity may not always be adequate to accommodate simultaneous peak loads, further exacerbating the issue. Given the aforementioned factors, it is imperative to establish charging stations within public areas.

In order to facilitate the advancement of EV, the State Electricity Company (PLN) has set a goal of constructing 24,720 public charging station units by the year 2030. As of May 2022, it has been reported that PLN has successfully constructed a total of 332 public charging station units around the country of Indonesia[38].

The findings of this study indicate that, by assuming one charging station for ten electric cars[33], the demand for charging stations in Indonesia base on BAU scenario will increase from 8.0 thousand in 2025 to 54.3 thousand units in 2030 and 202.4 thousand units in 2040. Meanwhile, for MOD scenario and optimized scenario, in 2025 and 2040 each will increase from 18.5 thousand and 33.4 thousand units (2025), increasing to 561.7 thousand units and 967.4 thousand units (2040).

In the context of the Jakarta region, the calculation of public charging station is determined in proportion to the quantity of EV present in the area. Historical data pertaining to the number of vehicles over the past five years indicates that 20% of electric cars are located in Jakarta. Therefore, up to 20% of the charging station must be located in Jakarta. The projected trend of the number of public charging station needs in Indonesia and Jakarta is shown in **Table 3**.

Table 3. Projected trend of charging stations needs in Indonesia and Jakarta

Area	Scenario	2025	2030	2035	2040
Indonesia	BAU	7,953	54,312	117,647	202,424
	MOD	18,511	105,139	284,430	561,743
	ADV	33,427	211,427	517,427	967,427
Jakarta	BAU	1,591	10,862	23,529	40,485
	MOD	3,702	21,028	56,886	112,349
	ADV	6,685	42,285	103,485	193,485

Dwiananto et al. also projected the number of EV and the demand for charging stations in the city of Jakarta through 2030 using three scenarios and the same ratio. According to the projections for the BAU scenario, the number of EV in Jakarta is expected to reach 1,472 units, with a demand for 829 charging stations. In the MOD scenario, it is anticipated that there will be 1,515 EV and 943 charging stations. And in the ADV scenario with substantial government intervention, it is estimated that there will be 1,631 EV in Jakarta, necessitating 1,035 charging stations[39].

PLN has established the standardization for the charging system of EV. Types of charging are generally divided into categories of slow chargers and fast chargers. Slow chargers use alternating current (AC) with a voltage below 400 volts. Meanwhile, fast chargers use direct current (DC) with over 400 volts.

In accordance with the initial assumption that the charging station category to be built in Indonesia is in the fast charging category (Level 3), the electric power requirement can be calculated based on each scenario, as shown in **Table 4** below.

Table 4. Projected of Electric power for each scenario

Scenario	2025	2030	2035	2040
BAU	206 MW	1.5 GW	3.5 GW	6.9 GW
Moderate	0.48 GW	2.9 GW	8.5 GW	19.2 GW
Advance	0.87 GW	5.9 GW	15.5 GW	33 GW

4. Conclusions

The major hurdles to developing EV in Indonesia are the initial costs and the lack of charging station infrastructure and standards. Furthermore, Indonesia faces challenges in maintaining the power supply and energy management required for EV consumption. The battery capacity of EV is limited to short distances. For this reason, many charging stations are needed which are scattered along travel routes in all cities of Indonesia. Another challenge is the need for universal standards and regulations for electric facilities and the electric car market.

Based on the modeling results of this study, it was found that projections based on BAU conditions were too pessimistic, making it difficult for the government to meet its target on time. In the meantime, modeling based on advanced conditions with extensive government intervention is also regarded as overly optimistic because, in addition to exceeding the world global target figure, it is also necessary to address the issue of supply availability and electricity management. Using moderate conditions is a more realistic way to model because it takes into consideration both world global goals and the ability to provide the power that needs to be given.

In order to support governmental initiatives aimed at promoting the adoption of EV in Indonesia, it is imperative to foster cooperation and coordination among manufacturers, scientists, electrical companies, government entities, and other relevant institutions.

Nomenclature

Abbrevation

ADV	advanced scenario
BAU	business as usual scenario
BEV	battery electric vehicles
BPS	central statistics agency
CO_2	carbon dioxide
ESDM	ministry of energy and mineral resources
EV	electric vehicles
ICE	internal combustion engine
GAIKINDO	the association of indonesia automotive industries
GDP	the income/capita (%/year)
MOD	moderate scenario
NZE	net zero emission
OECD	organization for economic co-operation and development
PLN	the state of electricity company
PPP	purchasing power parity
SSA	singular spectrum analysis
VAR	vector autoregressive

Symbol

α	negative parameters defining the curvature of the function
β	negative parameters defining the curvature of the function
γ	the saturation level
δ	correction factor
θ	the speed of adjustment ($0 < \theta < 1$)
t	time
V_{t*}	the long-run equilibrium level for the ratio of passenger cars to population
V_t	postulated

References

1) E. Djubaedah, A. Wulandari, Nasruddin, and K. Krisnandi, “Surface area modification of natural zeolite through nacl counterbalanced treatment to apply in adsorption heat storage system,” *Evergreen*, **7(1)** 26–31, (2020). https://doi.org/10.5109/2740938.
2) H. Ritchie, M. Roser., and P. Rosado, “CO_2 and greenhouse gas emissions,” (n.d.). https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions (accessed July 29, 2022).
3) Abdelgader A.S. Gheidan, Mazlan Bin Abdul Wahid, Opia A. Chukwunonso, and Mohd Fairus Yasin, “Impact of internal combustion engine on energy supplyand its emission reduction via sustainable fuel source,” *Evergreen*, **9**(3) 830–844 (2022). https://doi.org/10.5109/4843114

4) A.C.R. Teixeira, and J.R. Sodré, "Impacts of replacement of engine powered vehicles by electric vehicles on energy consumption and co 2 emissions," *Transportation Research Part D*: *Transport and Environment*, **59** 375–384 (2018). https://doi.org/10.1016/j.trd.2018.01.004.
5) N.A. Lestari, "Reduction of CO2 emission by integrated biomass gasification-solid oxide fuel cell combined with heat recovery and in-situ co_2 utilization," *Evergreen*, **6**(3) 254–261 (2019). https://doi.org/10.5109/2349302.
6) Gheidan, A. A., Wahid, M. B. A., Chukwunonso, O. A., & Yasin, M. F. (2022). Impact of Internal Combustion Engine on Energy Supplyand its Emission Reduction via Sustainable Fuel Source," *Evergreen*, 9(3) 830-844 (2022) https://doi.org/10.5109/4843114
7) Patil, L. N., & Khairnar, H. P. (2021). "Investigation of human safety based on pedestrian perceptions associated to silent nature of electric vehicle", *Evergreen*, **8**(2) 280–289 (2021). https://doi.org/10.5109/4480704
8) S. Sawant, Raja Mazuir Raja Ahsan Shah, M. Rahman, Abd Rashid Abd Aziz, S. Smith, and A. Jumahat, "System modelling of an electric two-wheeled vehicle for energy management optimization study," *Evergreen,* **8**(3) 642–650 (2021). https://doi.org/10.5109/4491656.
9) Yidan Chu and Hongyang Cu, "Annual update on the global transition to electric vehicles: 2022," Icct - the International Council on Clean Transportation, (n.d.). https://theicct.org/publication/global-transition-electric-vehicles-update-jun23/ (accessed July 5th, 2022).
10) S. Wappelhorst, and H. Cui, "Growing momentum: global overview of government targets for phasing out sales of new internal combustion enginer vehicles," Icct - the International Council on Clean Transportation, (n.d.). https://theicct.org/growing-momentum-global-overview-of-government-targets-for-phasing-out-sales-of-new-internal-combustion-engine-vehicles/ (accessed September 30, 2022).
11) P. Nikolov, "The full guide to ev and ev charging incentives in the netherlands," (n.d.). https://www.ampeco.com/blog/ev-and-ev-charging-incentives-in-the-netherlands/.
12) "Presidential Decree No. 55 of 2019, Program Acceleration for Battery Electric Vehicles for Road," in: n.d.
13) A. Habibie, M. Hisjam, W. Sutopo, and M. Nizam, "Sustainability evaluation of internal combustion engine motorcycle to electric motorcycle conversion," *Evergreen*, **8**(2) 469–476 (2021). https://doi.org/10.5109/4480731.
14) C. Akbar, and A.N.N. Hidayat, "Per Nopember 2021, kemenhub catat populasi kendaraan listrik di RI 14.400 unit," Tempo, Nopember 2021, (n.d.). https://bisnis.tempo.co/read/1531389/per-november-2021-kemenhub-catat-populasi-kendaraan-listrik-di-ri-14-400-unit.
15) F. A Padhilah, I. R. F. Surya and P. Aji, "Indonesia Electric Vehicle Outlook 2023, Electrifying Transport Sector: Tracking Indonesia EV Industries and Ecosystem Readiness", Institute for Essential Services Reform (IESR), 2023.
16) Veza I, Abas MA, Djamari DW, Tamaldin N, Endrasari F, Budiman BA, Idris M, Opia AC, Juangsa FB, Aziz M, "Electric Vehicles in Malaysia and Indonesia: Opportunities and Challenges", *Energies,* 15 (7) : 2564 (2022) https://doi.org/10.3390/en15072564
17) Azmi, M., Tokai, A. "Electric vehicle and end-of-life vehicle estimation in Malaysia 2040". *Environ Syst Decis* **37**, 451–464 (2017). https://doi.org/10.1007/s10669-017-9647-4
18) T. Wu, M. Zhang, and X. Ou, "Analysis of future vehicle energy demand in china based on a gompertz function method and computable general equilibrium model," *Energies*, **7** (11) 7454–7482 (2014). https://doi.org/10.3390/en7117454.
19) X. Li, E. Wang and C. Zhang, "Prediction of electric vehicle ownership based on Gompertz model," *2014 IEEE International Conference on Information and Automation (ICIA)*, Hailar, China, 2014, pp. 87-91, https://doi.org/10.1109/ICInfA.2014.6932631.
20) Alatawneh, Anas, and Adam Torok. "Potential autonomous vehicle ownership growth in Hungary using the Gompertz model." *Production Engineering Archives* 29.2: 155-161 (2022). https://doi.org/10.2478/czoto-2022-0017
21) S. Ayyadi and M. Maaroufi, "Diffusion Models For Predicting Electric Vehicles Market in Morocco," *2018 International Conference and Exposition on Electrical And Power Engineering (EPE)*, Iasi, Romania, 2018, pp. 0046-0051, doi: 10.1109/ICEPE.2018.8559858.
22) Y. Zhang, M. Zhong, N. Geng, and Y. Jiang, "Forecasting electric vehicles sales with univariate and multivariate time series models: the case of china," *PLoS ONE*, **12** (5) e0176729 (2017). doi:10.1371/journal.pone.0176729.
23) N. Rietmann, B. Hügler, and T. Lieven, "Forecasting the trajectory of electric vehicle sales and the consequences for worldwide co2 emissions," *Journal of Cleaner Productio*n, **261** 121038 (2020).
24) M. Sommer, J. Dargay, and D. Gately, "Vehicle ownership and income growth, worldwide: 1960-2030," *The Energy Journal*, **Vol. 28**, No. 4, 2007, 143-170. (n.d.). doi:10.2307/41323125.
25) A. Nurrohim, and H. Sakugawa, "Fuel-based inventory of no and so2 emissions from motor vehicles in the hiroshima prefecture, japan," *Applied Energy*, **80** (3) 291–305 (2005). doi:10.1016/j.apenergy.2004.04.003.
26) N. Singh, T. Mishra, and R. Banerjee, "Projection of private vehicle stock in india up to 2050,"

Transportation Research Procedia, **48** 3380–3389 (2020). doi:10.1016/j.trpro.2020.08.116.
27) BPS (The Central Statistics Agency), “Jumlah penduduk pertengahan tahun 1960 - 2022,” BPS, Jakarta, 2022, (n.d.).
28) World Bank, “GDP per capita , ppp (current international, $,” (n.d.). https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD (accessed May 12, 2022).
29) BPS (The Central Statistics Agency), “Perkembangan jumlah kendaraan bermotor menurut jenis (unit), 1990-2020,” BPS, Jakarta 2022, (n.d.).
30) BPS (The Central Statistics Agency) and Bappenas, “Proyeksi penduduk indonesia 2010-2045,” BPS, Jakarta, 2013, (n.d.). http://proyeksipenduduk.bappenas.go.id/query.
31) OECD (Organization for Economic Co-operation and Development), “Real GDP long-term Forecast", https://data.oecd.org/gdp/real-gdp-long-term-forecast.htm. (accessed Feb 8, 2023)
32) BloomberNEF, “All forecast signal accelerating demand for electric car,” (2017). https://about.bnef.com/blog/forecasts-signal-accelerating-demand-electric-cars/.
33) IEA, “Global electric electric outlook 2022,” (2022). https://www.iea.org/reports/global-ev-outlook-2022/.
34) Salsabila, Hana and Salehudin, Imam, Plugged in and charging, “Environmentalism Factors Does Affect Behavioral Intention to Purchase Electric Cars in Indonesia, But Non-Environmental Factors are Important Too” (2023). Available at SSRN: https://ssrn.com/abstract=4323150, http://dx.doi.org/10.2139/ssrn.4323150
35) Setyoko, Ajun Tri, et al. "Policy, Supporting Infrastructure and Market of Electric Cars in Indonesia." (2022). Proceedings of the International Conference on Industrial Engineering and Operations Management, Istanbul, Turkey
36) Kimura, Shigeru. "An analysis of alternative vehicles’ potential and implications for energy supply industries in Indonesia." *Books* (2018).
37) Gamawanto, Ardy, et al. "Pricing Scheme for EV Charging Load Penetration in Distribution Network: Study Case Jakarta." *2019 7th International Conference on Smart Grid (icSmartGrid)*. IEEE, 2019. DOI: 10.1109/icSmartGrid48354.2019.8990696
38) Khairani, Annisa, and Rahmat Nurcahyo Farizal. "Study on Electric Vehicle Policy in Indonesia.", Proceedings of the First Australian International Conference on Industrial Engineering and Operations Management, Sydney-Australia, IEOM Society International, 2022
39) Dwiananto, Y. I., et al. "Modeling projection of the number of charging stations and battery electric vehicles until 2030 in Jakarta Indonesia in order to reduce greenhouse gas (GHG) emissions." *IOP Conference Series: Earth and Environmental Science*. Vol. 1108. No. 1. IOP Publishing, 2022.